Statistical Analysis of Clay Parameters

An investigation of relationships between a number of external factors and various clay parameters

Master of Science Thesis in the Master's Programme Infrastructure and Environmental Engineering

JOHAN COLLINDER AND ELI MARTINEZ RAMM

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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

When calculating settlements using conventional methods, values of various clay parameters are usually estimated in areas in between sampling points. The general assumption is then that values of parameters in a limited surrounding of a sampling point is likely to be relatively similar to those evaluated from the sample. The uncertainty in settlement calculations is greatly affected by the uncertainty in estimated values of various clay parameters in between sampling points. Since the collection and evaluation of samples is expensive, it is desirable to reduce this uncertainty without taking additional samples. One hypothesis is that it could be possible to use external factors to predict the values of clay parameters in between sampling points. The aim of this master's thesis is to investigate if there are statistically significant relationships between a number of external factors and various clay parameters. The external factors included in this investigation are; the sampling depth, the grade of urbanization, the soil type according to the geological map, the thickness of the soil layer overlaying the clay, the time since the soil layer overlaying the clay was placed, a number of specified zones and the two cities Göteborg and Stockholm. The clay parameters that are analyzed are; σ'_0, σ'_C, σ'_L, M_L, M', OCR, CLR, ρ, w and w_L. The statistical analyses are performed with the analysis methods ANOVA (analysis of variance) and independent groups T-test, using the software SPSS. The raw data is collected from four big infrastructure projects; Götatunneln and E45-Norge/Vänerbanan from Göteborg and City Link and Bypass Stockholm from Stockholm. In order to avoid illogical values from back-calculation, achieve normal distribution and eliminate any intrinsic relationships with depth prior to the statistical analysis, the raw data is transformed and normalized. All statistical analyses are then performed on the residuals of the transformed data from a regression curve against the sampling depth. The results from the investigation indicate that the most relevant external factor is the zone, i.e. simply the location. Even though there are statistically significant relationships between some of the external factors and the clay parameters, the variation between different zones is likely acting as a lurking variable in many cases. The overall conclusion of this master's thesis is that the existence of any statistically significant relationships between the investigated external factors and clay parameters cannot be confirmed with reference to the outcomes from this investigation.

Keywords: clay, parameters, external factors, relationship, ANOVA, T-test

Statistisk analys av lerparametrar

En undersökning av samband mellan ett antal externa faktorer och olika lerparametrar

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SAMMANFATTNING

Vid konventionella sättningsberäkningar måste värden på lerparametrar i områden mellan provtagningspunkter vanligtvis uppskattas. Det generella antagandet är då att värdena på parametrarna i en begränsad omgivning av en provtagningspunkt sannolikt är förhållandevis lika dem värden som utvärderats från provtagningspunkten. Osäkerheten i sättningsberäkningar är starkt beroende av osäkerheten i de uppskattade värdena på parametrarna i områden mellan provtagningspunkter. Då det är dyrt att ta upp och utvärdera jordprover är det önskvärt att minska osäkerheten i dessa värden utan att behöva ta upp fler jordprover. En hypotes är att det skulle kunna vara möjligt att använda sig av externa faktorer för att förutspå värden på de olika lerparametrarna mellan provtagningspunkter. Syftet med detta examensarbete är att undersöka om det finns statistiskt signifikanta samband mellan ett antal externa faktorer och olika lerparametrar. De externa faktorer som inkluderas i denna undersökning är; provtagningsdjupet, urbaniseringsgraden, jordtypen enligt den geologiska jordartskartan, tjockleken på jordlaget som ligger ovan leran, tiden som gått sedan jordlagret ovan leran tillkom, ett antal specificerade zoner och de två städerna Göteborg och Stockholm. Lerparametrarna som analyseras är; σ'_0, σ'_C, σ'_L, M_L, M', OCR, CLR, ρ, w och w_L. De statistiska analyserna är utförda med analysmetoderna ANOVA (analysis of variance) och *T*-test i datorprogrammet SPSS. Inhämtade rådata kommer från fyra olika infrastrukturprojekt: Götatunneln och E45-Norge/Vänerbanan från Göteborg samt City Link och Förbifart Stockholm från Stockholm. För att undvika ologiska värden vid tillbakaräkning, uppnå normalfördelning och eliminera alla potentiella inneboende förhållanden med djupet har rådata transformerats och normaliserats. Alla statistiska analyser utförs sedan på residualerna av transformerad data från en regressionskurva mot provtagningsdjupet. Resultaten från undersökningen indikerar att den mest relevanta externa faktorn är zonen, dvs. helt enkelt platsen. Trots att det finns signifikanta samband mellan vissa externa faktorer och lerparametrar är det ofta sannolikt skillnaden mellan olika zoner som i själva verket agerar dold oberoende variabel. Den övergripande slutsatsen för detta examensarbete är att inga statistiskt signifikanta samband mellan de undersökta externa faktorerna och lerparametrarna kan bekräftas med referens till det som framkommit i denna undersökning.

Nyckelord: lera, parametrar, externa faktorer, samband, ANOVA, *T*-test

Contents

Preface

The study was carried out at the Department of Civil and Environmental Engineering, Chalmers University of Technology and the Department of Civil Engineering, COWI AB in Göteborg, Sweden.

We would like to thank the following people for all your help and support during the semester:

- Claes Alén, assistant professor and examiner, Chalmers University of Technology
- Lennart P Å Johansson, chief specialist geotechnical engineer and supervisor, COWI AB
- Jonas Sundell, industrial doctoral student, supervisor and initiator, COWI AB

Lastly, we would like to express our gratitude to the entire Group of Geotechnical Engineering at COWI for all their technical support and encouragement throughout the whole process.

Göteborg May 2014

Johan Collinder and Eli Martinez Ramm

Notations

Roman upper case letters

M_L	Compression modulus
M'	Compression modulus
M_s	Mass of solids
M_w	Mass of water
R	Coefficient of correlation
R^2	Coefficient of determination
V_v	Total volume of water and air
V_s	Total volume of solids

Roman lower case letters

e	Void ratio
u	Pore water pressure
u_e	Excess pore water pressure
w	Water content
w_L	Liquid limit
z	Depth under the ground surface

Greek lower case letters

α	Intercept
β	Regression coefficient
ε	Residual
γ	Unit weight
γ_w	Unit weight of water
ρ	Density
σ_0	Normal stress
σ'_0	Effective stress
σ'_C	Preconsolidation stress
σ'_L	Limit stress
$\Delta\sigma_Z$	Change in vertical normal stress

Abbreviations

CLR	Preconsolidation limit ratio
OCR	Overconsolidation ratio
SSE	Residual sum of squares

1 Introduction

The cities in the world are growing and with that, the infrastructure needs to be improved (Boverket, 2014). For all underground constructions, such as tunneling, there is a risk of lowering the groundwater table (Axelsson & Follin, 2000). A lowered groundwater table leads to an increase in effective stresses which can cause settlements of the ground surface, and thereby settlements of buildings, bridges and roads. If the groundwater table is lowered, it affects a large area. According to Sundell[1], there are high demands in urban areas on ensuring that no damaging settlements will occur due to a lowering of the groundwater table in connection with large infrastructural projects. It is of great importance to control and ensure that buildings with high economic and cultural value are not damaged (Banverket, 2007).

Each project is unique since the soil and its properties are inhomogeneous (Sällfors, 2001). A large challenge is to decide how many soil samples that has to be collected and evaluated in order to give good estimations of the soil properties at different locations. In order to calculate settlements, the compression properties of the clay have to be determined (Knappett & Craig, 2012). These are evaluated in a laboratory by testing undisturbed samples. There are several different tests but in Sweden, the Constant Rate of Strain (CRS) oedometer test is very common (Larsson, 2008). However, the evaluated values only apply for the specific sampling point and the values of clay parameters in the areas in between the sampling points have to be estimated.

According to a geotechnical engineer[2], one can only be relatively certain of the values of clay parameters in points where soil samples have been collected. The only uncertainty, in this case, is the one stemming from errors due to sampling and evaluation. In the areas in between sampling points, the values of parameters have to be estimated. The information given from the sampling points is used when predicting the properties of the soil in the area surrounding the sampling point. In the early stages of an investigation, the number of sampling points may be small and therefore, the distances between sampling points are large. In this case, there are areas where the values of clay parameters cannot be estimated at all. In later stages, the sufficient amount of samples to be able to make settlement calculations needs to be collected. If sampling points near each other have very similar properties they can be included in the same block. The size and shape of the blocks is hence decided by the relative position of sampling points with similar properties. The uncertainties in all geotechnical calculations are affected by the uncertainties in the estimated values of soil parameters between the sampling points.

An important element in determining if the settlements will be harmful is to estimate the reliability of the settlement calculations (Olsson, 2010). This is, in turn, dependent on the uncertainty in the estimated clay parameters in between the sampling points. The uncertainty in these estimated parameters can be reduced by taking more samples so that the general distance between boreholes decreases. This entails a high cost since the collection and evaluation of each individual sample is expensive, especially in urban areas. It is therefore desirable to reduce the uncertainty in estimated clay parameters without taking additional samples. One hypothesis is that it could be possible to use external factors to predict the values of clay parameters in between sampling points[3]. If the clay parameters that are evaluated from a sampling point could be related to cheap and easily accessible information about the external conditions in an area of investigation, the uncertainty in these clay parameters may be reduced without the need for additional samples.

[1] Jonas Sundell, industrial doctoral student, COWI, conversation January, 2014.
[2] Charlotte Junkers, chief specialist geotechnical engineer, COWI, conversation May 22, 2014.
[3] Jonas Sundell, industrial doctoral student, COWI, conversation January 2014.

1.1 Aim

The aim of this master's thesis is to investigate if there are statistically significant relationships between a number of external factors and various clay parameters. The identification of such relationships is meant to help better determine the uncertainty in clay parameters in areas in between sampling points in order to decrease the number of samples needed.

1.2 Limitations

The investigation is restricted to factors that can be derived from previously collected data and no new samples are thus collected to fulfill the purpose. The data is obtained from a few projects in Göteborg and Stockholm and mainly from CRS oedometer tests and laboratory protocols. The external factors and clay parameters that are included in the investigation are listed in Table 1.

Table: 1 Investigated external factors and clay parameters

External factors	Clay parameters
Sampling depth	Effective stress (σ_0')
Grade of urbanization	Preconsolidation stress (σ_C')
Soil type according to the geological map	Limit stress (σ_L')
Thickness of the soil layer overlaying the clay	The compression modulus M_L
Time since the soil layer overlaying the clay was placed	The compression modulus M'
Zone	Overconsolidation ratio (OCR)
City	Preconsolidation limit ratio (CLR)
	Density (ρ)
	Water content (w)
	Liquid limit (w_L)

Not all of the clay parameters are directly evaluated from CRS oedometer tests or stated in laboratory reports but are calculated. Such parameters are OCR, which is the ratio between σ_C' and σ_0', CLR, which is the ratio between σ_L' and σ_C' and σ_0', which is calculated from the unit weight of the soil, the pore water pressure and the depth.

One major limitation in the investigation is that the external loads from buildings and roads are excluded from the calculations of σ_0'. The reason for this is that it was considered too time consuming to make the proper investigations needed to include these.

The statistical analysis is performed with two different analysis methods; ANOVA (analysis of variance) and independent groups T-test. The analysis is performed using the software SPSS.

1.3 Question formulation

Are there any statistically significant relationships between the investigated external factors and clay parameters?

If so, could these be used to better determine the uncertainty in clay parameters in areas in between sampling points?

1.4 Outline of the thesis

Initially, some basic geotechnical theory and the theory behind the statistical analysis methods used are presented to give the reader the necessary insight in order to comprehend the overall investigation. Then, the methodology of the investigation is presented. This chapter explains how the data is collected and processed to fit the analysis methods and also how the statistical analyses are performed. The major part of the processing of data consists of the transformation and normalization procedure, which is thoroughly explained with an example. After that, the data is presented in its raw form as well as after transformation and normalization. Finally, the results, the discussion and the conclusions are presented.

2 Clay

This master's thesis mainly concerns two major subject areas, geotechnics and statistics. The geotechnical theory that is necessary for the reader to comprehend the content of the investigation is presented in this chapter. Information about how to measure the properties and also several ways how to use the data is presented. Initially, the theory concerning the structure of clay and the pore water pressure is presented. After that, the concept of effective stress and consolidation is covered. In Chapter 2.7, the definition of clay parameters and how they are evaluated is presented.

2.1 The structure of clay

Different soil types have different abilities to settle in a vertical direction (Knappett & Craig, 2012). Clay is a soft and fine grained soil type, which can be compressed due to an increase in effective stress. To be able to calculate the compressibility of a soil, in this context clay, the soils compression properties have to be evaluated.

All soils consist of particles and voids (Knappett & Craig, 2012). The voids are the space between the particles, which are filled with either water, air or both. This structure means that water is able to move relatively free in the material and the soil is therefore referred to as a permeable material. The water in the voids is called pore water and the pressure it causes in the pores (pore water pressure) is of interest since it has a big influence of the strength and stiffness of the soil. The soil is assumed to be fully saturated below the groundwater table, at which the pore water pressure (u) is equal to zero kPa.

2.2 Pore water pressure

Beneath the groundwater table, the pore water creates a pressure (Knappett & Craig, 2012). The pore water pressure (u) acts on all sides of the particles in the soil while the size of the particles is assumed to remain constant despite the pressure. When no information about the actual pore water pressure is available, the pore water pressure distribution can be assumed to be hydrostatic, which means that it increases with 10 kPa per meter below the groundwater table, see Equation (1).

$$u = \gamma_w \times z \qquad (1)$$

γ_w: unit weight of water, set to be 10 kN/m^3

z: depth beneath the groundwater table [m]

The pore water pressure at a certain point changes if the groundwater table is altered (Knappet, J.A & Craig, R.F, 2012). This can happen due to drainage caused by water leaking into a tunnel for example. In Figure 1, the change of the pore water distribution due to a lowered groundwater table is shown. Line 1 show the initial pore water pressure distribution corresponding to a water table (WT 1) and line 2 illustrates the new distribution after lowering the groundwater table (WT 2).

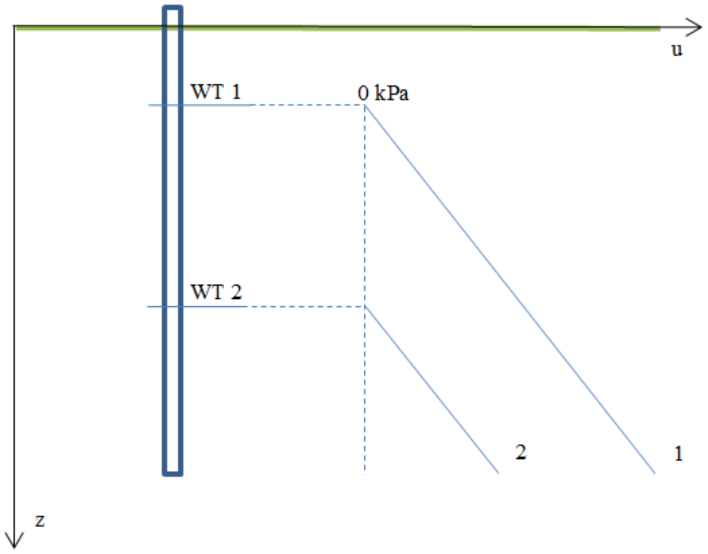


Figure 1: Change in pore water pressure distribution due to lowering of the groundwater table.

There are several ways to estimate the pore water pressure distribution in a soil (Sällfors, 2001). One is to measure the groundwater table with groundwater pipes and use hydrostatic pore water distribution. Another method is to use piezometers to measure the pore water pressure precisely at different levels. The ground water pipes are driven into the soils aquifer and measure the groundwater table that corresponds to the pressure in the aquifer. According to Karstunen[4], a soil can have several aquifers; for example one above the clay (an upper magazine) and one under the clay (a lower magazine), see Figure 2 on the next page. The clay has a very low hydraulic conductivity compared to the lower and upper magazines and therefore, the lower magazine is considered to be a confined aquifer while the upper magazine is considered to be an unconfined (or open) aquifer. The dot-dashed line in Figure 2 shows one possible theoretical pore water pressure distribution in the clay layer.

[4] Minna Karstunen, professor, lecture notes from the course Geotechnics BOM045, Chalmers University of Technology.

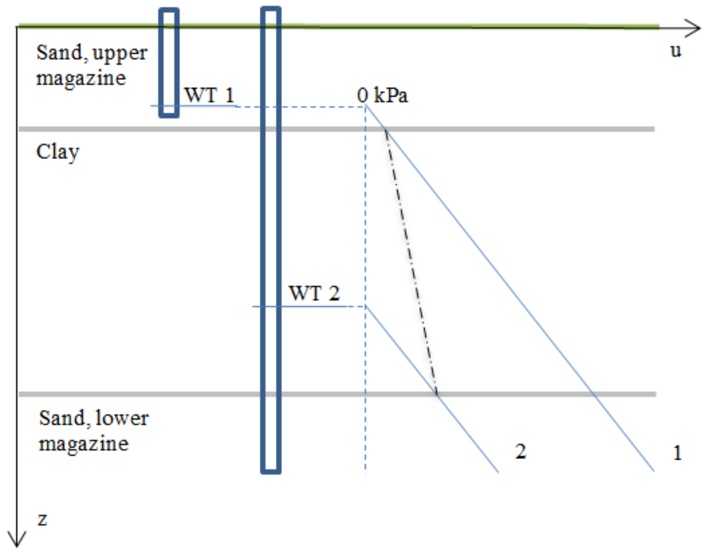


Figure 2: Upper and lower groundwater magazines.

2.3 Definition of effective stress

According to Knappett and Craig (2012), air is the only one of the three elements of soil (particles, water and air) that is compressible. The particles of a soil can be rearranged and the soil volume can then be decreased. The void ratio (e) has thus a big influence on if a soil is compressible or not. See Equation (2) for definition of void ratio. In the case of a fully saturated soil, the soil cannot change in volume unless the water seeps out, since water is considered to be incompressible.

$$e = \frac{V_v}{V_s} \qquad (2)$$

V_v: Total volume of water and air

V_s: Total volume of solids

Terzaghi (1943) presented the Principle of Effective Stress where he explains how forces are spread over the soil skeleton. The total normal stress σ_0 is the quota between the pressure (P) and the area (A). The normal stress can be carried by the pore water, but only for fully saturated soils, resulting in an increase in pore water pressure. The normal stress due to the soils self-weight is calculated with Equation (3) (Knappett and Craig 2012). The effective stress (σ'_0) is defined as the stress that is transmitted only through the soil skeleton, see Equation (4).

$$\sigma_0 = \gamma_{sat} \times z \quad (3)$$

γ_{sat}: unit weight of soil and water [kN/m³]

z: depth beneath ground surface [m]

$\sigma'_0 = \sigma_0 - u$ (4)

σ_0: total normal stress

u: pore water pressure

2.4 Consolidation

A soil with low permeability that is fully saturated can consolidate, reduce in volyme due to changes in effective stress (Knappett & Craig 2012). The effective stress can change for several reasons. For example, if the groundwater level is altered or if the total normal stress changes due to loading or unloading.

The static pore water pressure (u_s) is the initial pressure, that is, the pore water pressure prevailing prior to a change in normal stress (Knappett & Craig, 2012). When increasing the total normal stress by e.g. external loading, the pore water pressure will increase exactly as much as the load because the water is momentarily trapped within the pores and is incompressible. Until the water has seeped out and the particles have taken over carrying the stress, the pore water pressure is increased and the difference between this higher pressure and the original (static) one is called the excess pore water pressure (u_e). The water will flow towards a free-draining boundary until the excess pore water pressure has dissipated and the pressure is static once again. Then, the soil is said to be drained.

In a drained soil the total increase of the vertical stress is taken up by the soil skeleton (Knappett & Craig, 2012). The effective stress increases when the excess pore water pressure dissipates and at the same time, the volume decreases. How fast the water can flow through the soil, indirectly the time until the soil is drained, depends on the permeability of the soil. Soils of low permeability, such as clay, have a long drainage time. Another word for the process of compression due to dissipation of water is primary consolidation. The primary consolidation ends when the pore water pressure is static aging.

When considering consolidation, the theory of one-dimensional consolidation is the simplest one (Knappet, J.A & Craig, R.F, 2012). The stress is assumed to increase in only one direction, normally vertical, and there are thus no strains in any horizontal direction. this master's thesis considers only one-dimensional consolidation.

According to Knappett and Craig (2012), the vertical settlement of the soil surface is the consolidation settlement due to volume change. Different soils have different properties considering consolidation, which affects how large settlements a soil will have together with the load. Soil sampling and testing is required to be able to calculate how large the settlements will be. The different sampling and test methods are thoroughly explained in Chapter 2.7.

2.5 Load history

A soils stress history has an effect on the relationship between the strain and the effective stress (Sällfors, 2001). There are other relationships that are also affected by the stress history such as the one between void ratio and effective stress (Knappett and Craig, 2012). In this study, the relationship between strain and effective stress is used since this relationship is used in the most common Swedish oedometer test (Larsson, 2008).

During the sedimentation process of a soil, the effective stress will increase as the load increase due to the growing thickness of the soil (Sällfors, 2001). An increase of the effective stress will also increase the strain as the soil deforms and gets denser, see Figure 3 below. When the sedimentation process ends, the soil could be unloaded due to erosion. The soil will not heave to its original size since the majority of the deformations are plastic. In Figure 3, between points C and D, the soil is unloaded. If the soil is loaded again, due to e.g. construction or additional soil masses, the effective stress will increase, see the figure between points D and E. In this process, the deformation of the soil is limited. When the effective stress reaches the point E, the deformations will be large since the stress has never been higher before.

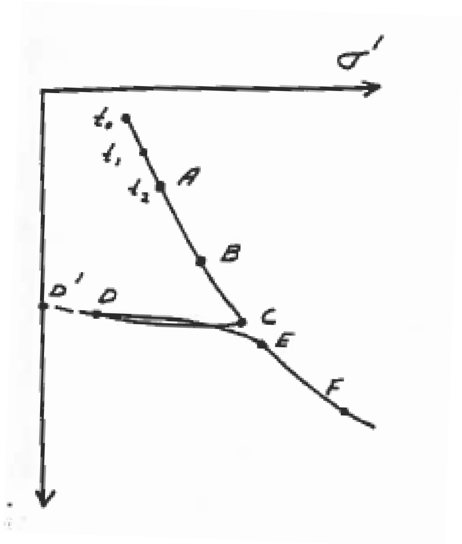


Figure 3: Stress-strain diagram (Sällfors, 2001).

2.5.1 Overconsolidation ratio

Normally consolidated clays have an effective stress that is equal to the largest stress the soil has ever experienced (Knappett & Craig, 2012). Soils can also be overconsolidated, which typically means that the present effective stress is lower than the largest stress the soil has ever experienced. The largest effective stress in the history of a soil is called the preconsolidation pressure (σ'_{max}). In Sweden, this stress is called preconsolidation stress σ'_C and is determined from CRS oedometer tests. The preconsolidation stress is shown at the point E in Figure 3 above. The overconsolidation ratio (OCR) is a ratio between the preconsolidation stress and the current effective stress (vertical). See Equation (5) for calculation of OCR.

$$OCR = \frac{\sigma'_C}{\sigma'_0} \qquad (5)$$

If σ'_0 is equal to σ'_C, OCR is thus equal to one and the clay is normally consolidated (Knappett & Craig, 2012).

2.5.2 Secondary compression and aging

Even after the excess pore water pressure has dissipated, the compression of the soil continues (Knappett & Craig, 2012). This process is called secondary compression. The reason for the secondary compressions is the rearrangement of the particles, which also leads to a decrease in void ratio.

Long term secondary compression has an effect on the preconsolidation stress (σ'_C) (Mitchell, 1993). Figure 4 illustrates how the void ratio decreases with time, even though the effective stress is constant. This is called delayed consolidation and leads to higher values of σ'_C than the one generated by the greatest load that the clay has ever experienced (Bjerrum, 1967). The size of the decrease in void ratio depends on time and the occurring loads. This means that a soil will become more overconsolidated with time even though the effective stress does not change. This phenomenon is sometimes referred to as aging and this designation is used in the rest of this master's thesis.

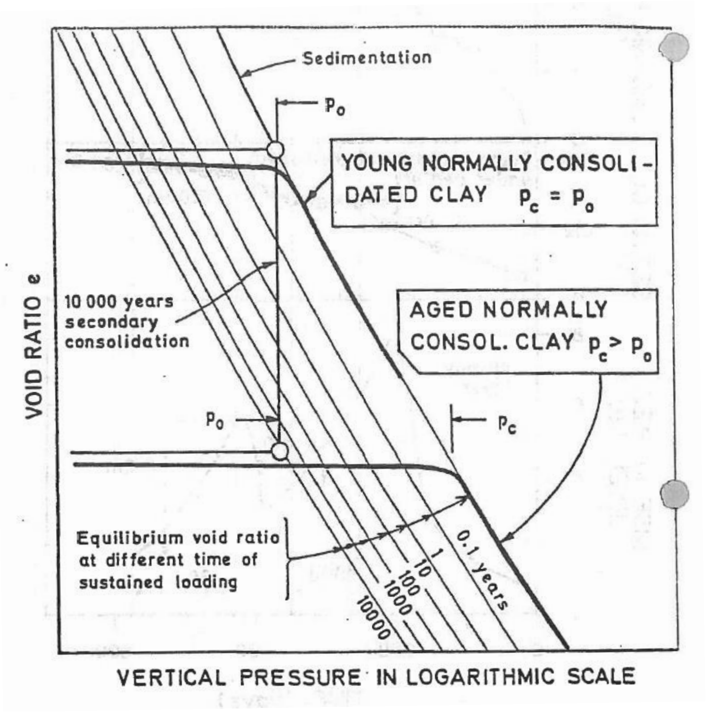


Figure 4: The aging process (Schmertmann, 1993).

2.6 Load distribution

Buildings and roads affect the soil differently depending on how they are built and the normal stress is dependent on how the loads are distributed in the soil (Alén, 2009). Buildings that have a foundation consisting of end bearing piles, which are in contact with the rock underneath the soil, do not have any effect on the soil since the load is transferred down to the rigid rock through the piles. Buildings that are, on the other hand, built directly on the soft soil affect the soil. There are different theories of how the load is distributed in the soil. One method for calculation of the load distribution is the 2:1 method (Sällfors, 2001). The additional stress from external loads is assumed to spread with an inclination of 2:1, see Figure 5. If a construction is founded on cohesion piles, the load distribution can be assumed by a rough estimation to start two thirds of the pile length beneath the soil surface.

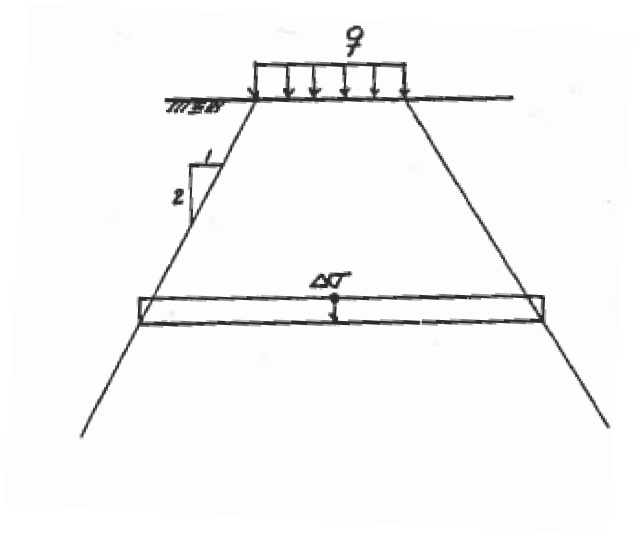


Figure 5: Load distribution from an external load (Sällfors, 2001).

The additional stress ($\Delta\sigma$) due to load (q) will decrease with depth, see Equation 6.

$$\Delta\sigma = \frac{W \times L \times q}{(W+z) \times (L+z)} \qquad (6)$$

W: width of the load

L: length of the load

q: load

z: depth

2.7 Definition of clay parameters, soil sampling and testing

To determine the values of the different clay parameters, soil samples have to be taken and analyzed (Knappett & Craig, 2012). Two of many sampling methods that can be used to determine some properties of the soil are disturbed and undisturbed tests. The samples from these tests are evaluated in a laboratory and the density (ρ), water content (w) and liquid limit (w_L) are some of the properties that can be determined, see Equations 7 for definition of the water content. The liquid limit is defined as the water content beyond which the clay starts to act like a liquid. Below the liquid limit, the clay has a plastic behavior.

$$w = \frac{M_w}{M_s} \qquad (7)$$

M_w: mass of water

M_s: mass of solids

There are some properties that can only be evaluated from undisturbed samples, for example compression properties. To determine the compression properties the undisturbed samples are tested in an oedometer test. In Sweden, the CRS oedometer test is commonly used (Larsson, 2008). Undisturbed tests consist of three cylindrical containers from each sampling depth. The middle or the lower container is used for the CRS oedometer test, since the upper is more disturbed.

2.7.1 Constant rate of strain oedometer test

To determine the characteristics of the soils compression properties, there are several tests that can be used (Larsson, 2008). In Sweden, the Constant rate of strain (CRS) oedometer test is commonly used as mentioned earlier.

The compression parameters σ'_C, σ'_L, M_L and M' are estimated from CRS oedometer tests (Sällfors & Andréasson, 1986). The CRS oedometer test is performed on undisturbed clay samples.

During the CRS test, a curve is drawn, showing the relationship between strain and the effective stress, see Figure 6 (Sällfors & Andréasson, 1986). From the given curves, the compression parameters are estimated.

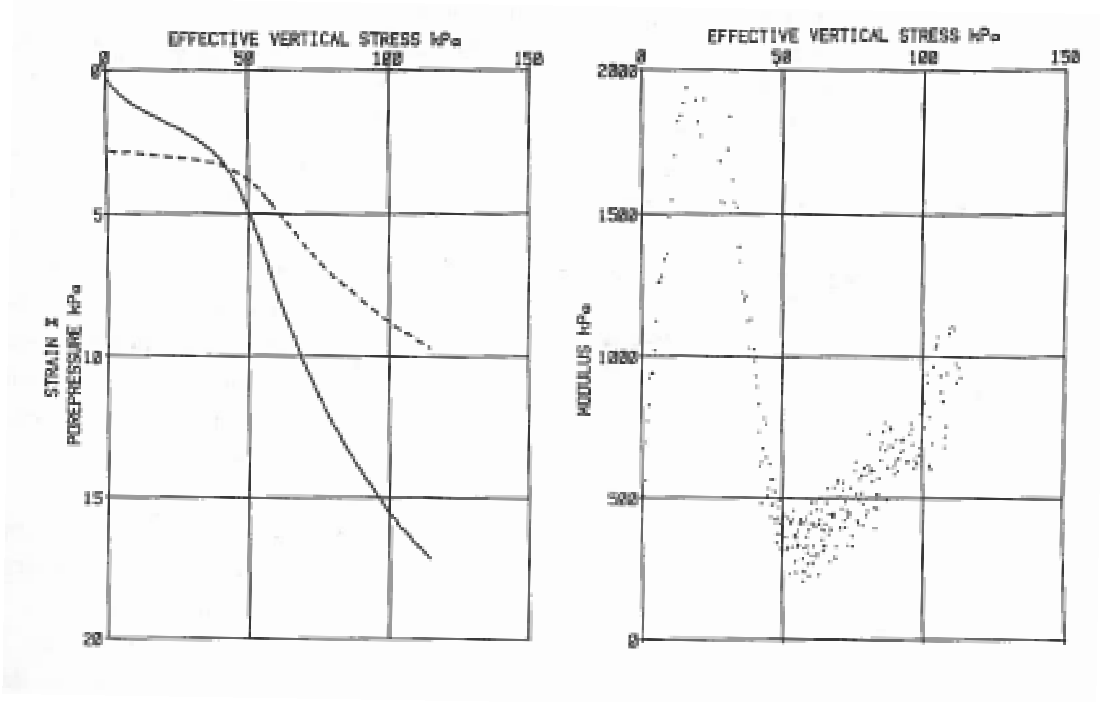


Figure 6: Outputs from a CRS oedometer test (Sällfors & Andréasson, 1986).

The preconsolidation stress is defined as the effective (vertical) stress where the soil compression modulus suddenly decreases, with other words, where the curve bends. To be able to evaluate the σ'_C there is a special method that has to be used for CRS oedometer tests (Sällfors & Andréasson, 1986). The two lines on the oedometer curve are extended, see Figure 7, then a tangent is drawn so that an isosceles triangle is created. σ'_C is located at the left corner of the isosceles triangle. The compression modulus M_L describes the inclination of the more vertical extended line to the right of σ'_C and is calculated as the division between the effective stress and the strain, that is, the derivative of this line, see Figure 8.

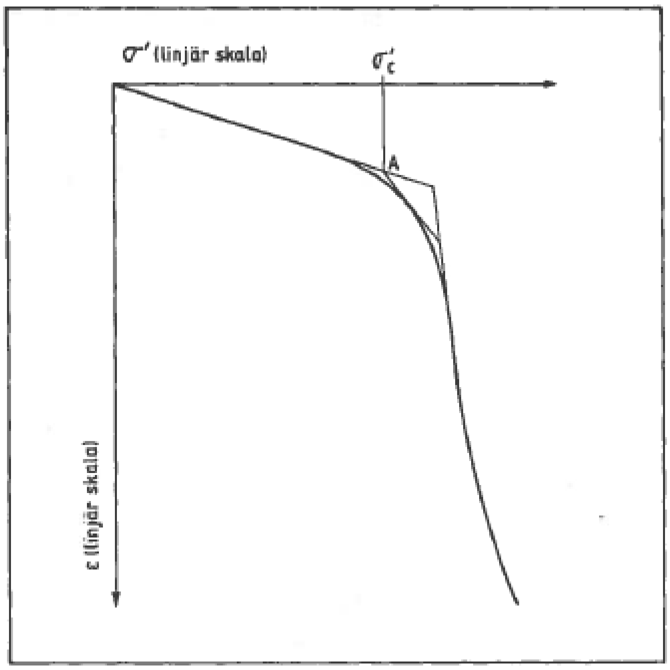


Figure 7: Illustration of how to evaluate the preconsolidation stress (Sällfors & Andréasson, 1986).

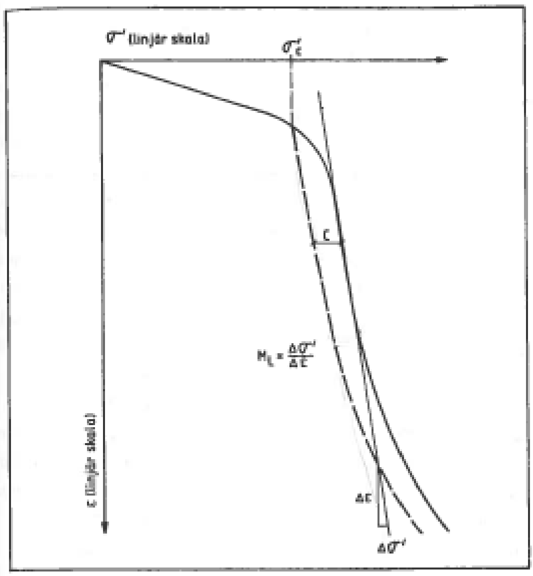


Figure 8: Illustration of how to evaluate the compression modulus M_L(Sällfors & Andréasson, 1986).

Figure 8 also shows how to evaluate the distance C, while Figure 9 shows how the limit stress (σ'_L) is evaluated using the distance C and also how *M'* is evaluated. σ'_L is defined as the stress where the modulus is no longer constant.

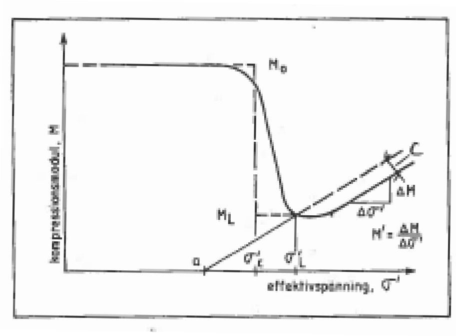


Figure 9: Illustration of how the limit stress and the compression modulus M' are evaluated (Sällfors & Andréasson, 1986).

The clay sample must be undisturbed for the test to give valid curves (Sällfors & Andréasson, 1986). In those cases when the sample has been disturbed, the curve will become straighter. Events that can disturb a sample are hits and vibrations. The test is made with constant speed and normal deformation speed is 0.0025 mm/min.

2.8 Present geotechnical approach

Each geotechnical project is unique since the soil and its properties are inhomogeneous (Sällfors, 2001). A large challenge is to decide how many soil samples that has to be collected and evaluated in order to give good estimations of the soil properties at different locations.

According to Junkers[5], in those points where a geotechnical engineer has taken soil samples, she or he can be certain of what parameters the soil has but only at that specific point. In the areas in between sampling points, the parameters have to be estimated. The information given from the sampling points is used when predicting the properties of the soil in the area surrounding the sampling point. The approach that is used today suggests that an area of investigation is divided into blocks around each available sampling point and the values of clay parameters within an entire block are then estimated assuming that they are similar to those evaluated from the sampling point. The size of these blocks cannot be made too large. The greater the distance from the sampling point is, the greater is also the uncertainty and too high uncertainties in estimated values cannot be accepted. In the early stages of an investigation, the number of sampling points may be small and therefore, the distances between sampling points are large. In this case, there are areas where the values of clay parameters cannot be estimated at all.

[5] Charlotte Junkers, chief specialist geotechnical engineer, conversation May 22, 2014.

3 Statistical analysis

In this chapter the theory behind the statistical analysis methods used for the investigation carried out in this master's thesis is presented. The methods used are analysis of variance (ANOVA) for independent variables with at least one degree of freedom and independent groups *T*-tests for analysis of independent variables with zero degrees of freedom. Both these methods require that the dependent variables are normally distributed. Since many of the clay parameters have an intrinsic relationship to depth, the data have to be normalized. This is done by fitting a regression curve to the data why the theory behind regression analysis is also included in this chapter. All statistical analyses are performed using the software SPSS and for that reason, the outputs from this tool are woven in and connected to the theories in this chapter as well. This is done to give the reader a better understanding for the method and results from chapters further on.

3.1 ANOVA

ANOVA is an abbreviation for analysis of variance and can be used to analyze the effect of one or more independent variables on a dependent variable (Brace, Kemp, & Snelgar, 2012). In ANOVA designs, the independent variables are denoted factors and these can in turn have a number of levels. For example, one of the factors in the analysis performed within this master's thesis is labelled "*Degree of urbanization*" and has the three levels "*Rural, Semi-urban* and *Urban*". However, in the rest of this master's thesis, factors are denoted independent variables and levels are denoted categories for convenience. It is only applicable to use ANOVA if the independent variables included have at least one degree of freedom, meaning that they each have at least three categories. Independent variables with zero degrees of freedom are not included in the ANOVA but are instead analyzed using an independent groups *T*-test. The independent variables (or factors) can also be divided into between-subjects factors and within-subjects factors, of which only the first class is applicable for the study in question. This class is defined as independent variables for which any observation is only noted for one single category. For example, an observation can only be noted for one single degree of urbanization (rural, semi-urban or urban).

The main purpose of an ANOVA design is to determine if one or more independent variables have a significant effect on a dependent variable (Brace, Kemp, & Snelgar, 2012). This is done by comparing the variance between the categories of the independent variable (variance due to manipulation of independent variable) to the variance within each category (error variance). The difference between these is expressed by the *F*-ratio which is calculated with Equation (8).

$$F = \frac{Variance\ due\ to\ manipulation\ of\ independent\ variable}{Error\ variance} \qquad (8)$$

One of the requirements that must be fulfilled in order to say that the effect of an independent variable is significant is that the *F*-ratio (or *F*-factor) is larger than one. The *F*-factor is, in turn, only considered significant if it exceeds a certain critical value, decided by the number of included observations and the level of certainty at which the test is performed. What is basically done here is a hypothesis test where the null hypothesis is that there is no difference between the categories and this is then either accepted or rejected.

The standard output from an ANOVA design in SPSS contains a number of different statistics compiled in tables. All of these statistics are not necessarily of interest for the investigation at hand and are therefore not presented further. The output can contain several *F*-factors which represent either main effects or interactions (Brace, Kemp, & Snelgar, 2012). The main effect describes the effect of one single independent variable on a dependent variable while the interaction describes the combined effect of two or more independent variables on a dependent variable. The output will contain one main effect *F*-factor for each independent variable included and one interaction *F*-factor for each unique combination of independent variables within the design. There is also an *F*-factor for the corrected model which indicates if the whole model is valid. For each *F*-factor, the output also contains a value of significance for the difference between the categories (*p*-value) which indicates if the *F*-factor in itself is significant or not. If the *p*-value is smaller than 0.05, the corresponding *F*-factor exceeds the critical value corresponding to a significance level of 0.05, meaning that one can be 95 percent sure that there is a significant difference between the categories.

ANOVA can be performed in several ways and in the methodology applied in this master's thesis, which was adopted by an expert[6], two different approaches are used; one-way ANOVA and full-factorial ANOVA. In a one-way ANOVA, only the main effects are analyzed while in a full-factorial ANOVA, both main effects and interactions are included. The one-way ANOVA is in this case used to make a first screening before the full-factorial ANOVA. This is further described in Chapter 4.7.

3.2 Independent groups *T*-test

There are several different types of *T*-tests and the one used in this master's thesis is called an independent samples *T*-test, or independent groups *T*-test (Pallant, 2011). This is used to compare the mean values of a dependent variable between two different groups. Therefore, it can be used to determine if an independent variable with zero degrees of freedom, meaning that it has only two categories, has a significant effect on a dependent variable by comparing the mean values of the dependent variable between the two categories of the independent variable. What is basically done here, same as for the ANOVA, is a hypothesis test where the null hypothesis is that there is no difference between the categories and this is then either accepted or rejected. Independent variables with at least one degree of freedom are not analyzed using a *T*-test but are instead included in the ANOVA.

The standard output from an SPSS run of an independent groups *T*-test contains a number of different statistics compiled in two tables, the Group Statistics table and the Independent Groups Test output table. All of these statistics are not necessarily of interest for the investigation at hand and are therefore not presented further. The Group Statistics table contains the mean value, standard deviation and number of observations (N) in each of the two groups, or levels. The Independent Groups Test output table contains the Levene's *p*-value (Sig.) and the value of significance for the difference between categories (Sig. (2-tailed)). The Levene's *p*-value, or Levene's test for equality of variances, indicates if the variance within the two different categories is equal or not. If the Levene's *p*-value exceeds 0.05, equal variances can be assumed and otherwise not. SPSS always displays two rows of output statistics, the upper with equal variances assumed and the lower with equal variances not assumed. The Levene's *p*-value then determines which statistics are valid for the particular *T*-test. The value of significance for the difference between categories indicates if there is a statistically significant difference between the mean values of the dependent variable for the two different categories. If Sig. (2-tailed) is equal to or smaller than 0.05, the difference between the mean values of the dependent variable in the two categories is significant and otherwise not. An example of the outputs as described in this chapter is shown in Figure 10. As can be seen, the Levene's p-value is smaller than 0.05 and therefore, the lower row of statistics is valid. In this case,

[6] Jonas Sundell, industrial doctoral student, COWI, conversation April 2014.

the value of Sig. (2-tailed) is smaller than 0.05 meaning that there is a significant difference in the mean values of the tested dependent variable between the two levels of the independent variable.

Group Statistics table

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,7484229	,80880748	,07711677
Götatunneln, Göteborg	79	1,0421079	,98243276	,11053232

Independent Groups T-test output table

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	7,425	,007	-13,713	187	,000	-1,79053080	,13057184	-2,04811391	-1,53294769
Equal variances not assumed			-13,285	147,421	,000	-1,79053080	,13477533	-2,05687199	-1,52418961

Levene's *p*-value

Value of significance for the difference between levels

Figure 10: Output from Independent Groups T-test in SPSS.

3.3 Regression analysis

The estimation, or more accurately the prediction, of unknown values of a dependent variable in between known ones is often the main aim of statistical analysis (Johnson, Probability and Statistics for Engineers, 2011). In this endeavor, it is desirable to obtain some mathematical formula that describes the relationship between the dependent variable and one or more independent variables. It is usually assumed that the independent variables can be observed with no or at least negligible error while the dependent variable has some intrinsic error, so-called chance variation. The dependent variable is therefore a random variable whose distribution depends on the independent variable. A regression curve represents the mean values of the dependent variable. This is thoroughly explained in the chapter.

3.3.1 Linear Regression

If it is possible to fit a straight line to the scatter plot of Y on x, then the regression of Y on x may be referred to as linear, see Figure 11 (Johnson, Probability and Statistics for Engineers, 2011). For a linear regression of a random variable Y that depends on one single independent variable x, the mean of the distribution of the Y's for any given x is given by the following Equation 9 where α is the intercept, the Y-value corresponding to an x-value of zero, and β is the regression coefficient, the incline of the curve (Johnson, Probability and Statistics for Engineers, 2011).

$\alpha + \beta x$ (9)

When fitting a regression curve to a data set, the parameters α and β have to be estimated in order to obtain a formula. These constants are then denoted a and b respectively and the formula of the fitted line can be written as follows, see Equation 10 where a and b are called estimates of α and β.

$\hat{y} = a + bx$ (10)

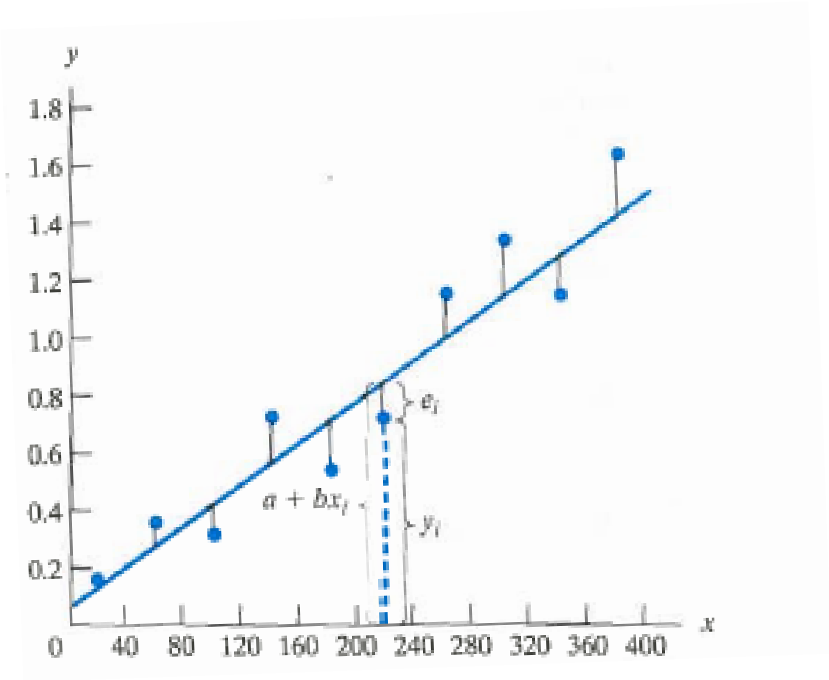


Figure 11: Linear regression (Johnson, Probability and Statistics for Engineers, 2011).

For linear regression, the data must have a normal distribution and linearity (Brace, Kemp and Snelgar, 2012). According to Brace (2012) the data should also be screened from outliers. The independent variables should also be chosen so that there might be a correlation between the independent and dependent variables.

3.3.2 The Method of Least Squares

Since Y is a random variable whose distribution depends on x and the regression curve represents the mean of Y on x, a randomly selected known value on Y will generally differ from the corresponding value on the regression curve (Johnson, Probability and Statistics for Engineers, 2011). The formula describing any individual known value on Y can be written as Equation 11 where α is the intercept, β is the regression coefficient and ε is the difference between the individual Y-value and the corresponding value on the regression curve.

$Y = \alpha + \beta x + \varepsilon$ (11)

This difference (or residual), when fitting a regression curve to a data set, can be written as Equation 12 and since y is a random variable, e is also a random variable, see Figure 11 above.

$e_i = y_i - \hat{y}_i$ (12)

The best possible fit of a straight line to the scatter plot of Y on x is thereby the one making the mean of the distribution of e equal to zero. The method of least squares is a non-subjective technique for obtaining the values of the estimates a and b. These are chosen so that the following expression is a minimum, see Equation 13.

$$\sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n}[y_i - (a + bx_i)]^2 \qquad (13)$$

The reason for squaring the errors before summing them up is that the sum of the unsquared errors could very well be made equal to zero by fitting a lot of different unsuitable lines to the data set, just making the positive and negative errors cancel each other out.

The estimates a and b, as well as the error sum of squares *SSE*, are calculated using a number of sums of squares and cross-products as shown below, see Equations 14, 15 and 16: where $\bar{x}$ and $\bar{y}$ are the means of x and y respectively and n is the number of observations in the data set.

$$S_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2 = \sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n} \qquad (14)$$

$$S_{yy} = \sum_{i=1}^{n}(y_i - \bar{y})^2 = \sum_{i=1}^{n} y_i^2 - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n} \qquad (15)$$

$$S_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) = \sum_{i=1}^{n} x_i y_i - \frac{\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{n} \qquad (16)$$

The estimates a and b are then calculated with Equation 17 and 18, and the error sum of squares *SSE* with Equation 19.

$$a = \bar{y} - b \cdot \bar{x} \qquad (17)$$

$$b = \frac{S_{xy}}{S_{xx}} \qquad (18)$$

$$SSE = \sum_{i=1}^{n}(y_i - a - bx_i)^2 = S_{yy} - S_{xy}^2/S_{xx} \qquad (19)$$

The error sum of squares is also referred to as the residual sum of squares.

It is often desirable to state confidence intervals for the regression coefficients α and β. This is done using an estimate of the error variance σ^2 referred to as the standard error of the estimate s_e^2 which is calculated with Equation 20.

$$s_e^2 = \frac{\sum_{i=1}^{n}(y_i - a - bx_i)^2}{n-2} = \frac{S_{yy} - S_{xy}^2/S_{xx}}{n-2} = \frac{SEE}{n-2} \qquad (20)$$

Depending on which one of the coefficients that is being assessed, the confidence limits are calculated with ether Equation 21 or 22 where $t_{\alpha/2}$ is a table value that is chosen in accordance with a certain confidence level α[7] and degree of freedom.

$$\alpha{:}\ a \pm t_{\alpha/2} \cdot s_e \sqrt{\frac{1}{n} + \frac{(\bar{x})^2}{S_{xx}}} \qquad (21)$$

$$\beta{:}\ b \pm t_{\alpha/2} \cdot s_e \frac{1}{\sqrt{S_{xx}}} \qquad (22)$$

It is also possible to calculate a confidence interval for the mean response at a certain point $\hat{y}(x_0)$ as following Equation 23.

[7] This should not be confused with the regression coefficient α which is the intercept of the regression curve and the Y-axis and is denoted with the same sign.

$$\alpha + \beta x_0 : (a + bx_0) \pm t_{\alpha/2} \cdot s_e \sqrt{\frac{1}{n} + \frac{(x_0 - \bar{x})^2}{S_{xx}}} \qquad (23)$$

3.3.3 Curvilinear Regression

It is not always possible to directly fit a straight line to the scatter plot of Y on x (Johnson, Probability and Statistics for Engineers, 2011). However, it may very well be possible to fit some other curve to the data set. In order to apply the method of least squares to this kind of data, the variables must first be transformed in such a way so that it is once possible to fit a straight line to the new scatter plot obtained from the transformed variables.

If, for example, the regression curve of Y on x is exponential, the dependent variable y_i can be transformed into $log\ y_i$ and plotted against the independent variable x_i to be able to fit a straight line and then use the method of least squares to obtain the estimates needed to construct the formula (Johnson, 2011). This formula can then be expressed in either logarithmic form as:

$\alpha + \beta x$ and the fitted curve as: $\widehat{\log y} = c + dx$

where c and d are the estimates of α and β respectively, or in exponential form as:

$\alpha \cdot \beta^x$ and the fitted curve as: $\hat{y} = 10^c \cdot (10^d)^x$

If the functional form of the regression curve is hard to see by eye, it is common practice to test a number of different transformations in order to be able to transform the curve into a straight line and then use the method of least squares.

The software SPSS is a tool that can be used to estimate what kind of curve best fit a data. The transformation to a straight line is a process SPSS automatically performs when evaluating a nonlinear curve. This master's thesis will with SPSS only find the curve that best fits the data.

3.3.4 Correlation and Causation

In regression analysis it is, as mentioned earlier, usually assumed that the independent variables can be observed with little or no error while the dependent variable is randomly distributed (Johnson, Probability and Statistics for Engineers, 2011). This is, however, not always the case and when both dependent and independent variables are random, a correlation analysis might be in place. The strength of the correlation is expressed by the sample correlation coefficient R that can be calculated with Equation 24 where R can assume values between -1 and 1.

$$R = \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{s_x}\right)\left(\frac{y_i - \bar{y}}{s_y}\right) = \frac{S_{xy}}{\sqrt{S_{xx} \cdot S_{yy}}} = \frac{\sqrt{S_{xx}}}{\sqrt{S_{yy}}} b \qquad (24)$$

A high value in any direction indicates a strong linear relationship, either positive or negative depending on the sign, while a value close to zero indicates a weak relationship. As can also be seen in the third expression above, the correlation coefficient R has the same sign as a possible least squares estimate for the slope b. If the correlation coefficient is squared, it represents the coefficient of determination R^2. This coefficient is commonly used to explain how much the equation of the regression line can be used to explain the values of the dependent variables.

The fact that there is a strong correlation between two variables does not necessarily mean that the variation in one of them is causing the variation in the other (Johnson, Probability and Statistics for Engineers, 2011). Both of the observed variables may instead be dependent on a third unknown, so called lurking variable. It is therefore important to examine all possible cause-and-effect relationships between variables and discuss the plausibility of observed correlations before jumping to conclusions. Moreover, it is not safe to say that there is a strong positive causal relationship between two variables just because there is a strong positive correlation between them. Without further information, the exact opposite is equally likely. With respect to this, it is also important to study how exactly the variation in one variable is causing the variation of another before stating any conclusion about the cause-and-effect relationship between them.

3.4 The measures of variables

Data can have different measures; nominal, ordinal or interval (scale) (Sundell, 2013). The nominal measure is suitable for categories, such as e.g. zone. There are several zones, but none of them are more zone than the other, e.g. they have no order relative to each other and cannot be ranked. An ordinal measure can be ranked but the distance between the categories cannot be determined. A variable that consists of the categories e.g. grade of urbanization with the categories; rural, semi-urban and urban can be ranked but it is not possible to determine the difference in urbanization between the different categories. The interval measure is categorized, ranked and the distance between the categories is the same. The distance between one and two meters, is the same as between five and six meters.

4 Method

Initially, a literature study has been made of geotechnical soil parameters and ANOVA, *T*-test and regression analysis. The theories are presented in Chapter 2 and 3. This chapter covers the methodology of the study and the overall process is illustrated in Figure 12. Data has been collected from different infrastructure projects and compiled in different Excel files. How the data is collected is further presented in Chapters 4.3 and 4.4. The raw data has then been processed through transformation and normalization before it is analyzed, see Chapter 4.6. The ANOVA analyses and *T*-tests have been performed using the software SPSS and its methodology are covered in Chapter 4.7 and 4.8**Error! Reference source not found.**.

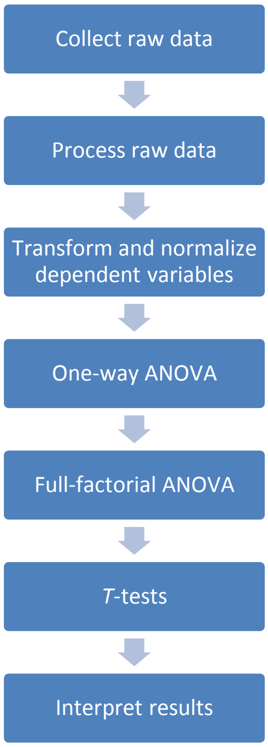


Figure 12: The overall process of the investigation.

4.1 Four infrastructural projects

The geotechnical compression parameters are collected from four different infrastructural projects, two from Stockholm (City Link and Bypass Stockholm) and the other two from Göteborg (Götatunneln and E45-Norge/Vänerbanan). All of the projects are tunnel projects except E45-Norge/Vänerbanan, which is a railway and highway project. The four projects were started at different times, Götatunneln is the oldest and the data is from 1995, E45-Norge/Vänerbanan has data from 2008. The two Stockholm projects Bypass Stockholm and City Link have data from 2009 and 2013 respectively.

In Table 1, the references of the different reports for each project are presented.

Table 2: References to the infrastructural projects.

Project	**References**
Bypass Stockholm	Lindberg (2011) and Lindeholm (2013)
City Link	Bouzas (2014) and Nylander (2014)
E45-Norge/Vänerbanan	Junkers (2008), (2009) and (2010)
Götatunneln	Vägverket (2000a-d)

The study only assesses data stemming from undisturbed and disturbed field tests. The projects around Göteborg constitute a smaller area of investigation compared to the two Stockholm projects. The two cities differ from each other in the way that Stockholm has many boreholes but few depth levels while Göteborg has few boreholes and many depth levels.

All data on clay parameters comes from geotechnical reports from these four projects. The four projects have used different laboratories to evaluate the soils properties. All observations that were surveyed are not used, see Chapter 4.5 for the screening process of collected data.

4.2 Data sets

The collected data is divided into three data sets; Göteborg, Stockholm and All observations from 3-8 meters. This is done due to the overall dominance of observations from shallow sampling depths, which stems from the fact that clay in Stockholm generally has a far smaller depth span than clay in Göteborg. The division into subgroups represented by the two cities is hence made to prevent that this dominance would lead to an intrinsic bias in the data. In order to be able to assess statistical differences between the two cities, a data set consisting of all observations from sampling depths between 3 and 8 meters is created. The reason for using this depth span is that it is rather well represented by observations from both cities. The frequency of observations from different sampling depths can be seen in Figure 13.

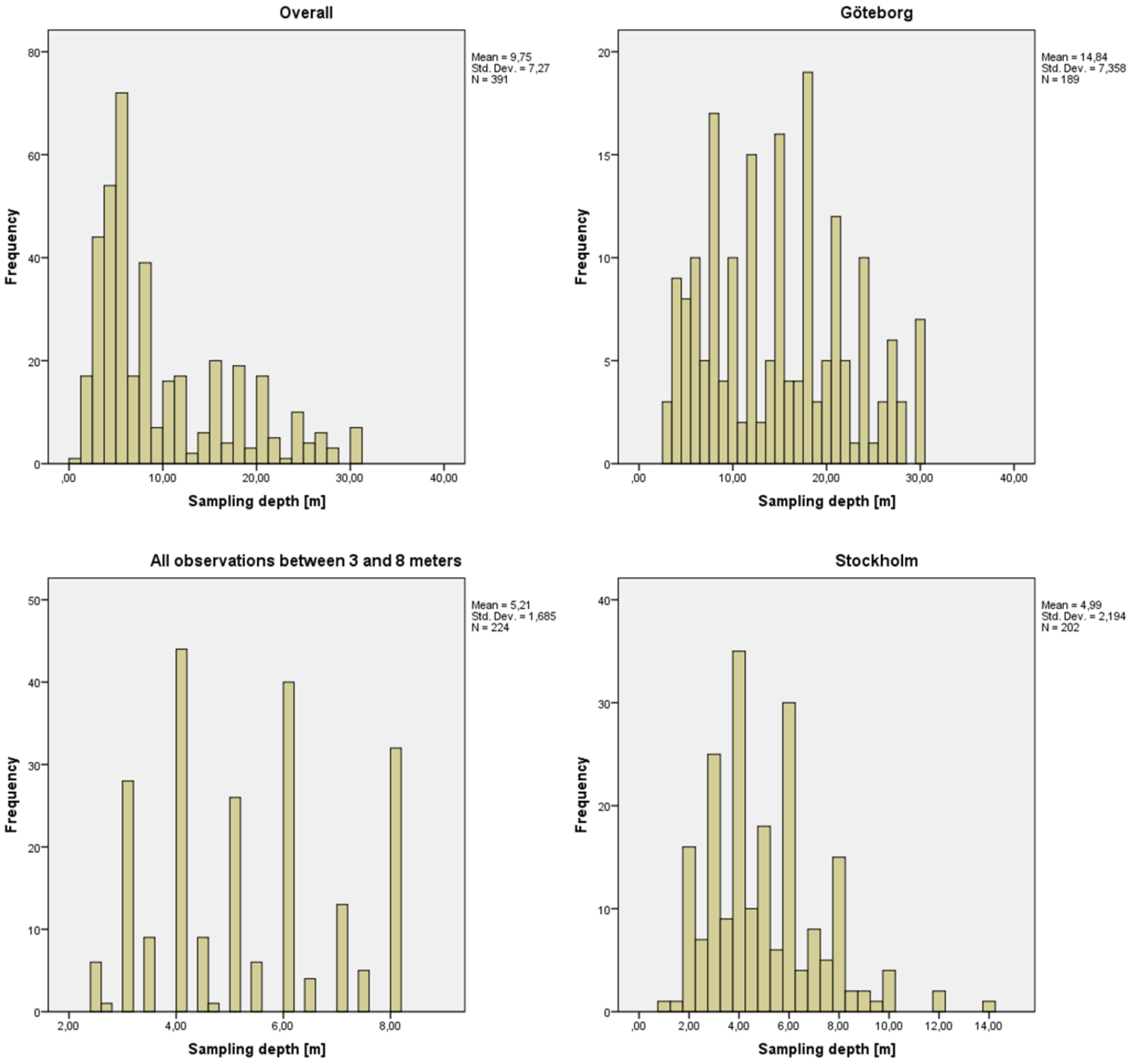


Figure 13: Frequency of data over the sampling depth in the different data sets.

4.3 Clay parameters

In this section, the selected clay parameters, which serve as raw data for the dependent variables in the statistical analyses, are presented. The data is assumed to be independent, meaning for example that observations from different sampling depths within the same borehole are assumed to be independent from each other.

4.3.1 Effective stress, σ'_0

For all projects, σ'_0 is calculated manually with the equations in Chapter 2.3, except for City Link where the values were given from the geotechnical report *City Link Tunnel Riskanalys marksättningar hydrogeologiska utredningar* by Sundell and Haaf (2014).

The normal stress is calculated by only taking the weight of the soil into consideration, see Equation 4 in Chapter 2.3. The normal stress is calculated for each level by dividing the soil into layers of different thicknesses. Each layer is assigned one single density value given from lab tests. If one level has several densities, a mean value is used. For example, if the density is measured at level 3 and 5 under the surface, the three first meters is assumed to have the same density as level 3, while the two following meters have the same density as level 5. The normal pressure is calculated by multiplying the density with the thickness of the layer and adding the normal stress imposed by overlaying layers. In those cases where no information about the density of the soil overlaying the clay is available, it is assumed to have a density of 1.7 t/m³. This value is taken from TK Geo 11 and represents clay or macadam ballast over the groundwater table (Trafikverket, 2011).

The pore water pressure is calculated in several ways. For Stockholm, the data that is available is groundwater levels from the water pipes. If the water pipe installed in the lower magazine indicates a water table within the clay layer, the pore water pressure is set to be zero at the top of the clay layer. The pressure distribution is then not hydrostatic, since the measured pore water pressure for the bottom of the clay is used as a fixed value. A theoretical pore water pressure distribution is calculated, see Figure 14, where the dot-dashed line shows the theoretical pore water pressure distribution in the clay layer.

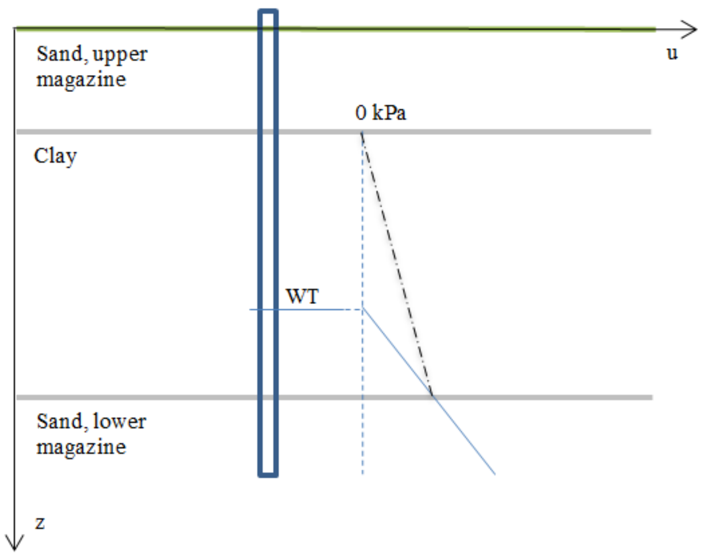


Figure 14: Illustration of the theoretical shift upwards of the groundwater level.

If the groundwater level from a lower magazine is indicated above the clay and there is no information about the water level in the upper magazine, the pore water pressure distribution is set to be hydrostatic. If there is information about both an upper and a lower groundwater level, the theoretical pore water pressure distribution looks like the dot-dashed line in Figure 15. For the project Bypass Stockholm, the groundwater levels are given in the geotechnical report. For City Link, the pore pressure is calculated by Sundell and Haaf[8]. They have used the methods described above for Stockholm.

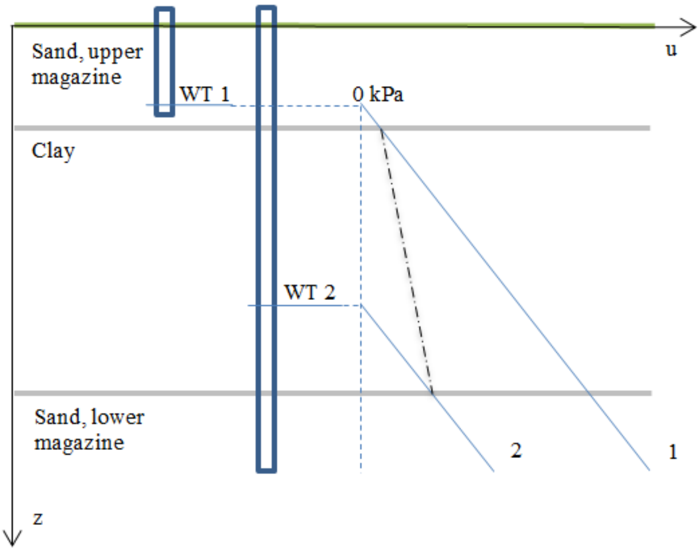


Figure 15: Illustration of the adjustment of the pore water pressure distribution when there are two different groundwater levels.

For Göteborg, the available data concerning pore water pressure has been measured for some boreholes. This has been done with piezometers installed at several levels under the ground surface. There are no data of the groundwater table for the upper magazine in the projects in Göteborg. The geotechnical report from Götatunneln presents the ground water table corresponding to the measured pore water pressure. To be able to determine the pore water pressure that occurred in the clay at the time for the measurement, a back calculation is made, see Equation 25.

$$u = (z - given\ water\ table\ level) \times 10 \quad (25)$$

z: level of piezometer beneath ground surface

The water tables that are used are the maximum measured levels. The increase of the pore water pressure between two measured levels is calculated by Equation 26.

$$k = \frac{\sigma'_{01} - \sigma'_{02}}{z_1 - z_2} \quad (26)$$

The water table is set to be below a dry crust or at a level that corresponds to a k_1 of 10 kPa per meter (hydrostatic pressure between the first piezometer and the water table) since no information about the upper groundwater table is given for both the Göteborg projects. Figure 16 shows an example of how the pore water pressure distribution could look like.

[8] Jonas Sundell, industrial doctoral student, COWI and Ezra Haaf, engineer, COWI.

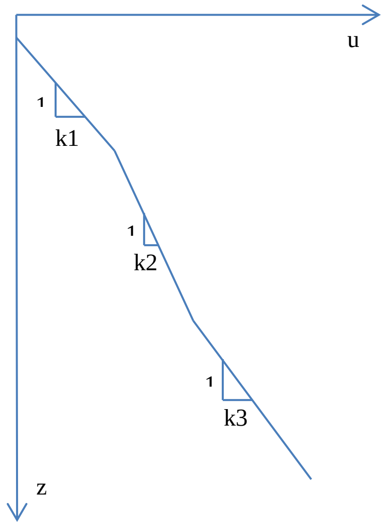


Figure 16: Example of pore water distribution in Göteborg.

The effective stress is calculated with Equation 5 that is found in Chapter 2.3. For City Link, the effective pressure is already calculated by Sundell and Haaf[9].

4.3.2 Preconsolidation stress, σ'_C

The parameter σ'_C is evaluated from CRS oedometer tests, as mention earlier. For all the projects, except E45-Norge/Vänerbanan, the parameter is compiled in the geotechnical reports that are surveyed. It is assumed that the already evaluated values cannot be evaluated better and thus, no further investigation of these is done. For the project E45-Norge/Vänerbanan, the given data are CRS oedometer curves. σ'_C is then evaluated by the method explained in Chapter 2.7.1 before compiling the values in an Excel file.

4.3.3 Limit stress, σ'_L

As with σ'_C, the parameter σ'_L is evaluated from CRS oedometer tests. For the project E45-Norge/Vänerbanan, the given data are CRS oedometer curves and therefore, σ'_L is evaluate by the method explained in Chapter 2.7.1 before compiling the values in an Excel file. For all the other projects, σ'_L was already evaluated.

4.3.4 The compression modulus M_L

The parameter M_L is also evaluated from CRS oedometer tests. For the project E45-Norge/Vänerbanan, the given data are CRS oedometer curves and therefore, M_L is evaluated by the method explained in Chapter 2.7.1 before compiling the values in an Excel file. For all the other projects, M_L was already evaluated.

[9] Jonas Sundell, industrial doctoral student, COWI and Ezra Haaf, engineer, COWI.

4.3.5 The compression modulus M'

As with σ'_C, σ'_L and M_L, the compression modulus M' is evaluated from CRS oedometer tests. For the project E45-Norge/Vänerbanan, the given data are CRS oedometer curves and therefore M' is evaluate by the method explained in Chapter 2.7.1 before compiling the values in an Excel file. For all the other projects, M' was already evaluated.

4.3.6 Overconsolidation ratio, OCR

OCR is calculated for each level by dividing σ'_0 by σ'_C, see Equation 5.

4.3.7 Preconsolidation limit ratio, CLR

A new parameter, the ratio between the preconsolidation stress and the limit stress, is introduced. It is denoted the Preconsolidation limit ratio (CLR). This variable takes in consideration that the two variables are related to each other. The limit stress must be larger than the preconsolidation stress. Hence, CLR must be larger than one, see Equation 27.

$$CLR = \frac{\sigma'_L}{\sigma'_C} > 1 \qquad (27)$$

4.3.8 Density, ρ

The density data is collected from the geotechnical reports that contain protocols from the different tests made in the laboratory. The four projects have used different laboratories to evaluate the soil samples. Some levels have several density values; in those cases, the value in the middle is used. For example, at a level of 3 meters beneath the ground surface, the density has been evaluated for three different levels, one for each container of the undisturbed test. As mentioned earlier, an undisturbed test contains three containers, stacked on top of each other.

4.3.9 Water content, w

The water content data is, same as the density, collected from the geotechnical reports that contain protocols from the different tests made in the laboratory. As mentioned earlier, the four projects have used different laboratories to evaluate the soil samples.

4.3.10 Liquid limit, w_L

The liquid limit data is, same as the density and water content, collected from the geotechnical reports that contain protocols from the different tests made in the laboratory. As mentioned earlier, the four projects have used different laboratories to evaluate the soil samples.

4.4 External factors

In this section, the selected external factors, which serve as raw data for the independent variables in the statistical analyses, are presented.

4.4.1 Sampling depth

The depth beneath ground surface from which a sample is collected is always reported together with the CRS-parameters. In order to form an ordinal independent variable suitable for the statistical ANOVA analyses to be performed, actual reported depths have been grouped into intervals with a spacing of one meter. The range of depths differs a lot between the two cities and while samples from Göteborg often reach down to 30 meters, samples from Stockholm rarely reach a depth over 10 meters.

4.4.2 Grade of urbanization

The grade of urbanization is expressed through three categories as specified below. The categories have been adopted from an expert[10].

(1) Rural: Untouched natural area or farmland that is not surrounded by any significant urbanization. If the point, for example, is located in the woods beyond the ditch next to a road, it can be considered as belonging to the category.
(2) Semi-urban: Area that has been processed to some degree and is surrounded by some urbanization. If the point, for example, is located in a green area in the middle of a roundabout or a lawn in a residential area, it can be considered as belonging to the category.
(3) Urban: Areas surrounded by significant urbanization containing buildings with multiple floors. If the point, for example, is located in the street between two high apartment buildings, it can be considered as belonging to the category.

The assessment of urbanization has been made by ocularly investigating the sites of each sampling point using the Internet based service Google Maps. This variable is in SPSS set to have an ordinal measure.

4.4.3 Soil type according to the geological map

The soil type according to the geological map at the site of a sampling point is evaluated simply by looking at geological soil maps that indicate what type of soil is in the top soil layers (SGU, 2014). The different types of soil discovered in this way typically forms a category each as specified below.

(1) Glacial clay
(2) Postglacial clay
(3) Mud
(4) Muddy clay
(5) Sandy till

[10] Jonas Sundell, industrial doctoral student, COWI, conversation February 2014.

(6) Fill
(7) Till
(8) Class one or two, a sampling point that lay between to soil types
(9) Peat
(10) Alluvium, clay—silt

This variable is in SPSS set to have a nominal measure.

4.4.4 Thickness of the soil layer overlaying the clay

The thickness of the soil layers stretching from ground surface down to the clay interface is evaluated from inspection of laboratory protocols and sectional geotechnical drawings. In order to form an ordinal variable suitable for the ANOVA analyses to be performed, actual evaluated thicknesses are grouped into intervals with a spacing of one meter.

4.4.5 Time since the soil layer overlaying the clay was placed

The time span over which the soil layers overlaying the clay has been in place is expressed through six categories representing time intervals as specified below. These categories have been developed in conjunction with this master's thesis.

(1) >250 years: Sampling points which are located in areas that were urbanized more than 250 years ago, for example the area Östermalm in Stockholm, belong to this category (Stockholmskällan, 2014). Moreover, all sampling points located in rural areas have been assigned to this category since the soil layers, whatever they are made up of, most likely have been laying there for at least 250 years.
(2) 200-250 years: The area Järntorgsmotet in Göteborg (Göteborgs stad, 2014).
(3) 150-200 years: The area Lilla Bommen in Göteborg (Göteborgs stad, 2014).
(4) 100-150 years: Strandvägen, Östermalm Stockholm (Stockholmskällan, 2014). The railway stretch from Göteborg to Vänersborg was built around 1850-1900 and since the sampling points are close to the old stretch, these observations have also been included in this category (Sten, 2009).
(5) 80-100 years: Norra Hammarbyhamnen, Södermalm Stockholm (Stockholmskällan, 2014).
(6) <80 years: Sampling points which are located in areas which have been developed during the last 80 years.

The assessment of the time factor has been made by first identifying areas which have been covered with fill material, determining when the fill material was placed and then grouping the areas into intervals as specified above. The identification of filled areas is done by looking at geological soil maps and locating the areas which are marked with fill. These areas are then thoroughly investigated with the aid of historical maps (Stockholmskällan, 2014) (Göteborgs stad, 2014) and notations (Sten, 2009) to be able to date the material.

The boreholes that are not lying in an area that is marked with fill in the geological soil map is evaluated by looking at what kind of soil it is from the laboratory protocol. If there is no fill it is assumed that the soil has been there more than 250 years. If the soil contains fill, and if the borehole is in an urban area the time factor of the fill is evaluated by how long time there has been constructions in the area with an ocular investigation of the sites using the Internet based service Google Maps.

This variable is in SPSS set to have an ordinal measure.

4.4.6 Zone

The data is divided into seven different zones, see Appendix A for maps. The zones in Stockholm have been adopted from an expert[11], while the zones in Göteborg have been defined by the authors of this master's thesis.

(1) Danderyd, Stockholm
(2) Norra Djurgården, Stockholm
(3) Södermalm and Östermalm, Stockholm
(4) South Bypass, Stockholm
(5) North Bypass, Stockholm
(6) Göta älv (Project E45-Norge/Vänerbanan)
(7) Göteborg Centre (Project Götatunneln)

This variable is in SPSS set to have a nominal measure.

4.4.7 City

In the statistical analysis, the two cities Göteborg and Stockholm are mixed together in one of the data sets (All observations from 3-8 meters) and to investigate if there are any significant differences between the two cities, an additional variable is introduced. The variable is named City and has the value (1) for Göteborg and (2) for Stockholm.

This variable is considered as a subjective variable and in SPSS it is set to have a nominal measure.

4.5 Screening

It is mentioned earlier in this master's thesis that that the values of OCR and CLR must be larger than one. Therefore, all observations showing values of OCR and CLR lower than one are removed from the data sets. Also, observations that miss some value of clay parameters are removed.

4.6 Transformations

As mentioned in previous chapters, the raw data is not suitable for the intended statistical analyses as it is but needs to be transformed and normalized against depth first. One requirement is that the results from the analyses can be used for back-calculation without giving rise to illogical values of the analyzed clay parameters. For example, if a result from the ANOVA is used to estimate a value of OCR, the calculation should not be able to give values of OCR<1. It is also necessary to eliminate any known dependencies between the dependent and independent variables prior to the statistical

[11] Jonas Sundell, industrial doctoral student, COWI, conversation April 2014.

analysis and since most of the clay parameters have an intrinsic relationship to the sampling depth, the data needs to be normalized against depth. Furthermore, one of the prerequisites for ANOVA is that the dependent variables are normally distributed, see Chapter 3.1. This is, however, not necessarily the case for the raw data which gives another reason for transformation, see Figure 17, where the two top boxes shows the raw data. An example of the process of transformation and normalization of variables is given for the clay parameter OCR below. The methodology is adopted from an expert[12] and made for all the clay parameters. The software SPSS is used for the transformation and normalization.

Example of the process of transformation and normalization for OCR

Since OCR cannot assume values equal to or less than one, see Chapter 2.5.1, the following condition must be satisfied.

$$OCR = \frac{\sigma'_C}{\sigma'_0} > 1$$

The transformations shown below will prevent illogical values from back-calculations and these are then all individually normalized against depth. Note that they are all valid only for values of OCR>1.

$$log10(OCR - 1), ln(OCR - 1)\ and\ \sqrt{OCR - 1}$$

The normalization is done for each transformation by first plotting the transformed variable against depth and fitting a regression curve to the data. The regression curve is fitted by letting SPSS test a number of different equations and then selecting the one giving the highest R^2, see Figure 17 the two middle boxes. The functions that were tested were linear, logarithmic, inverse, quadratic, cubic and power. If the difference in R^2 between different equations is small, the least advanced function is selected. For example, if a cubic fit gives an R^2 of 0.238 and a quadratic fit gives an R^2 of 0.235, the quadratic fit is selected.

Then the residuals from the fitted curve for each transformation is examined by producing histograms over the frequency and plotting them against depth as shown in the two bottom boxes in Figure 17. The transformation that shows the best fit to the normal distribution curve and also seems to be best normalized against depth is selected for further analysis, in this case the residuals from a quadratic fit of the square root of $OCR - 1$ against depth. The assessment of which transformation is best is made by ocular examination.

[12] Jonas Sundell, industrial doctoral student, COWI, conversation April 2014.

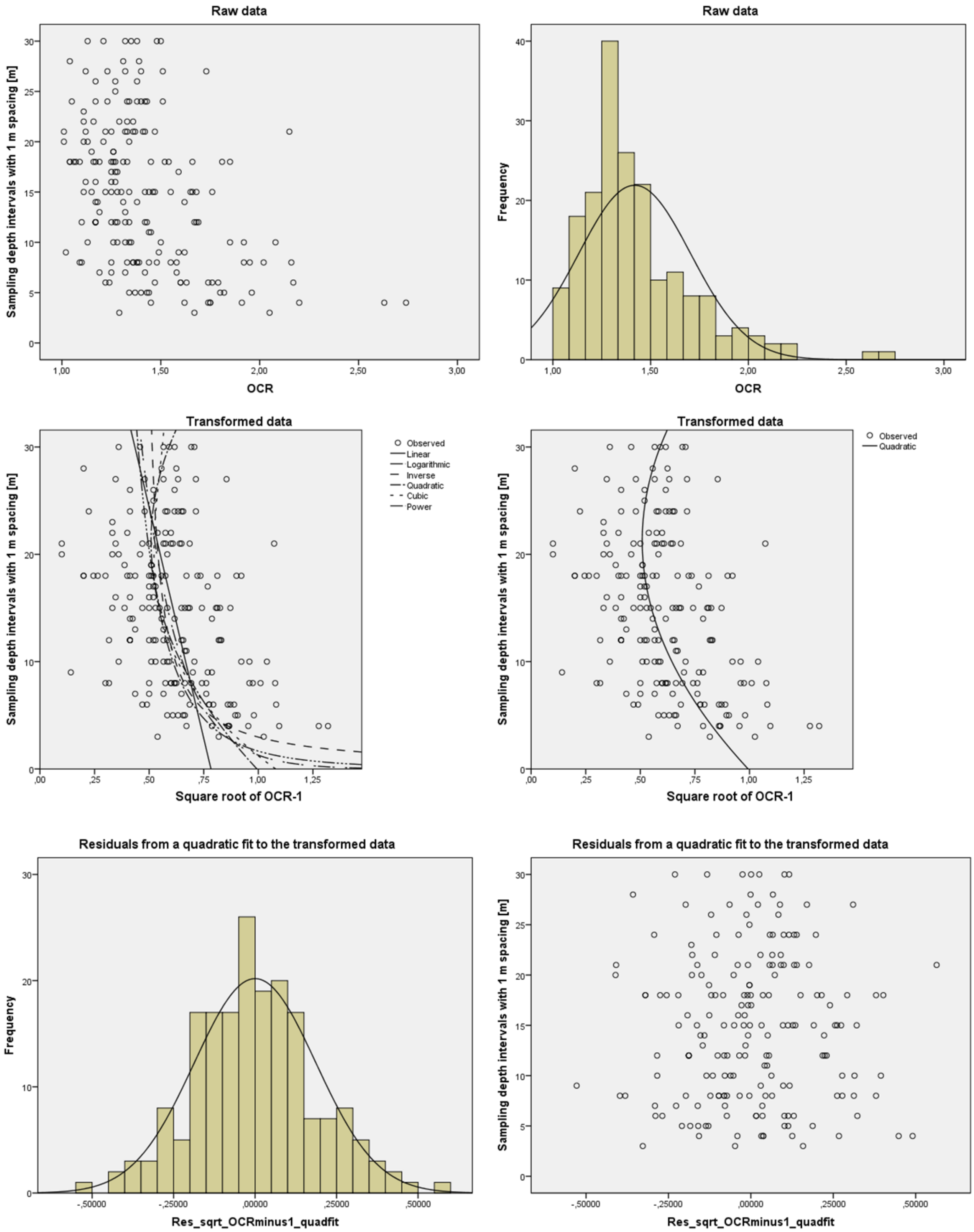


Figure 17: Example of the stages of the transformation and normalization of raw data.

In association with an expert[13] it is decided that it is reasonable to assume that there should be one transformation and curve fit that is representative for all clay parameters. For the data set from Göteborg, there is a dominating pattern indicating that the best transformation is the square root of the raw data and that the best curve fit is described by a quadratic function. At the same time, the data set from Stockholm and the data set constituted of all observations from sampling depths between 3 and 8 meters totally lack patterns. Therefore, all transformations and curve fits are adjusted to the dominating pattern found in Göteborg. Figure 18 shows a flow-chart describing the process of transformation and normalization of variables.

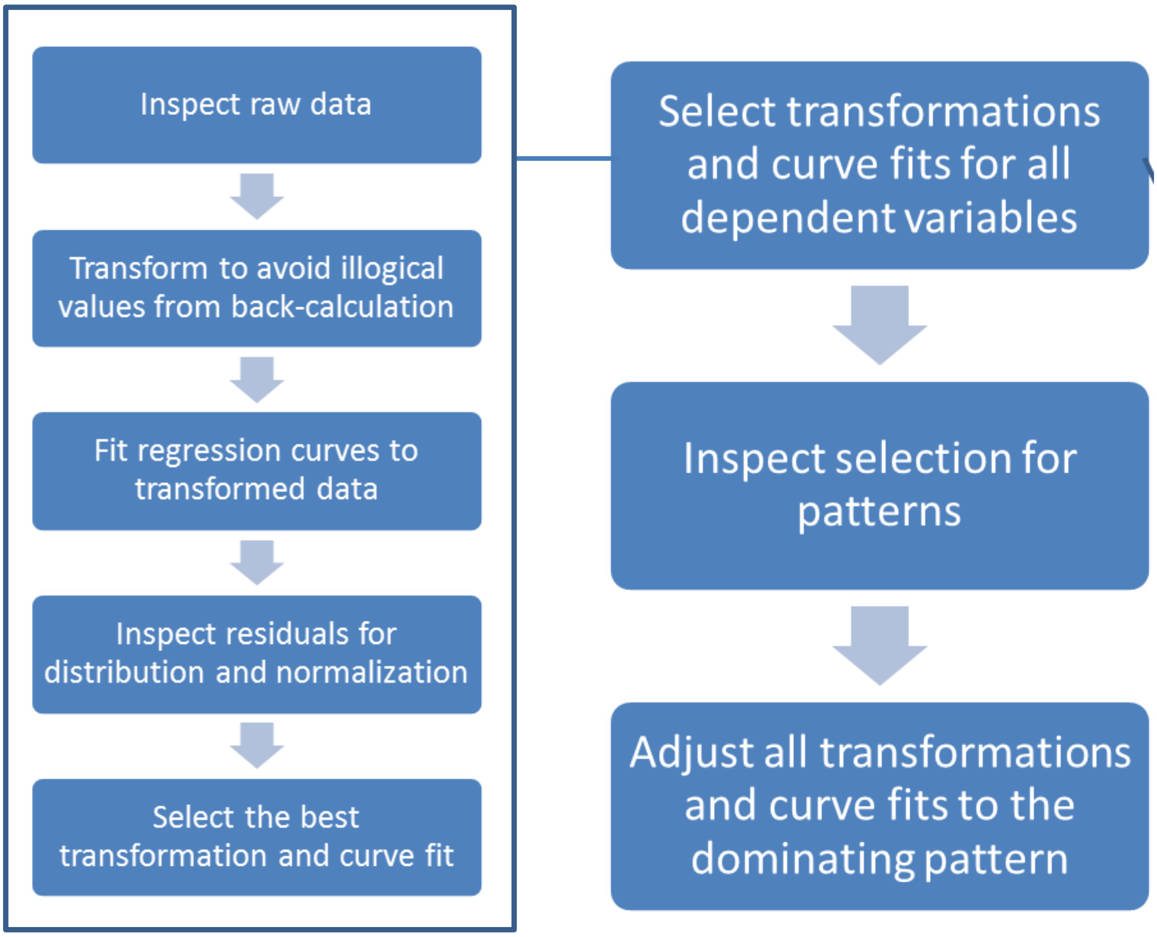


Figure 18: Flow-chart describing the transformation and normalization process.

4.7 ANOVA

The ANOVA is performed with the software SPSS and the analysis is made for one dependent variable at the time. It starts with a one-way between-subjects ANOVA, in which all independent variables are included.

The next step is to perform a full-factorial ANOVA. The factors that are included in this analysis are those that show an F-factor higher than one in the one-way ANOVA.

[13] Jonas Sundell, industrial doctoral student, COWI, conversation April 2014.

After this, a second full-factorial ANOVA is performed, just including those independent variables showing both *F*-factors higher than one for their main effects and *p*-values less than 0.05.

Finally, all results of significant main effects and interactions from the last performed step are plotted and evaluated.

The tools that are used in SPSS for both analyses are General Linear Model – Univariate, see Figure 19. For the one-way ANOVA the settings for the model is Custom and the type is Main Effect, see Figure 20 and 21. For the full-factorial ANOVA, the setting for the model is Full factorial.

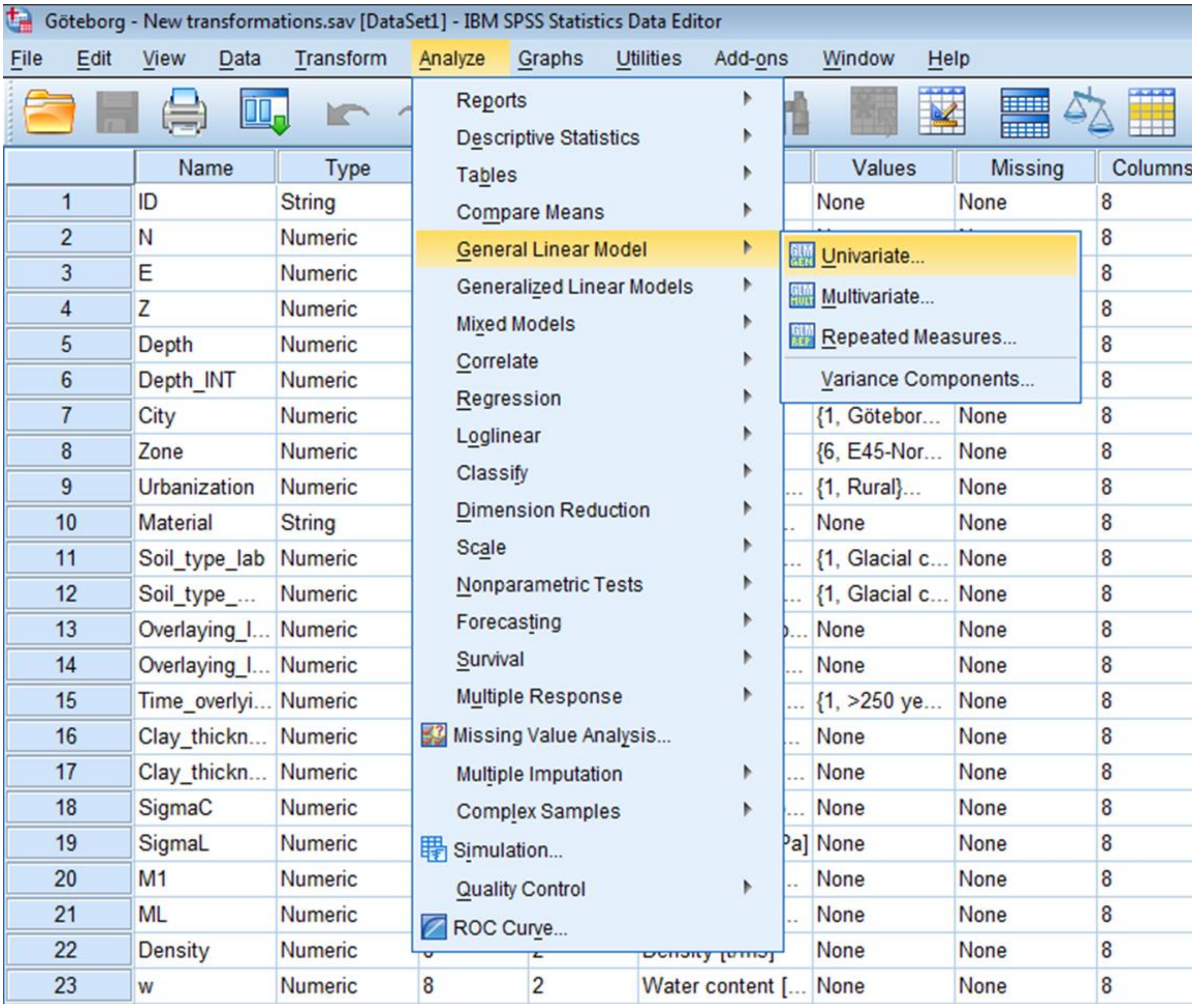


Figure 19: Illustarion of how to perform an ANOVA in SPSS.

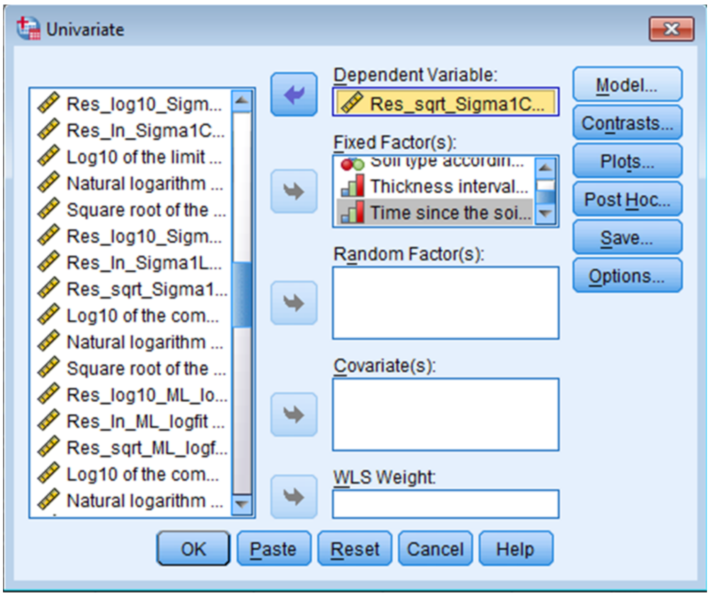


Figure 20: Illustration of how to select variabels and factors in SPSS.

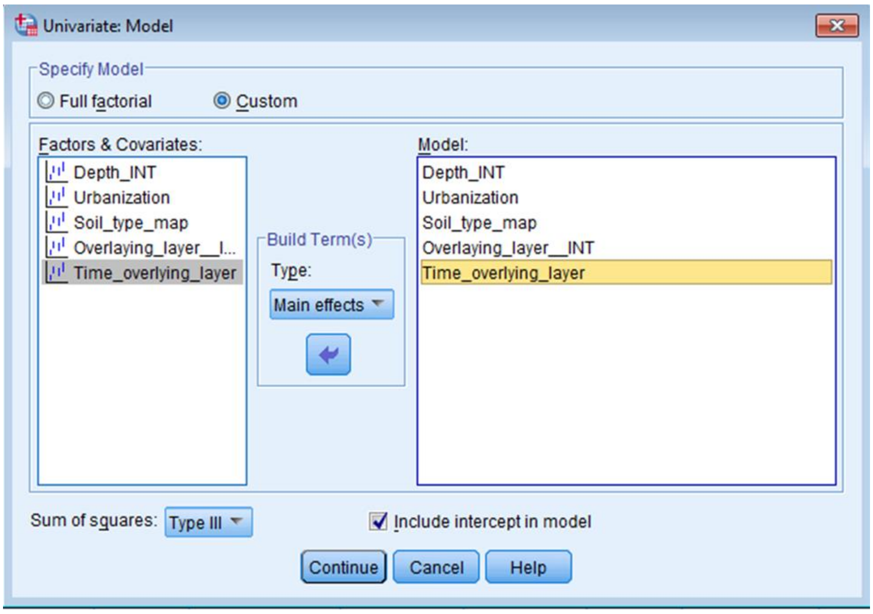


Figure 21: Illustration of how to select model in SPSS.

4.8 *T*-test

The *T*-test is performed using the software SPSS and is only used for analysis of the effect of independent variables with zero degrees of freedom, see the theory chapter for further explanation on this. To perform the test, select: Analyze – Compare Means – Independent-Samples T Test, as shown in Figure 22.

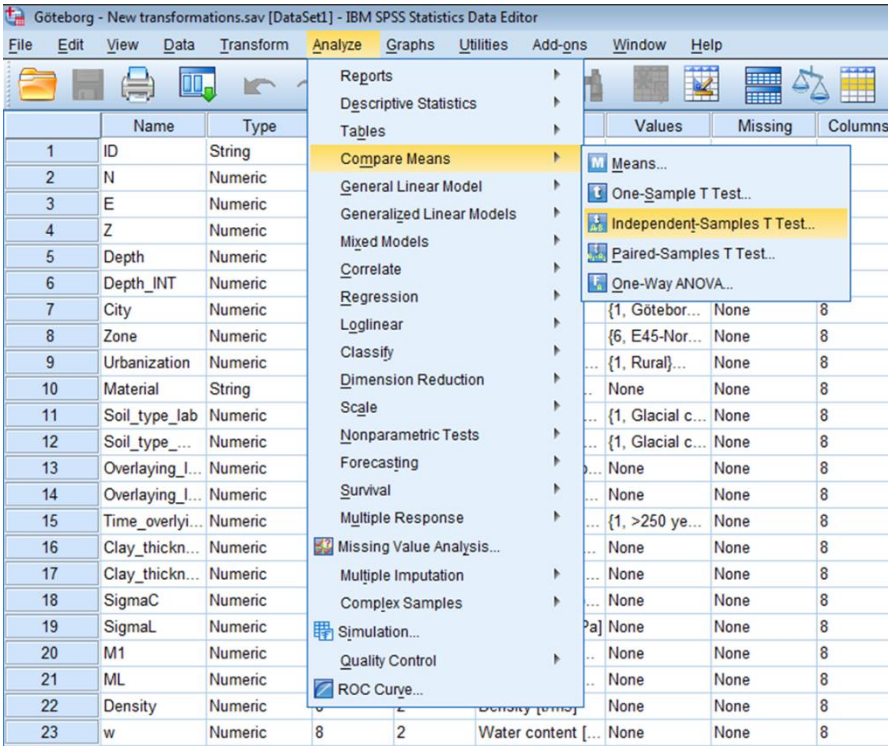


Figure 22:Illustration of T-test in SPSS.

This opens the Independent-Samples T Test box shown in Figure 23. To define the groups to be compared, click the Define Groups button and type in the numbers representing the two groups, in this case 6 for the zone E45-Norge/Vänerbanan and 7 for the zone Götatunneln.

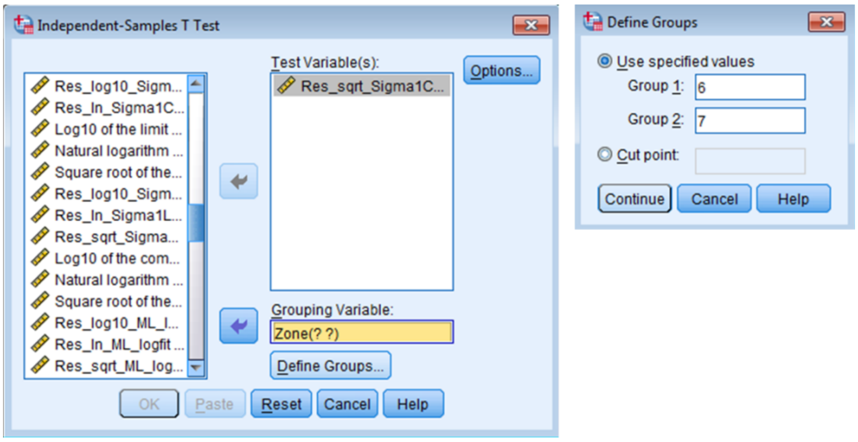


Figure 23: Illustration of how to define groups in a T-test.

4.9 Sensitivity analysis

A sensitivity analysis is made for one specific sampling point at Götatunneln (JF8) to see how much σ'_0 is affected by the act of excluding the external loads from buildings. The effect from nearby houses is assessed by first investigating which houses are within a perimeter of 50 meters from the point (in this case only one house at the property 701:27 is considered potentially affecting the point since it is located 5 meters away). The normal stress is calculated for three scenarios; once without the external load from the building, once including the external load from the building assuming a foundation consisting of 12 meters long cohesion piles and once including the load from the same building assuming it is founded directly on the ground without any deep foundation. The volume of the house is calculated by looking at a geotechnical drawing and using the tool Google Maps. To be able to calculate the load of the building, the density is estimated by values from the report *City Link Tunnel Riskanalys marksättningar hydrogeologiska utredningar* by Sundell and Haaf (2014), where a table of different densities of houses, depending on how old the house is and what type of building material is used etc., is presented. The additional normal stress from the house is calculated with the 2:1 method described in Chapter 2.6. The difference in effective stress between the three scenarios at different depths in the sampling point is then evaluated to determine if the effect of excluding the external loads from buildings could have a large impact on the overall investigation or not.

5 Data

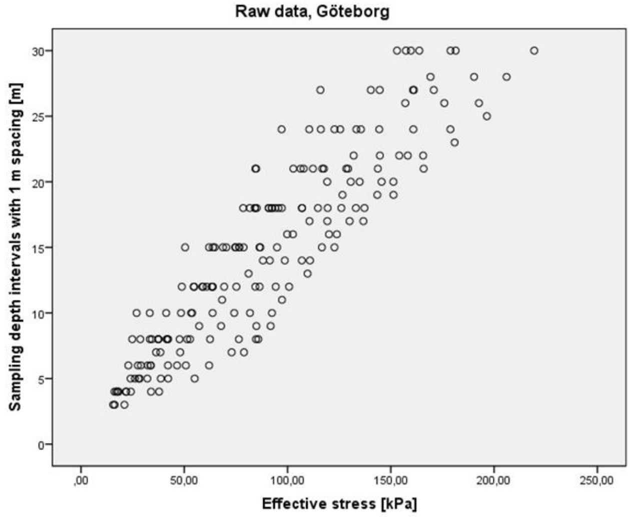
In the following chapter, the data that is analyzed are presented. The dependent variables are presented in Chapter 5.1. and the independent variables are presented for each dependent variable in Chapter 5.2.

5.1 Dependent variables

In this chapter, all clay parameters that serve as dependent variables in the statistical analyses are presented. They are presented in the form of raw data, transformed data and as residuals from a quadratic fit to the transformed data, which constitutes the basis for further analysis. The raw data is displayed with a scatter plot against depth and a histogram against the frequency, containing a normal distribution curve. The transformed data is presented with a scatter plot against depth, containing the fitted quadratic regression curve from which the residuals are extracted. The residuals from a fitted regression curve to the transformed data are also displayed with a scatter plot against depth and a histogram against the frequency, containing a normal distribution curve.

5.1.1 Effective stress (σ'_0), Göteborg

The scatter plot of the raw data shows the relationship between $\sigma_0^{'}$ and the sampling depth, see Figure 24. The histogram of the raw data shows that $\sigma_0^{'}$ is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.831. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 1.074.



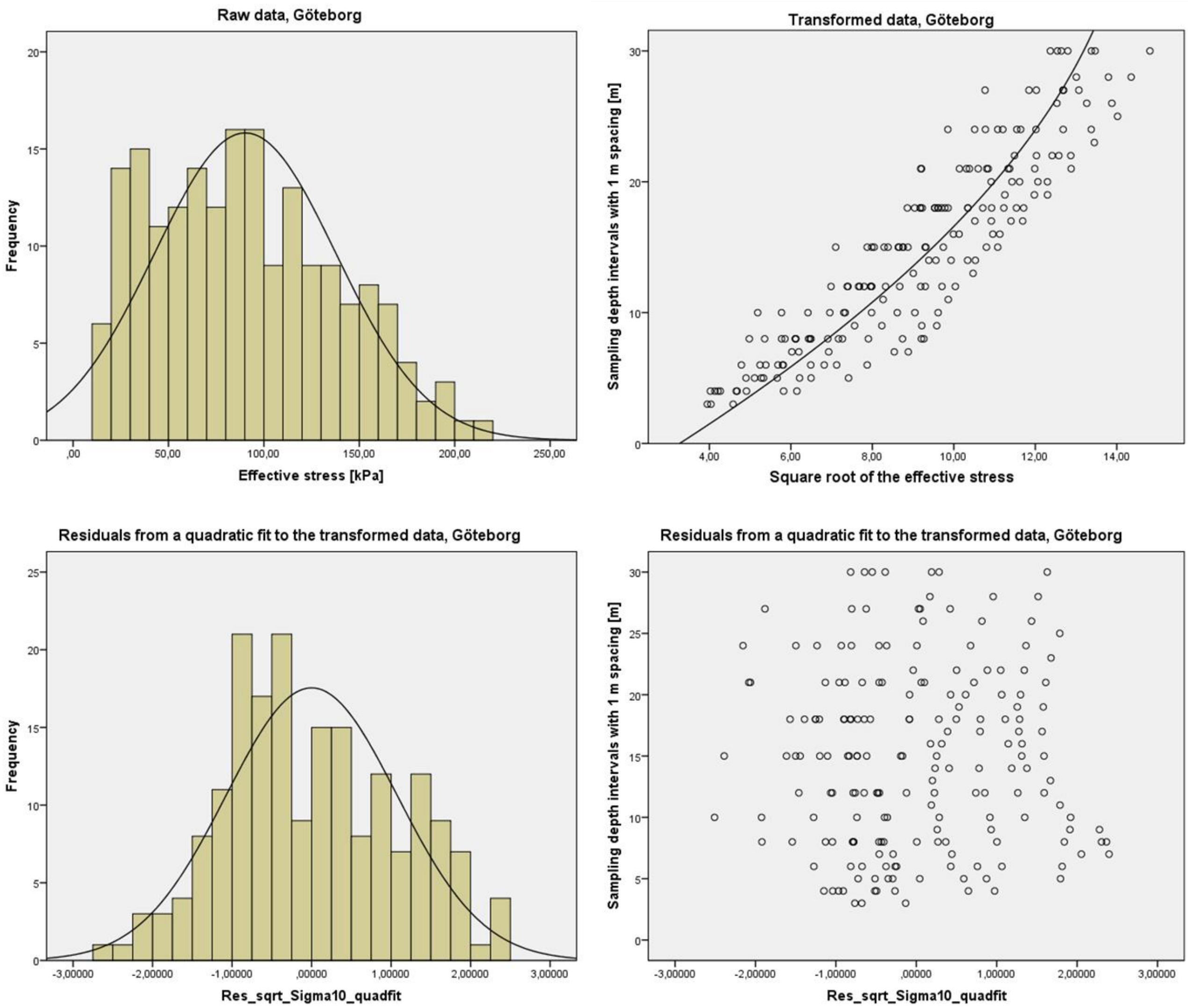
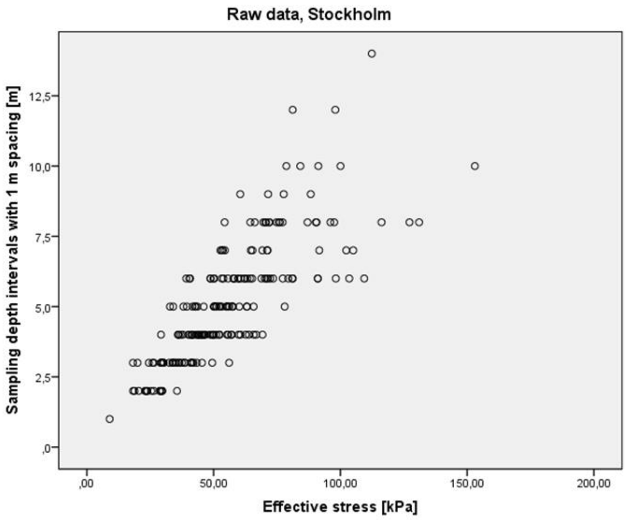


Figure 24: The transformation and normalization of the effective stress, Göteborg.

5.1.2 Effective stress (σ'$_0$), Stockholm

The scatter plot of the raw data shows the relationship between $\sigma_0^{'}$ and the sampling depth, see Figure 25. The histogram of the raw data shows that $\sigma_0^{'}$ is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.700. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.841.



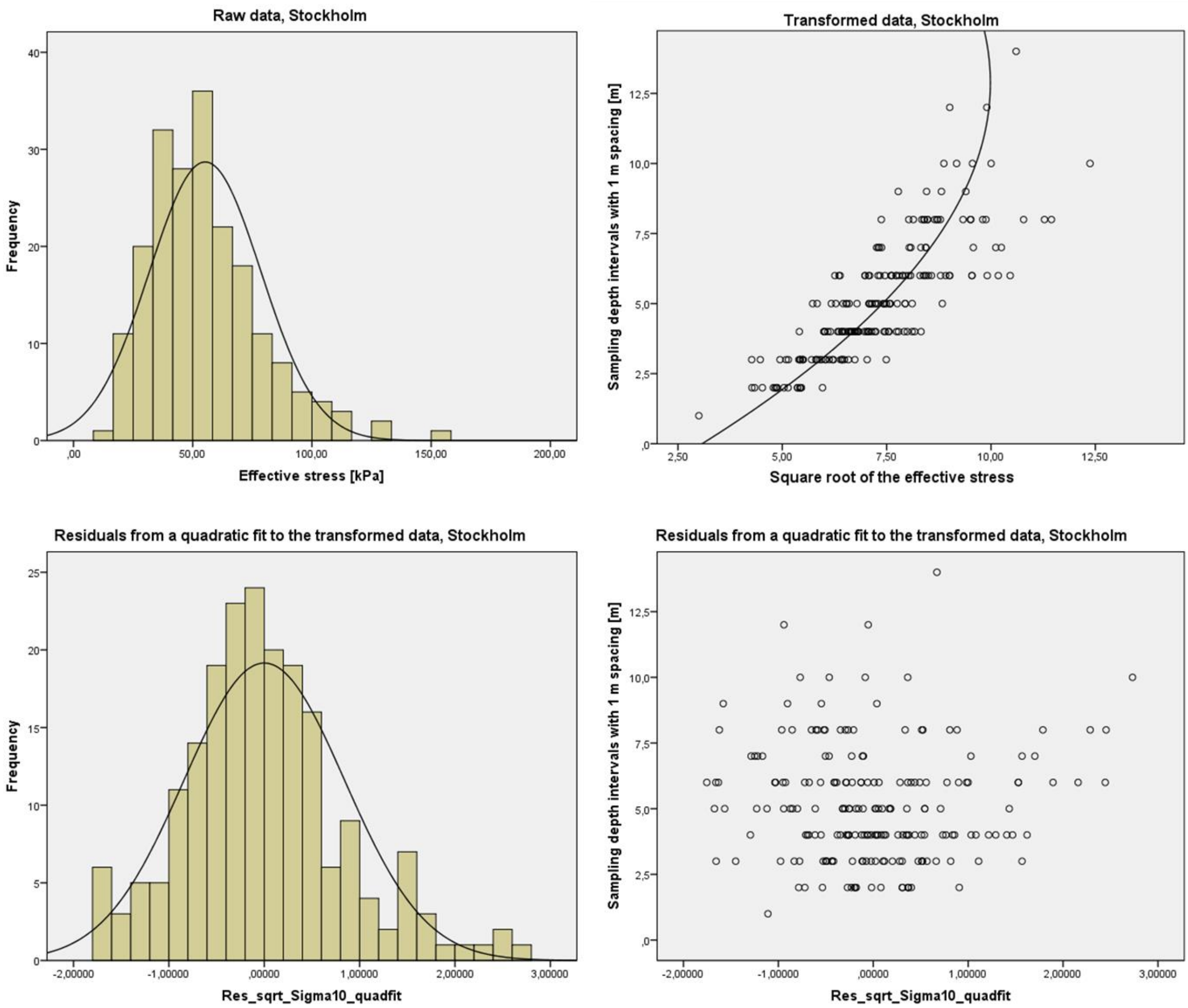
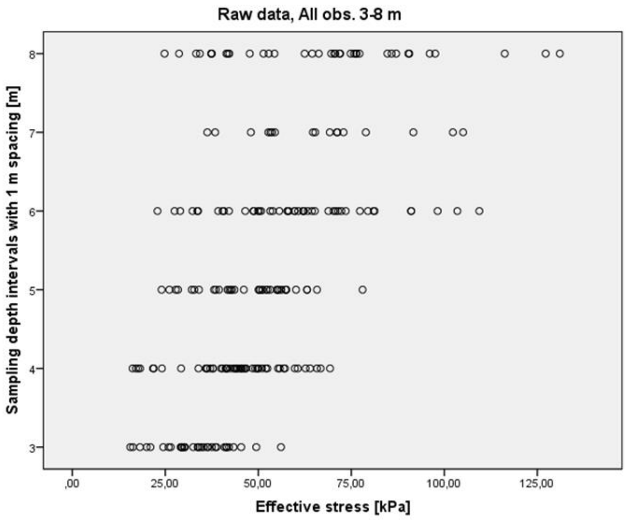


Figure 25: The transformation and normalization of the effective stress, Stockholm.

5.1.3 Effective stress (σ'_0), All observations from 3-8 m

The scatter plot of the raw data shows the relationship between σ_0' and the sampling depth, see Figure 26. The histogram of the raw data shows that σ_0' is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.319. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 1.179.



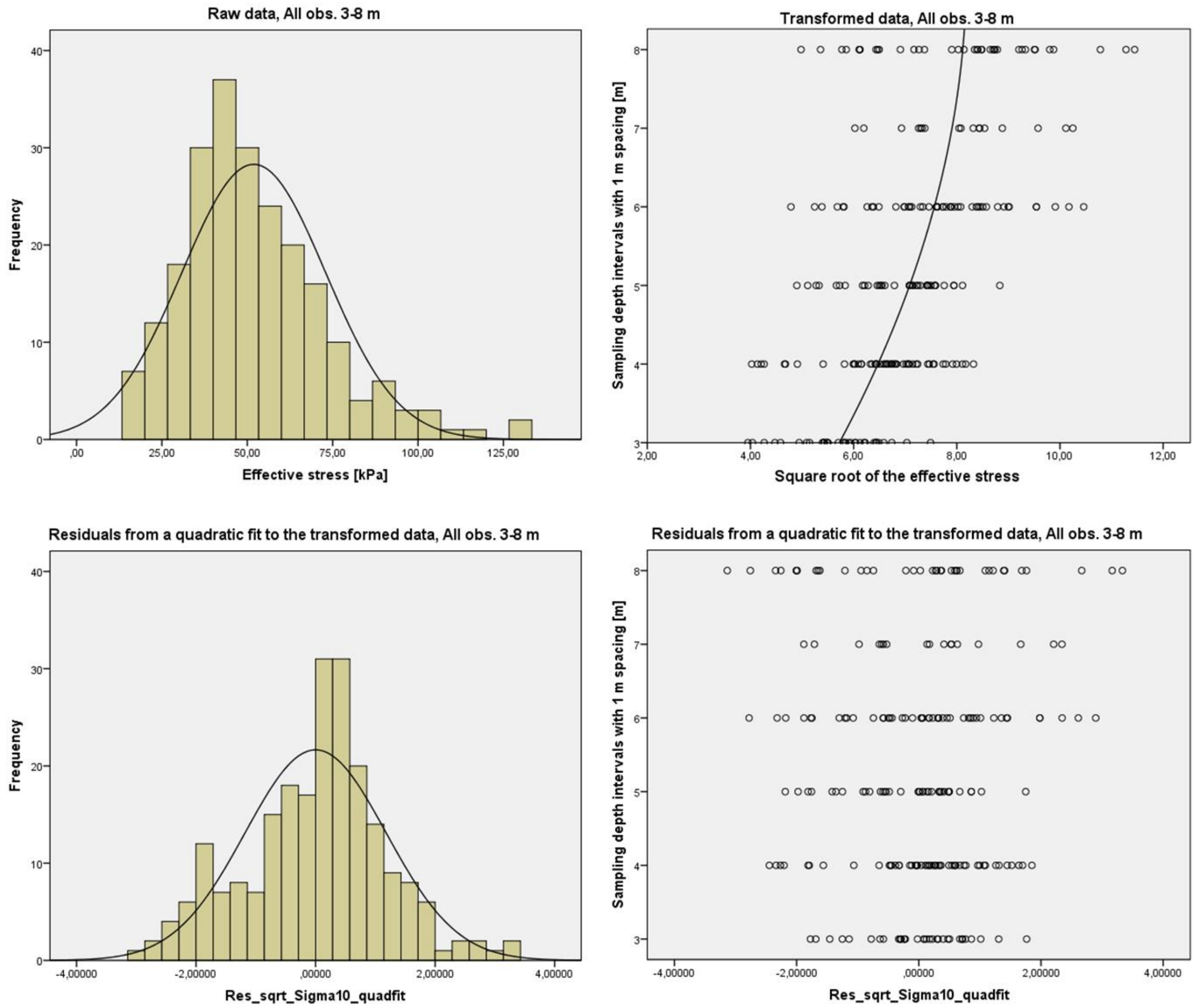
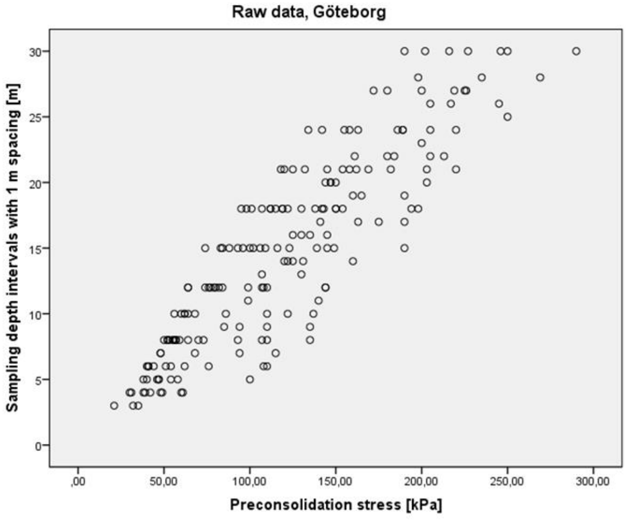


Figure 26: The transformation and normalization of the effective stress, All obs. 3-8 meters.

5.1.4 Preconsolidation stress (σ'_c), Göteborg

The scatter plot of the raw data shows the relationship between σ'_C and the sampling depth, see Figure 27. The histogram of the raw data shows that σ'_C is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.792. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 1.251.



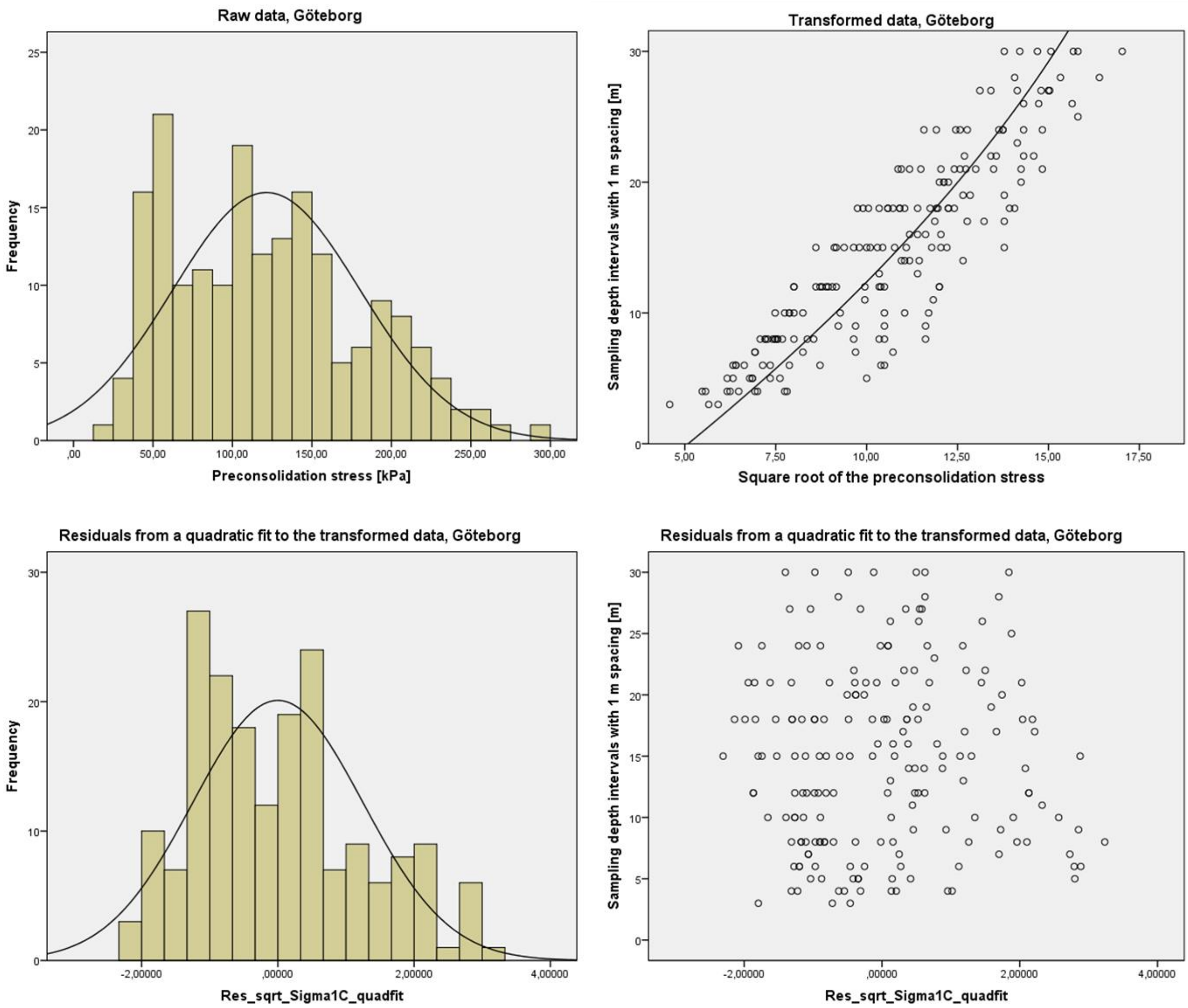
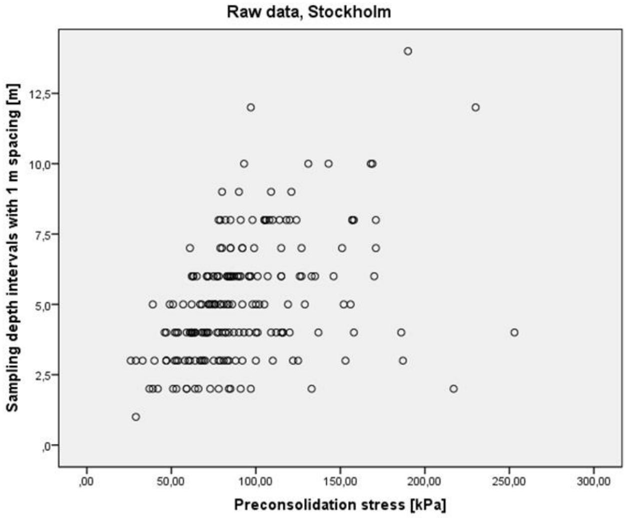


Figure 27: The transformation and normalization of the preconsolidation stress, Göteborg.

5.1.5 Preconsolidation stress (σ'$_c$), Stockholm

The scatter plot of the raw data shows the relationship between $\sigma_C^{'}$ and the sampling depth, see Figure 28. The histogram of the raw data shows that $\sigma_C^{'}$ is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.214. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 1.636.



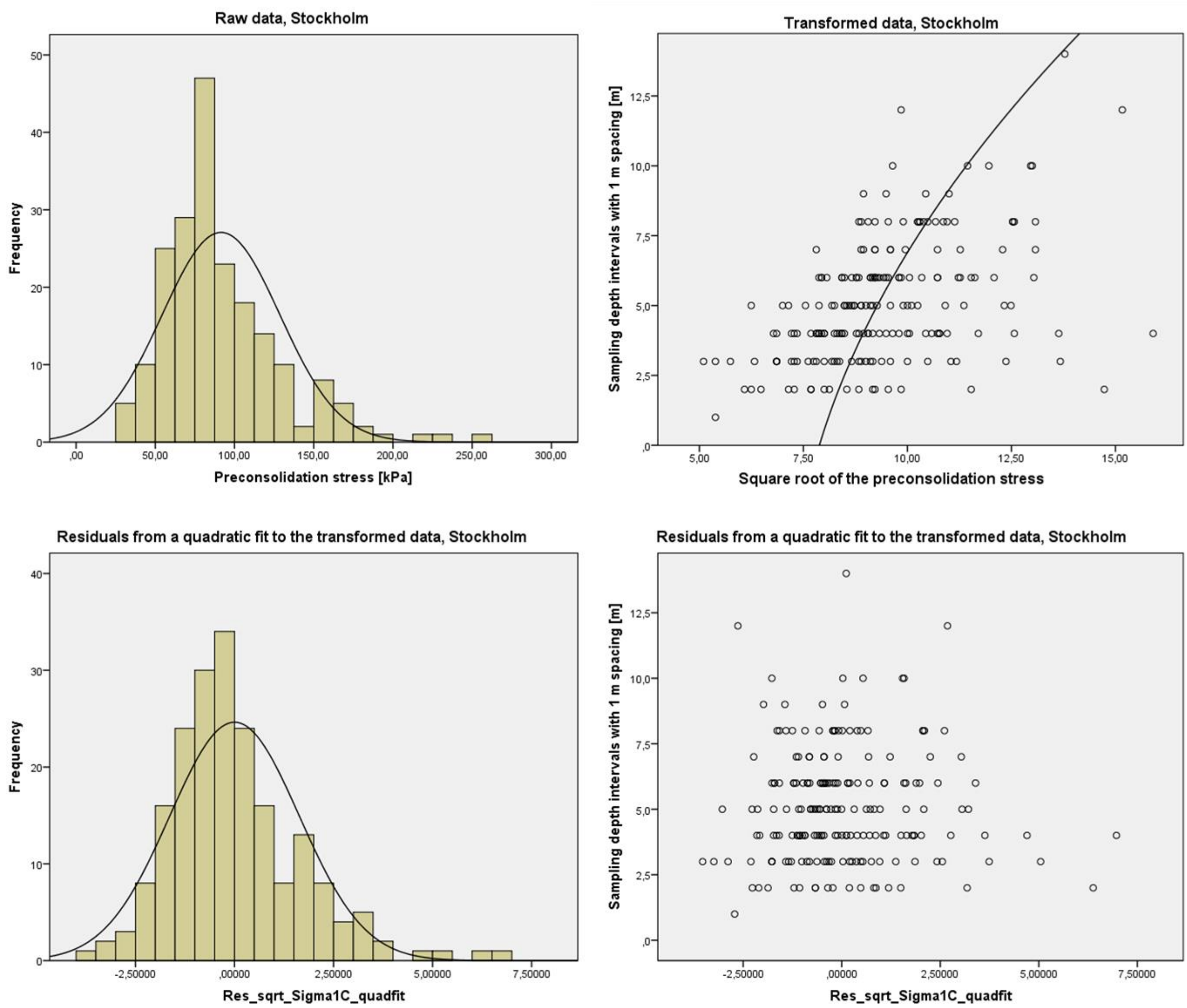
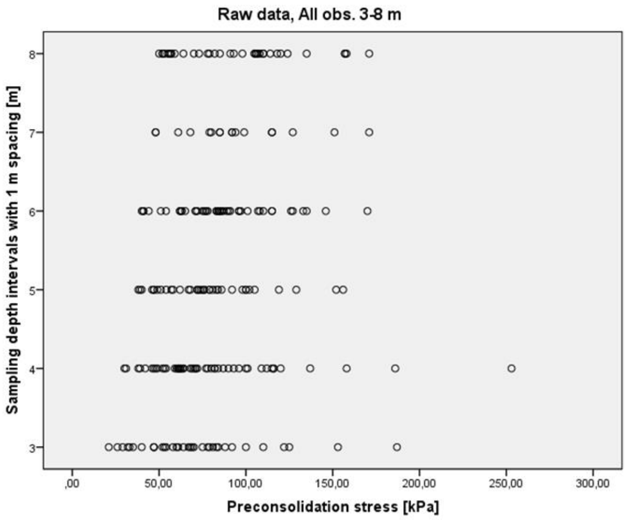


Figure 28: The transformation and normalization of the preconsolidation stress, Stockholm.

5.1.6 Preconsolidation stress (σ'_c), All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between σ_c' and the sampling depth, see Figure 29. The histogram of the raw data shows that σ_c' is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.060. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 1.757.



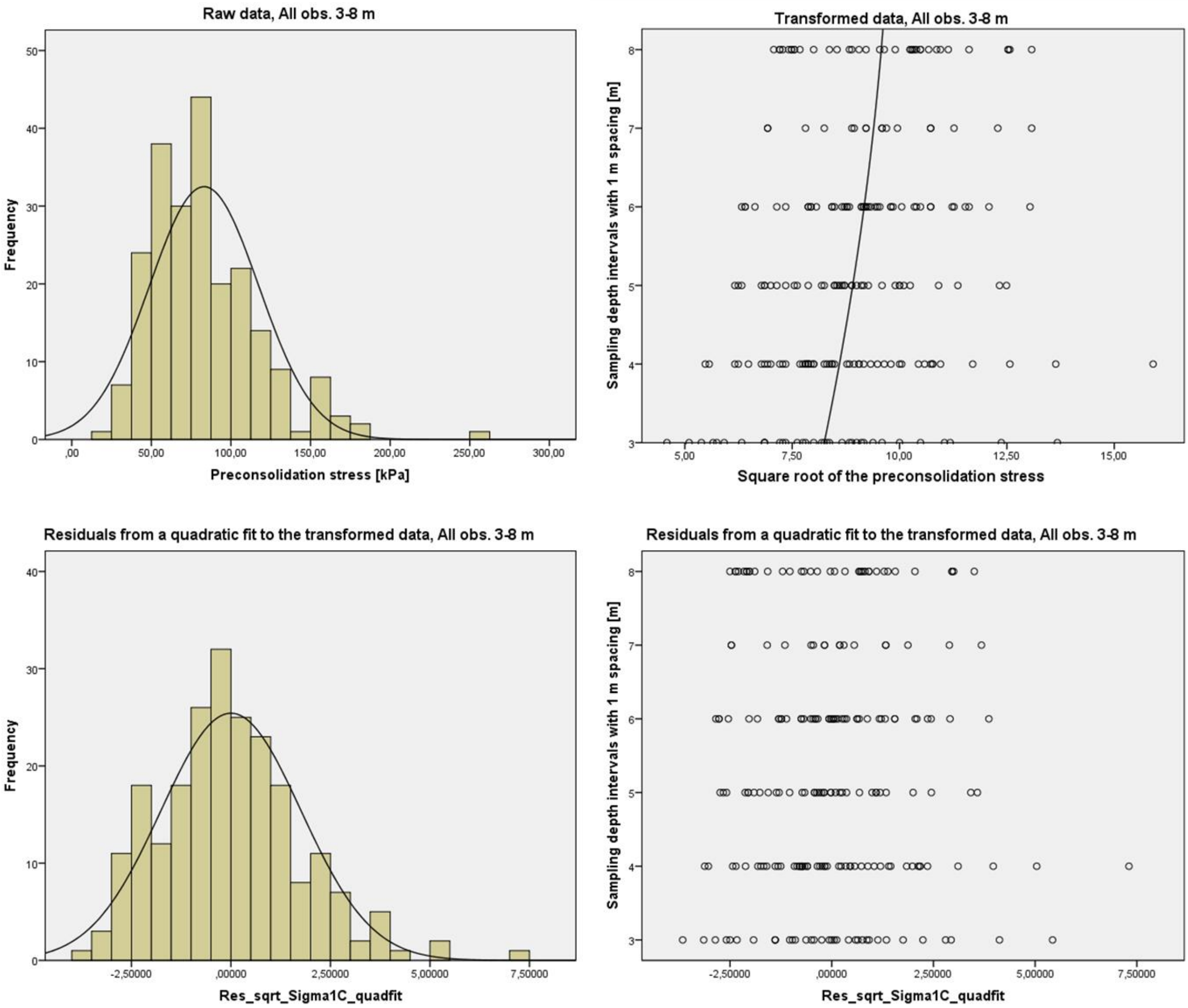
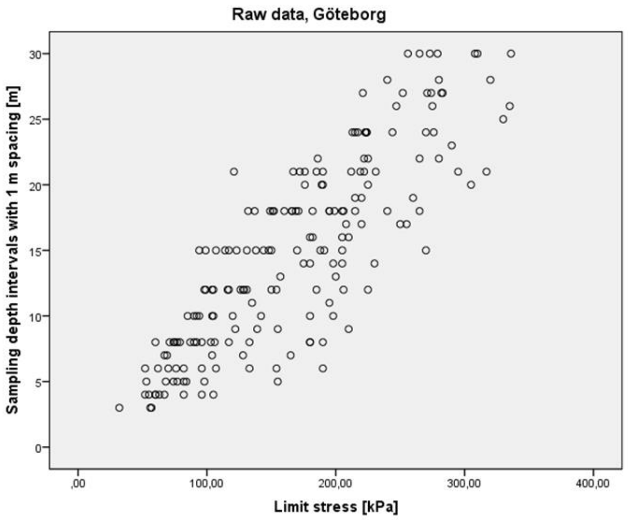


Figure 29: The transformation and normalization of the preconsolidation stress, All obs. 3-8 meters.

5.1.7 Limit stress (σ'$_L$), Göteborg

The scatter plot of the raw data shows the relationship between $\sigma_L^{'}$ and the sampling depth, see Figure 30. The histogram of the raw data shows that $\sigma_L^{'}$ is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.715. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 1.551.



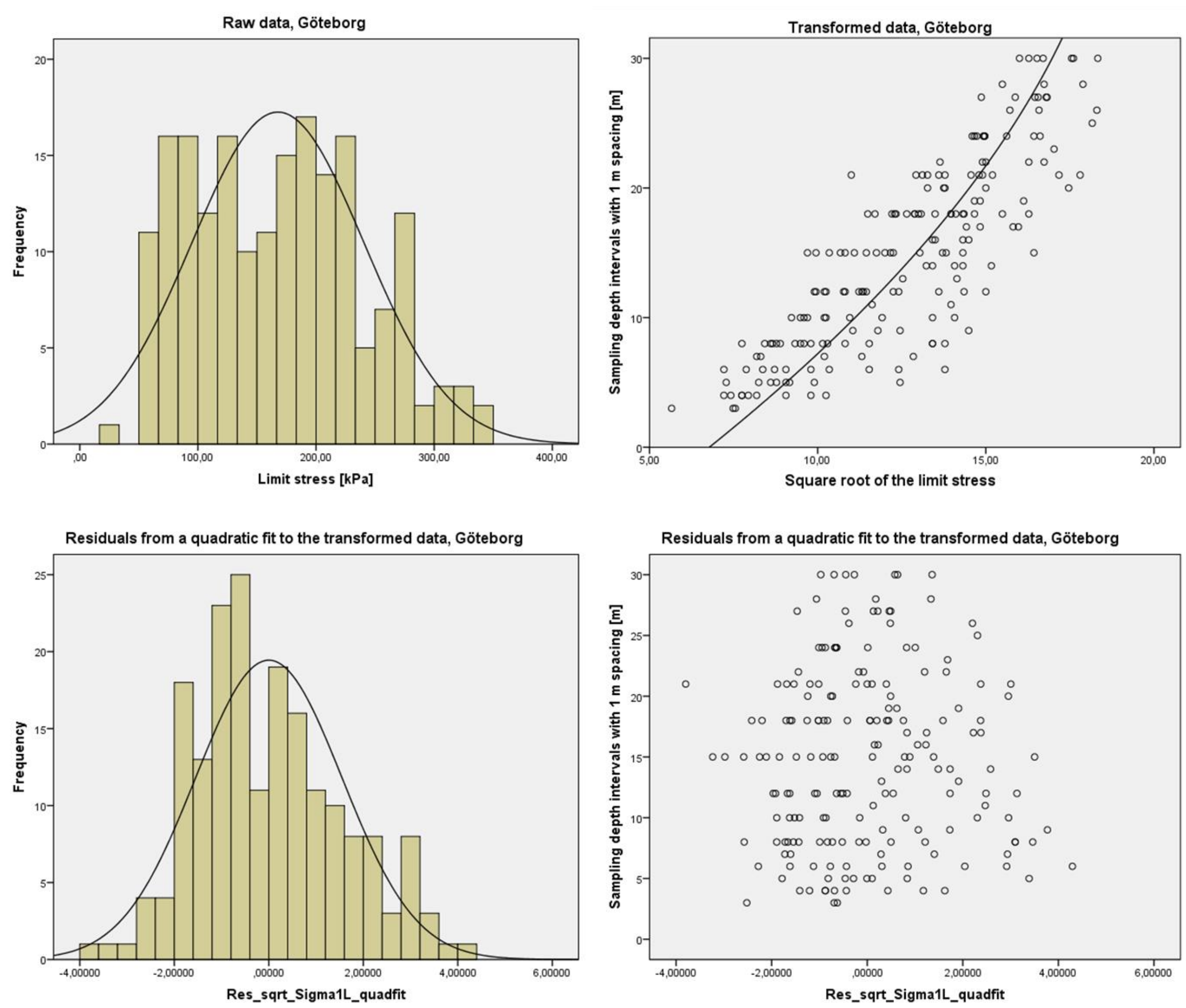
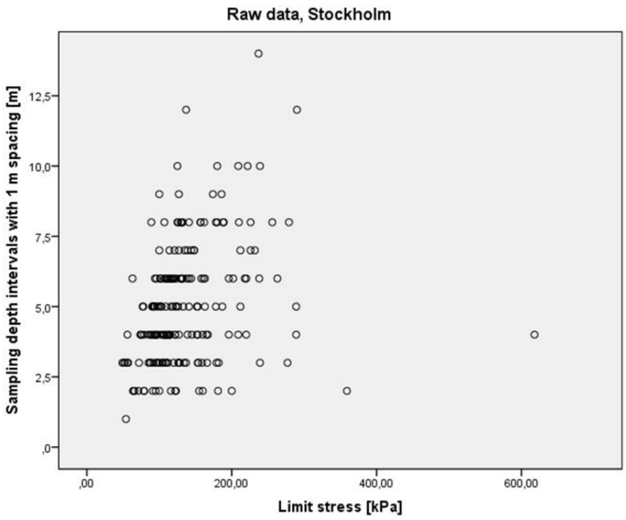


Figure 30: The transformation and normalization of the limit stress, Göteborg.

5.1.8 Limit stress (σ'$_L$), Stockholm

The scatter plot of the raw data shows the relationship between σ_L' and the sampling depth, see Figure 31. The histogram of the raw data shows that σ_L' is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.119. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 2.219.



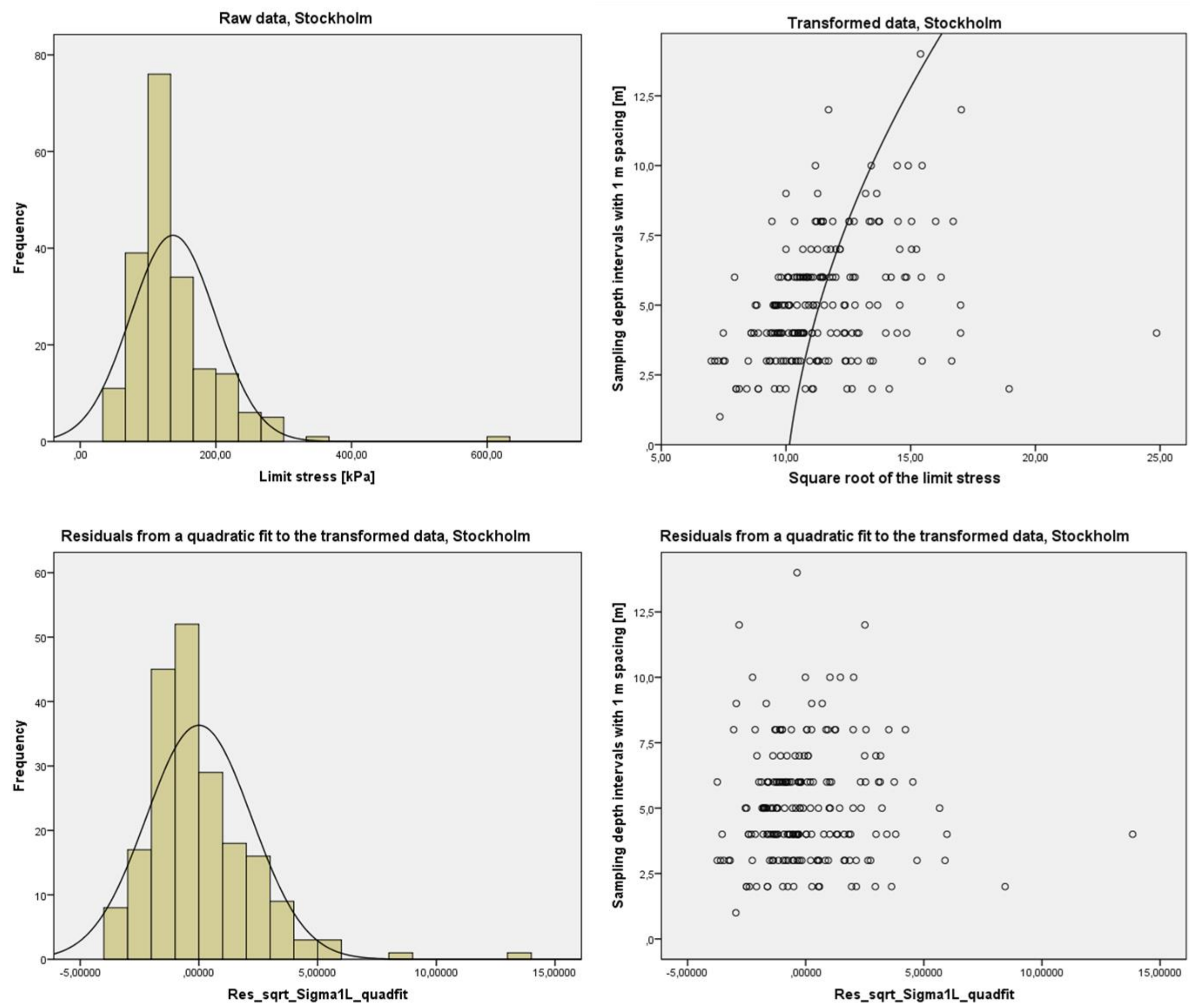
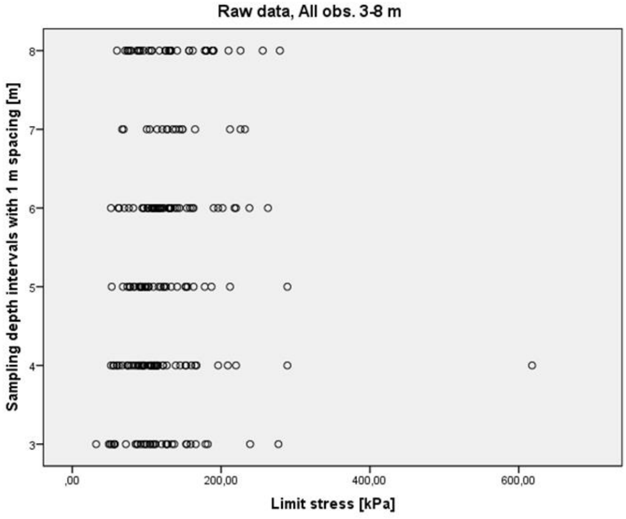


Figure 31: The transformation and normalization of the limit stress, Stockholm.

5.1.9 Limit stress (σ'_L), All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between $\sigma_L^{'}$ and the sampling depth, see Figure 32. The histogram of the raw data shows that $\sigma_L^{'}$ is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.033. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 2.285.



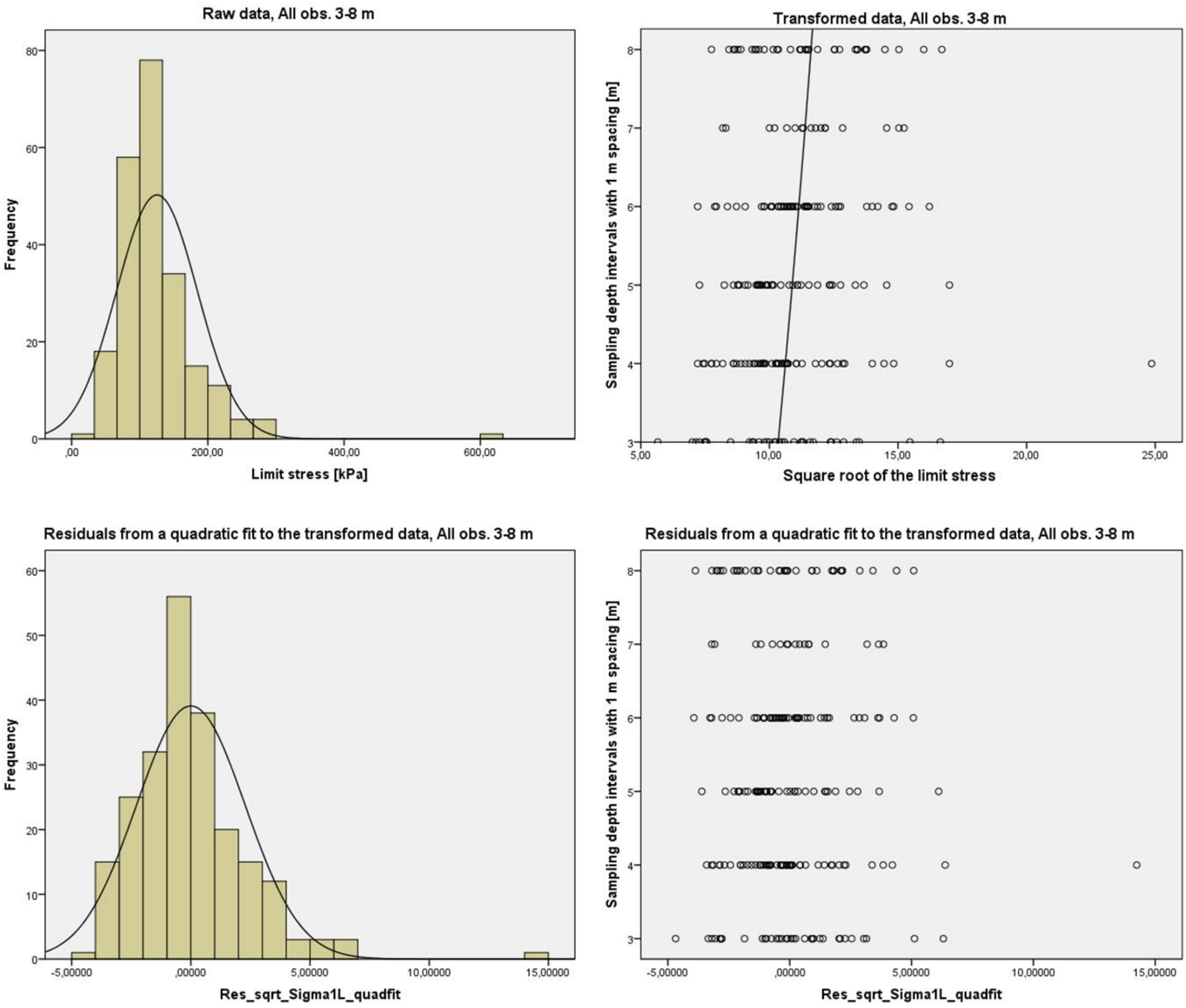
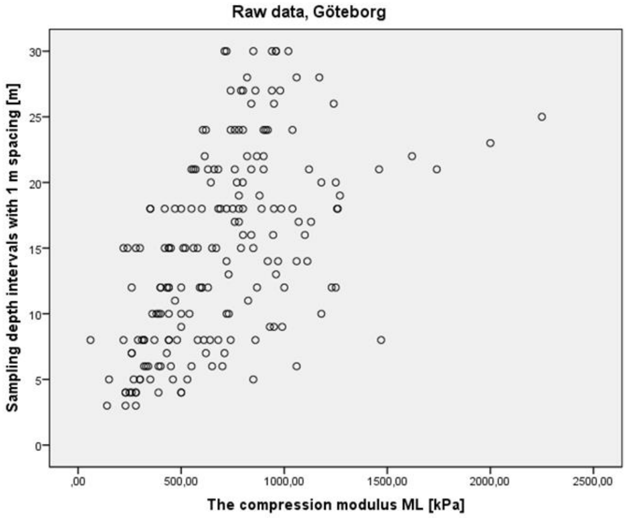


Figure 32: The transformation and normalization of the limit stress, All obs. 3-8 meters.

5.1.10 The compression modulus M_L, Göteborg

The scatter plot of the raw data shows the relationship between M_L and the sampling depth, see Figure 33. The histogram of the raw data shows that M_L is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.350. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 5.183.



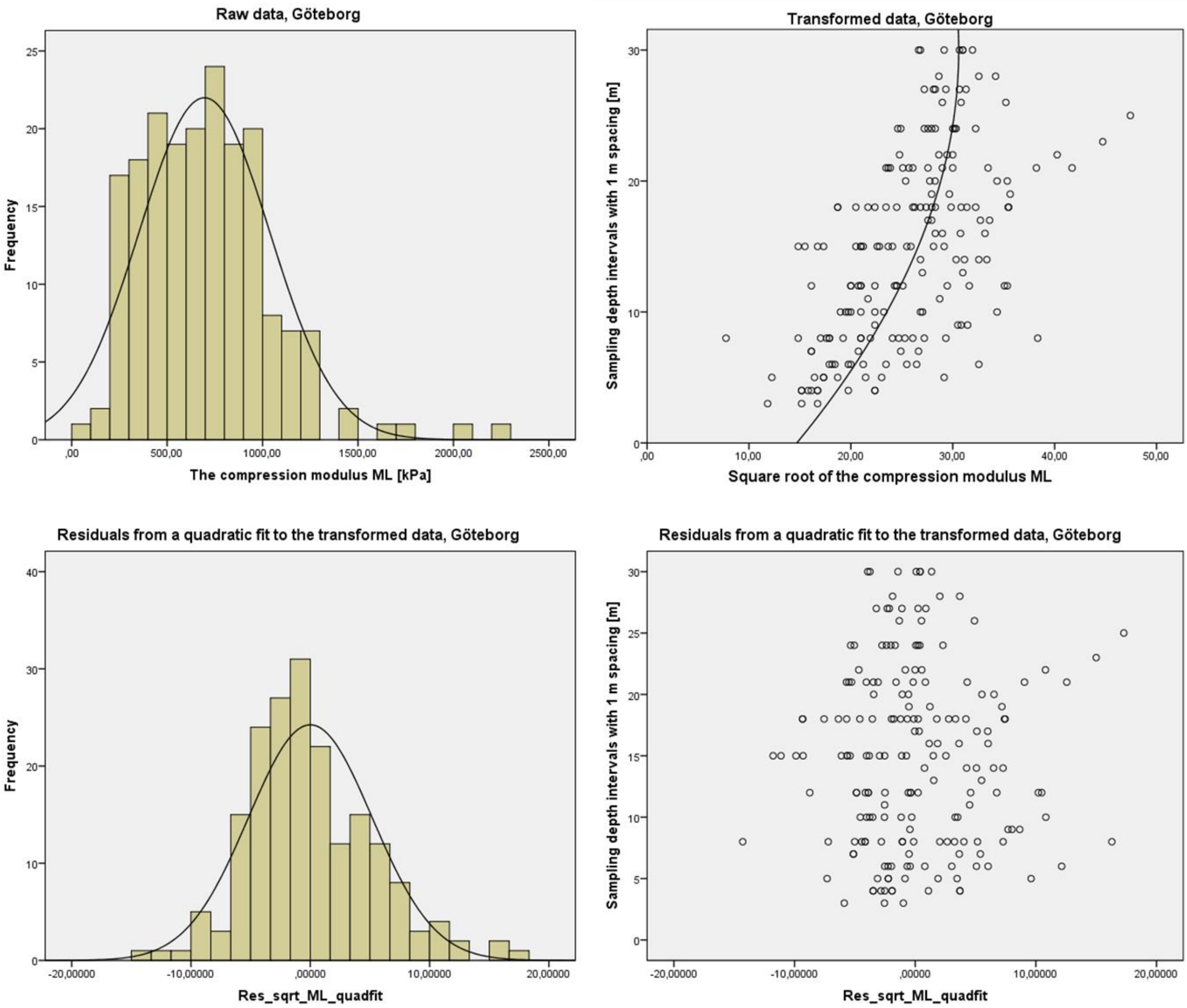
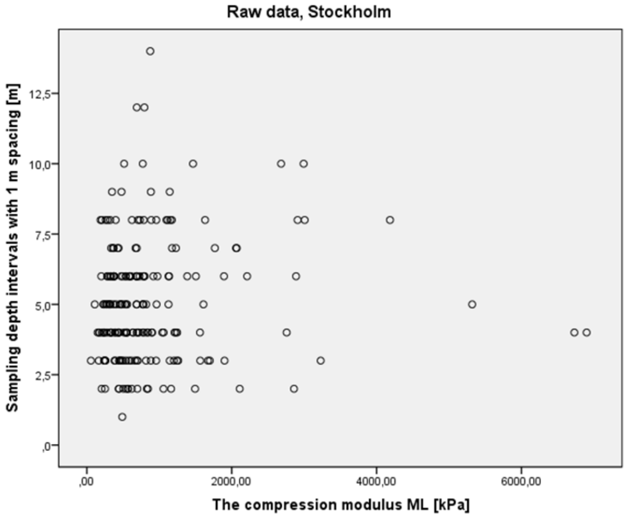


Figure 33: The transformation and normalization of the M_L, Göteborg.

5.1.11 The compression modulus M_L, Stockholm

The scatter plot of the raw data shows the relationship between M_L and the sampling depth, see Figure 34. The histogram of the raw data shows that M_L is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.015. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 11.692.



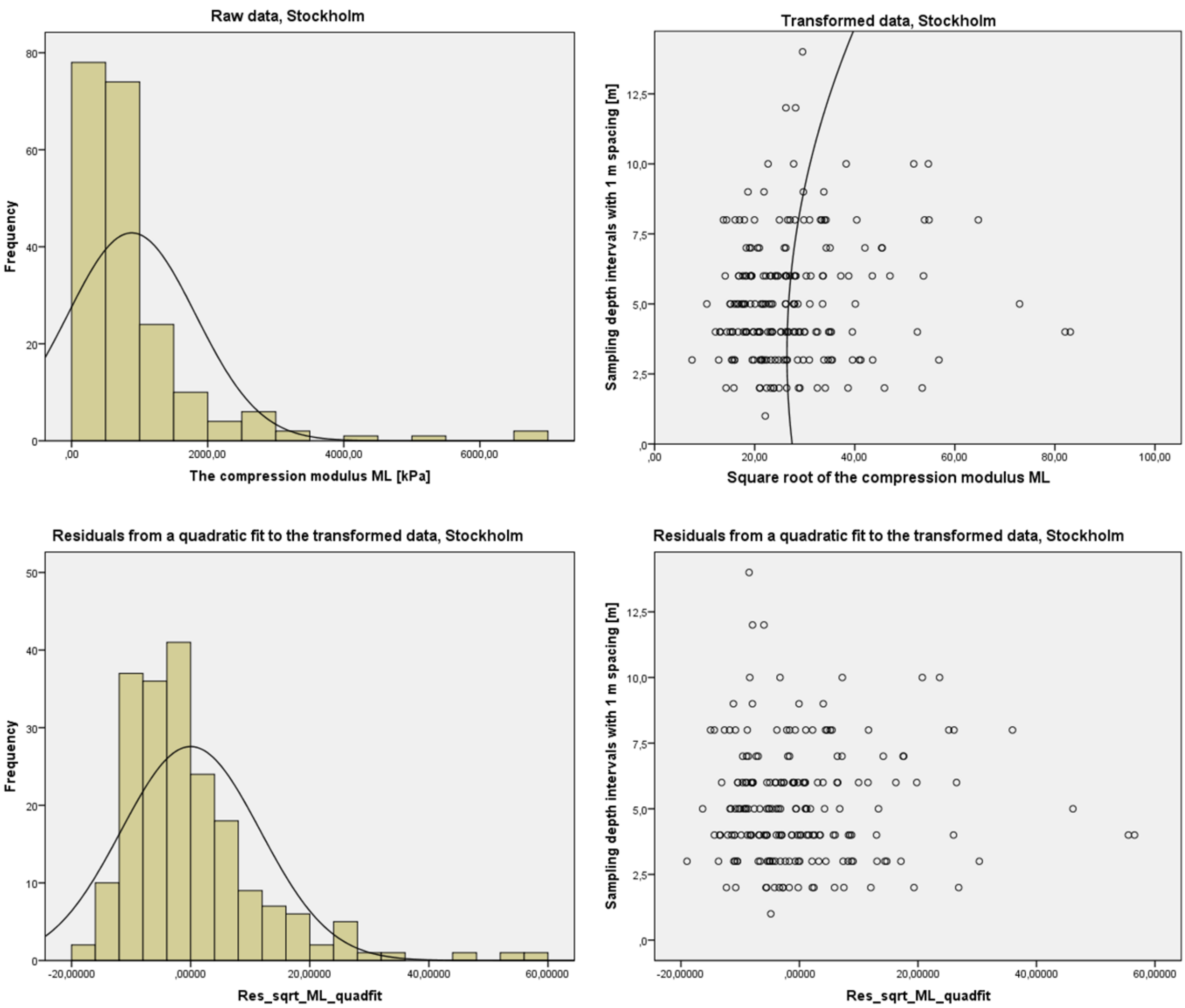
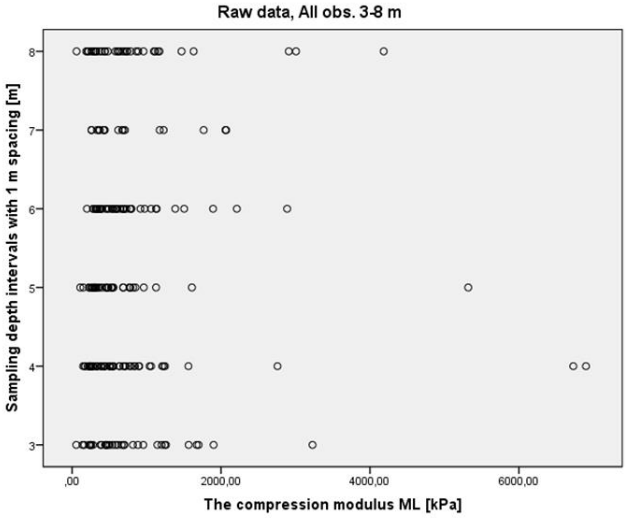


Figure 34: The transformation and normalization of the M_L, Stockholm.

5.1.12 The compression modulus M_L, All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between M_L and the sampling depth, see Figure 35. The histogram of the raw data shows that M_L is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.005. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 11.123.



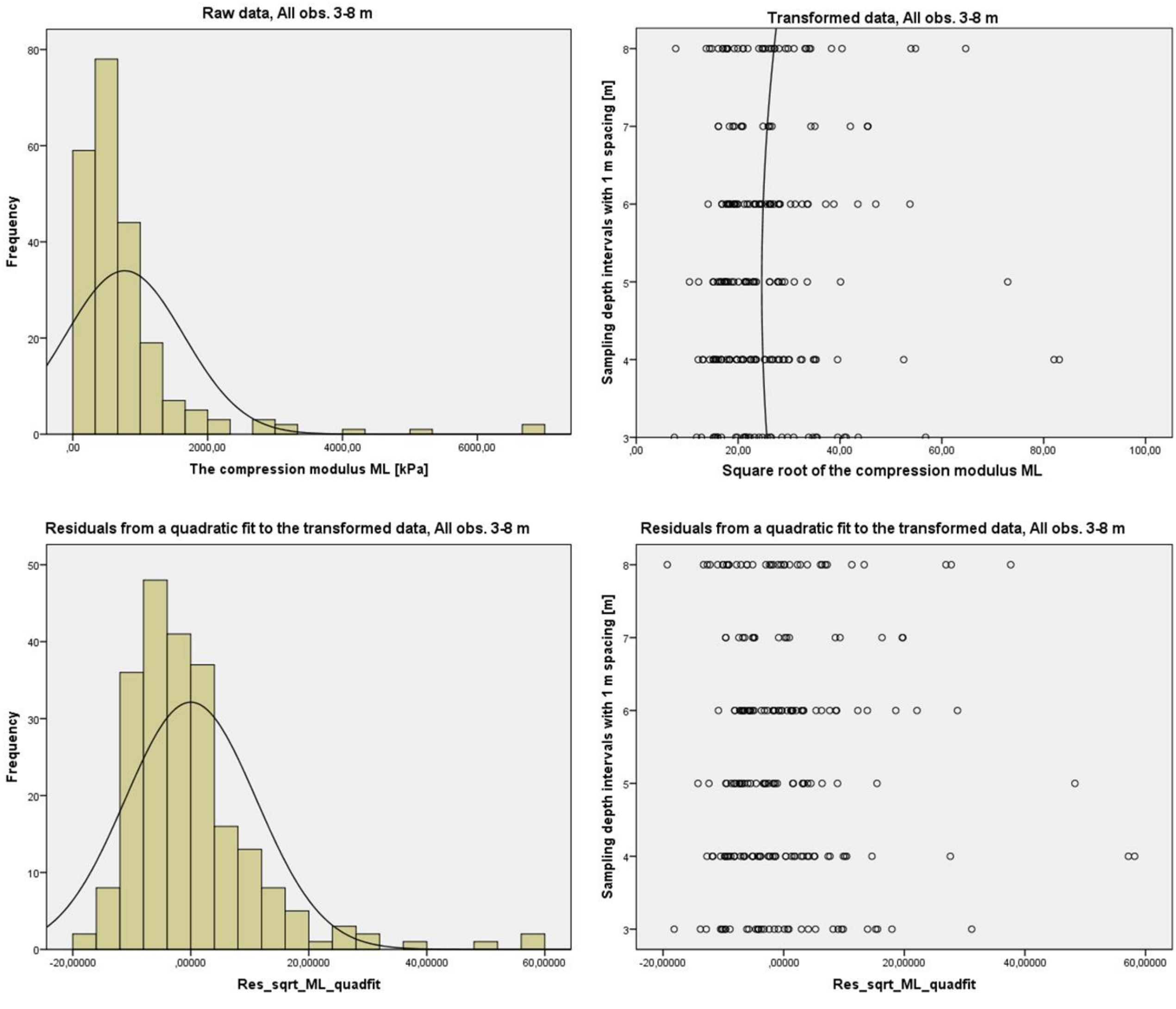
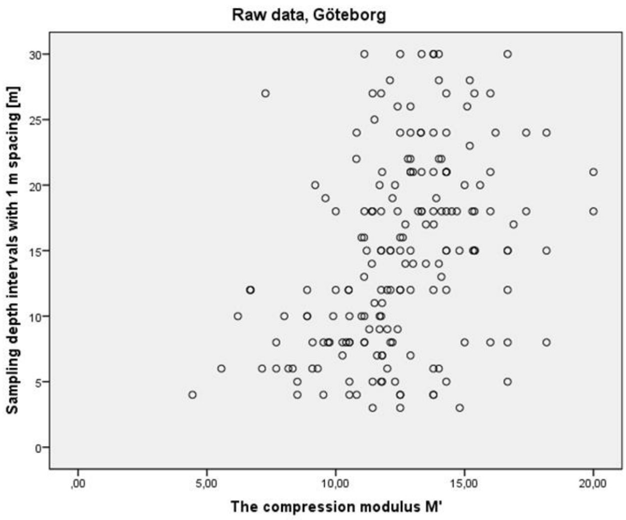


Figure 35: The transformation and normalization of the M_L, All obs. 3-8 meters.

5.1.13 The compression modulus M', Göteborg

The scatter plot of the raw data shows the relationship between M' and the sampling depth, see Figure 36. The histogram of the raw data shows that M' is already almost normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.168. The histogram of the residuals from the regression curve shows that they, like the raw data, also are almost normally distributed. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.347.



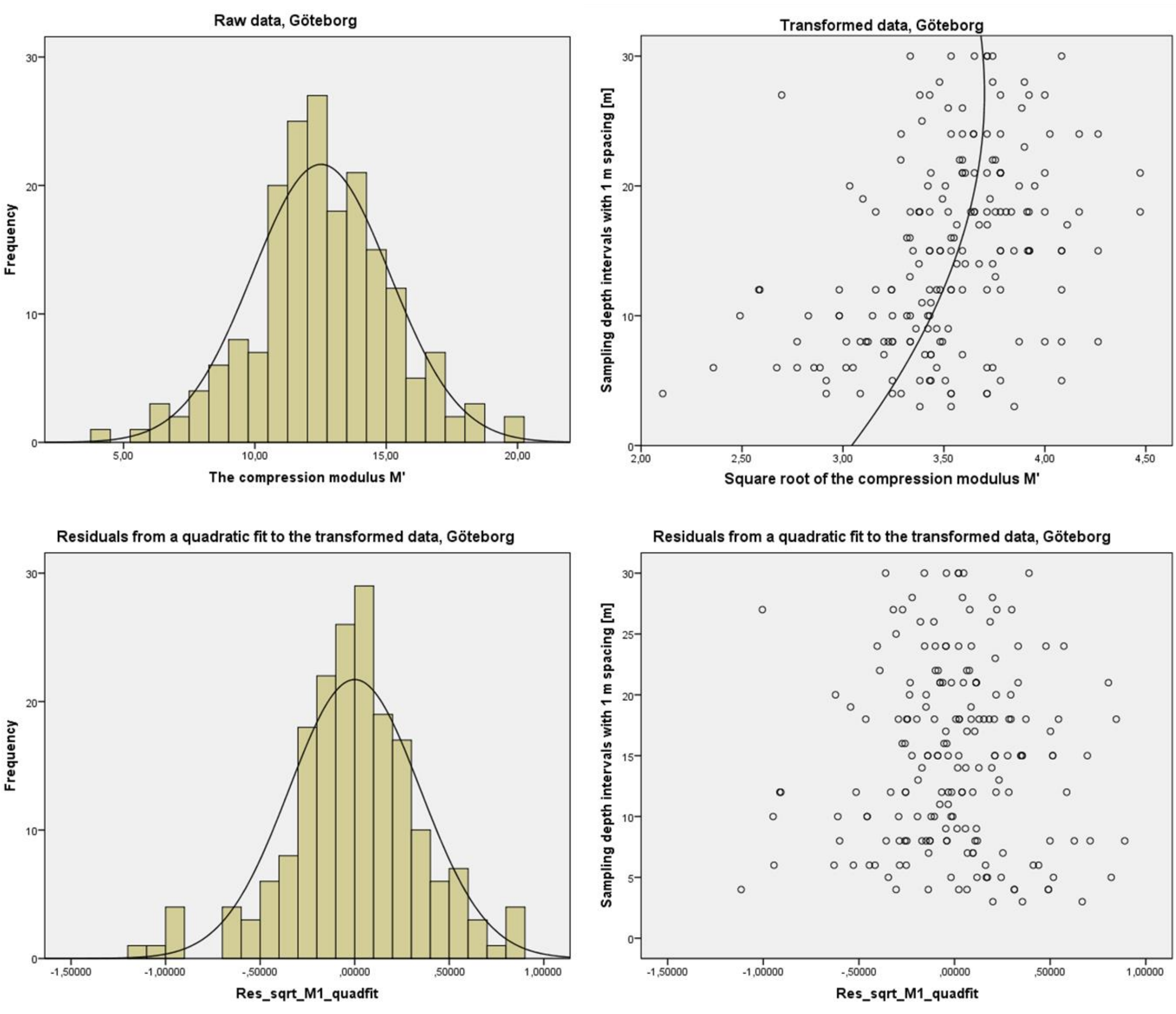
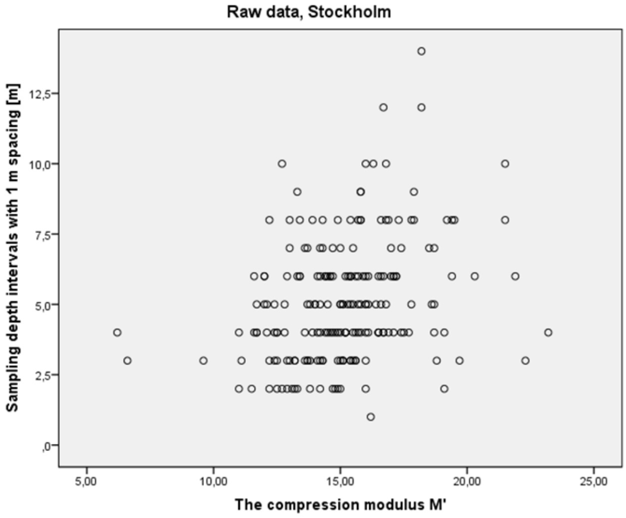


Figure 36: The transformation and normalization of the M', Göteborg.

5.1.14 The compression modulus M', Stockholm

The scatter plot of the raw data shows the relationship between M' and the sampling depth, see Figure 37. The histogram of the raw data shows that M' is already almost normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.091. The histogram of the residuals from the regression curve shows that they, like the raw data, also are almost normally distributed. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.303.



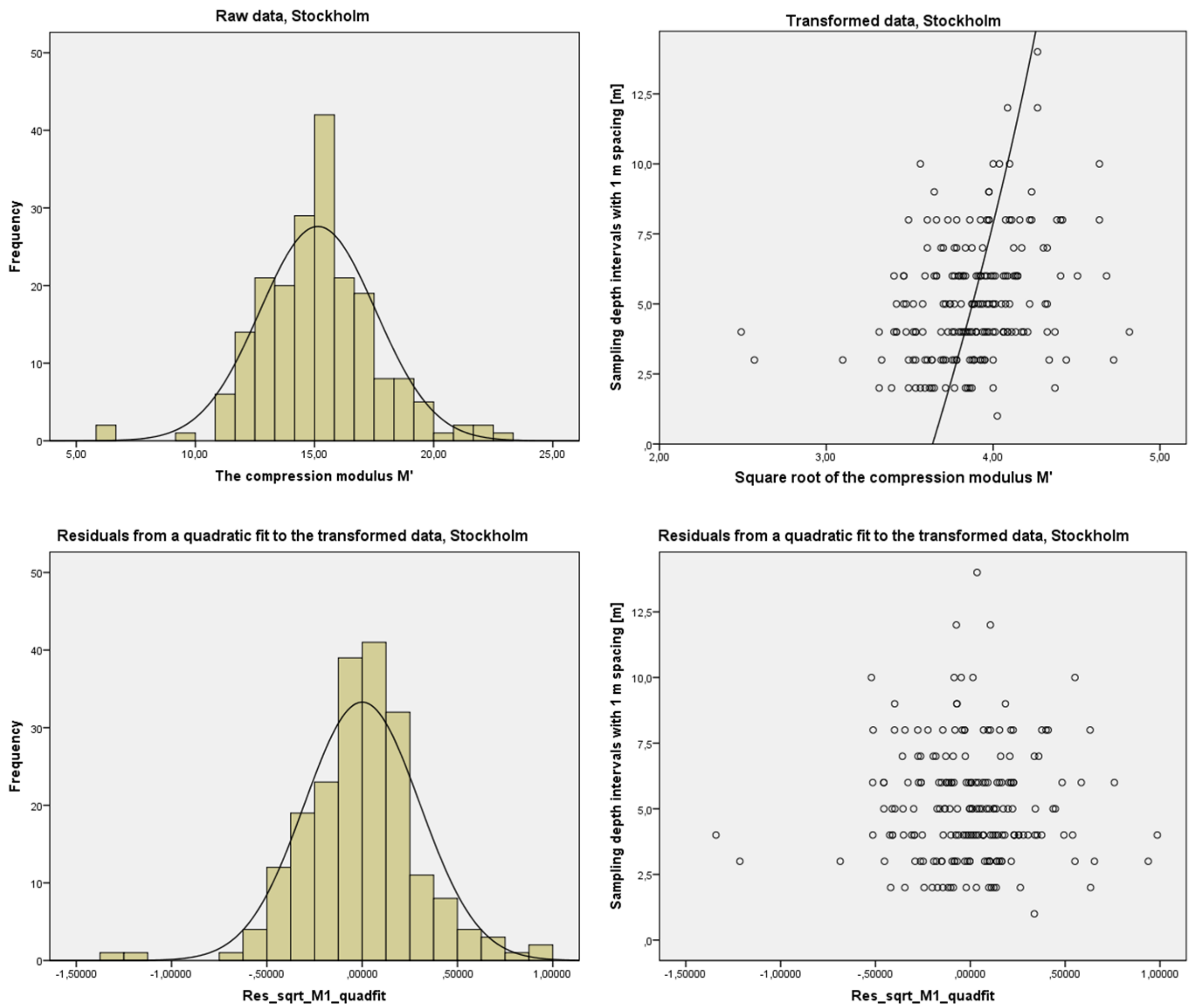
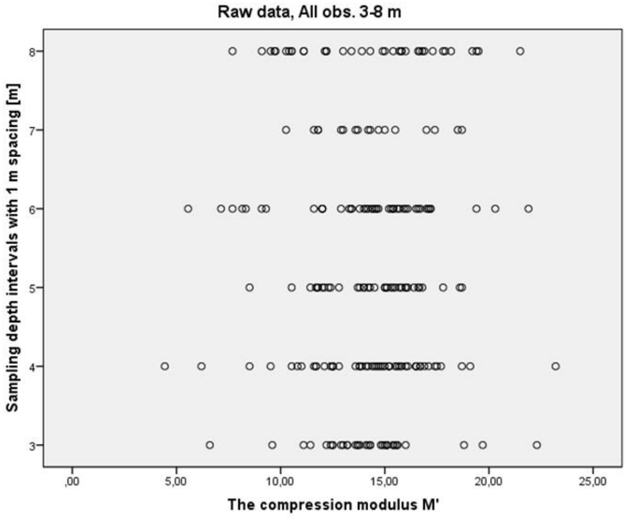


Figure 37: The transformation and normalization of the M', Stockholm.

5.1.15 The compression modulus M', All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between M' and the sampling depth, see Figure 38. The histogram of the raw data shows that M' is already almost normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.000. The histogram of the residuals from the regression curve shows that they, like the raw data, also are almost normally distributed. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.416.



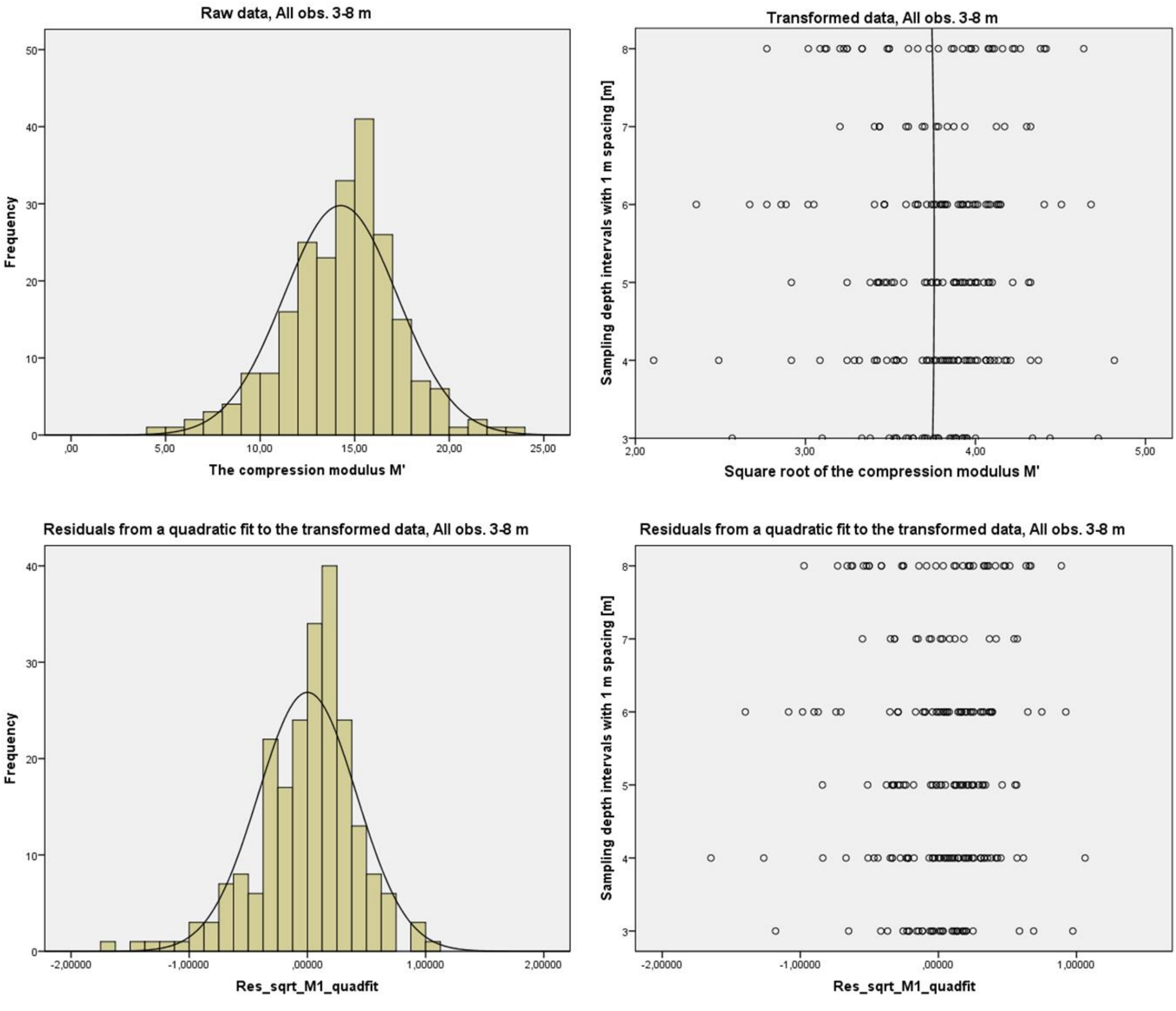
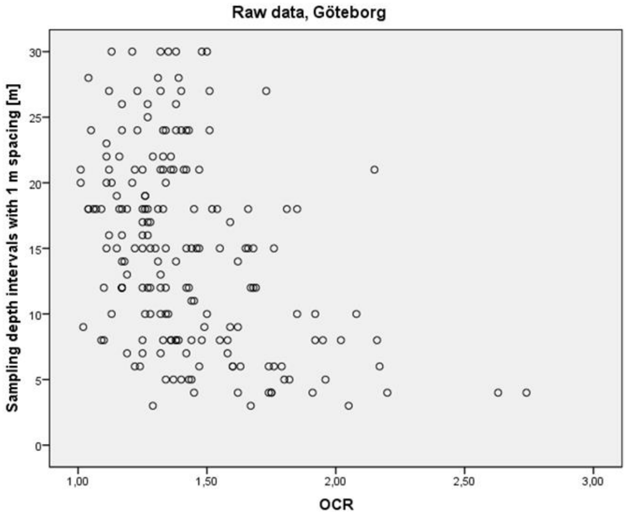
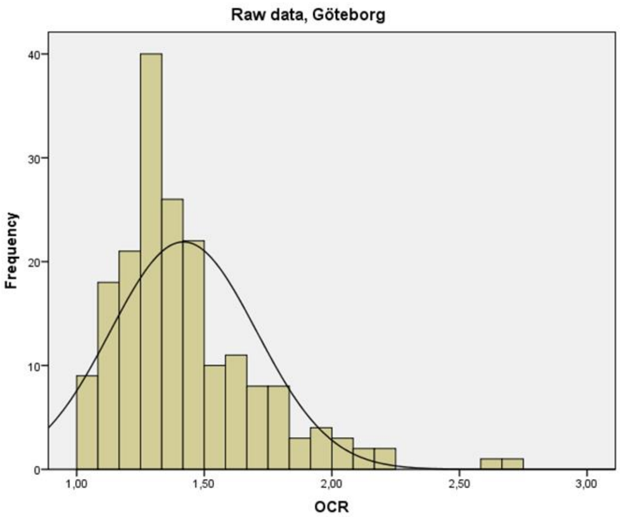


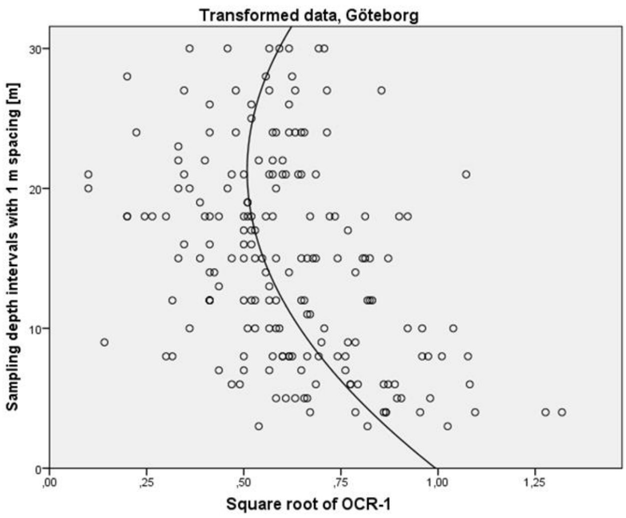
Figure 38: The transformation and normalization of the M', All obs. 3-8 meters.

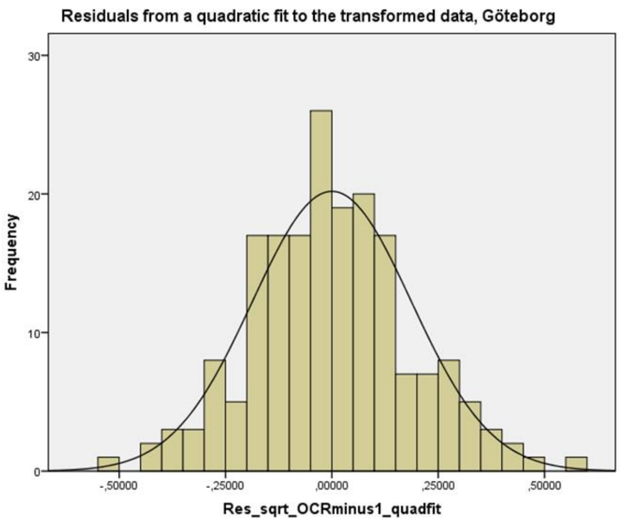
5.1.16 OCR, Göteborg

The scatter plot of the raw data shows the relationship between OCR and the sampling depth, see Figure 39. The histogram of the raw data shows that OCR is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.235. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.187.









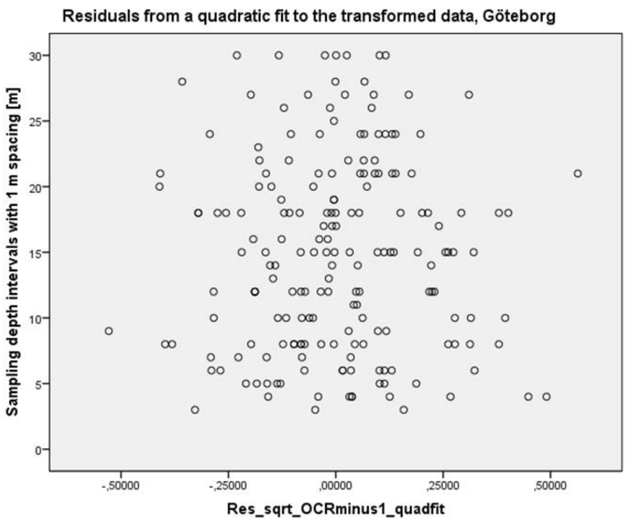
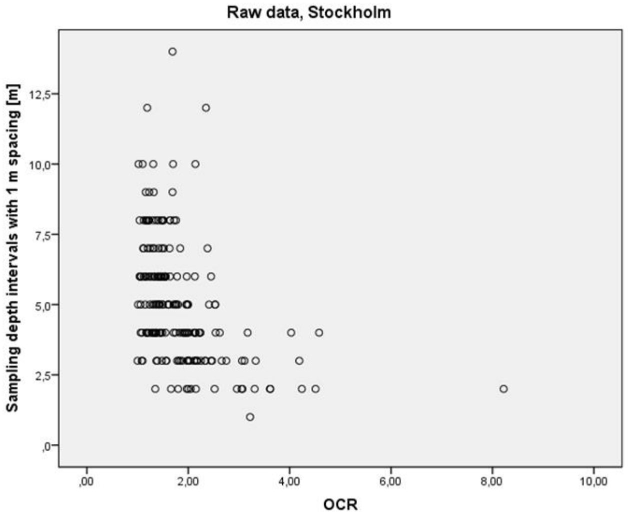


Figure 39: The transformation and normalization of the OCR, Göteborg.

5.1.17 OCR, Stockholm

The scatter plot of the raw data shows the relationship between OCR and the sampling depth, see Figure 40. The histogram of the raw data shows that OCR is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.317. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.316.



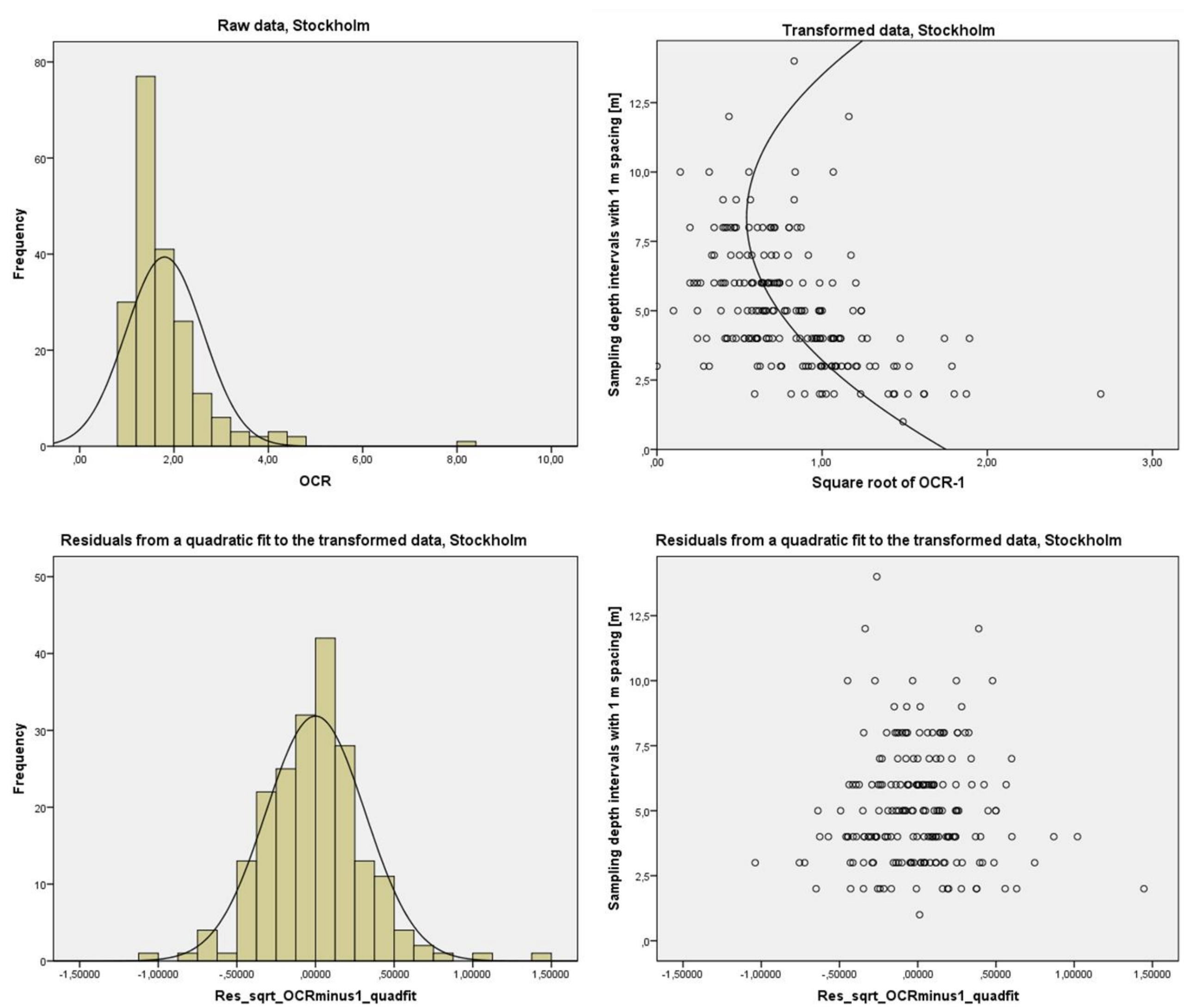
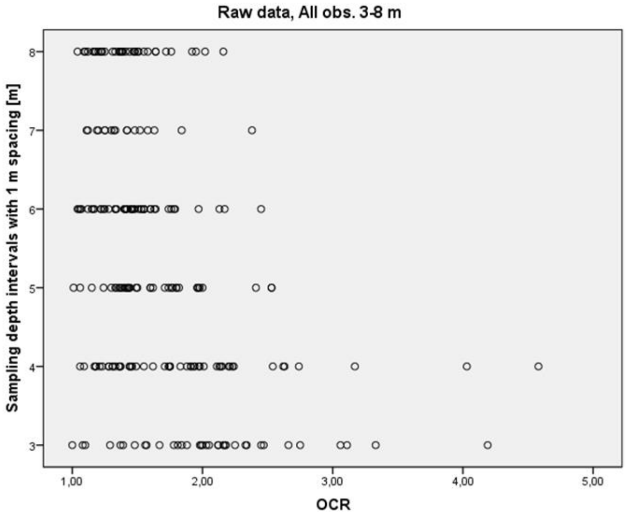


Figure 40: The transformation and normalization of the OCR, Stockholm.

5.1.18 OCR, All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between OCR and the sampling depth, see Figure 41. The histogram of the raw data shows that OCR is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.173. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.276.



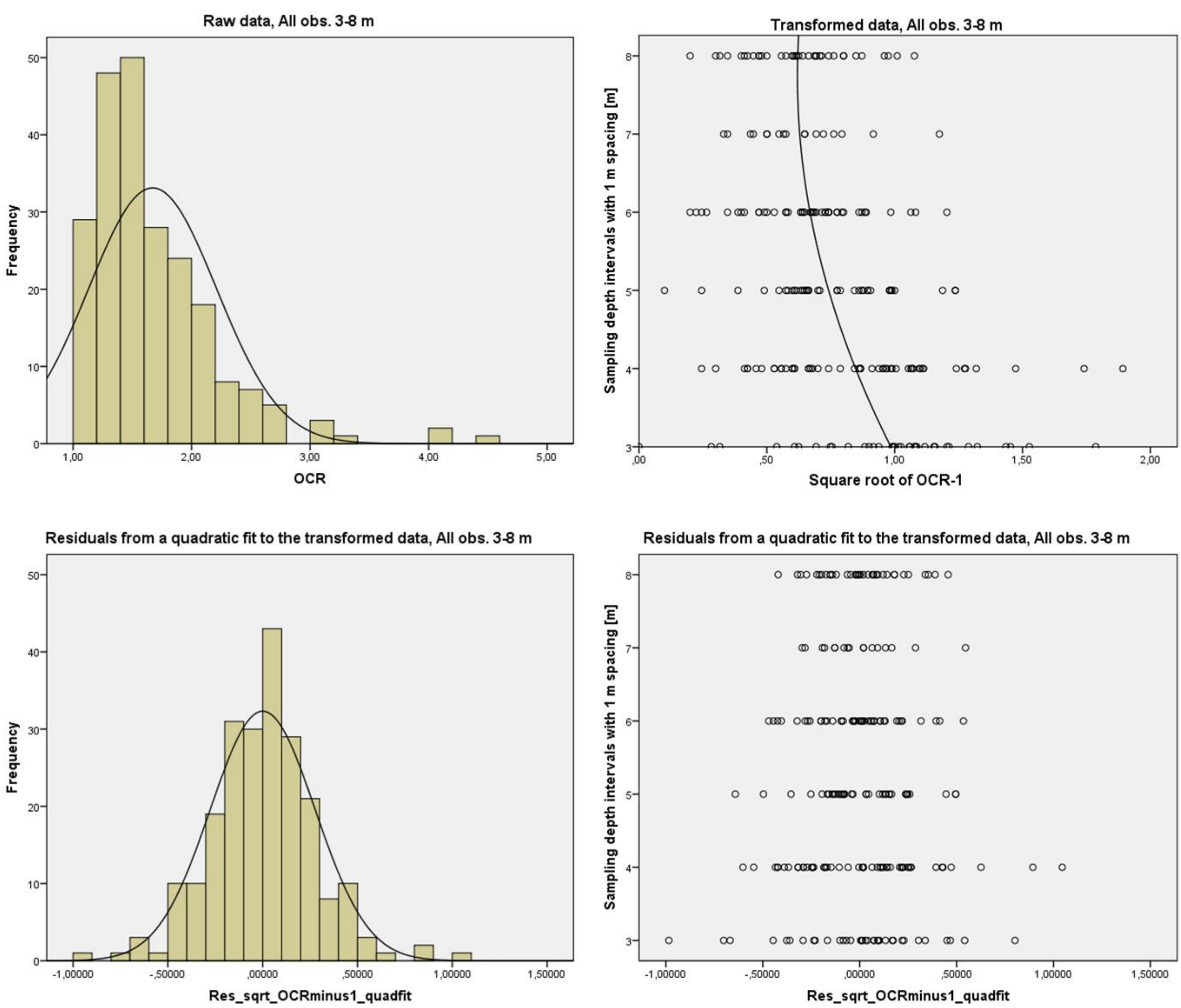
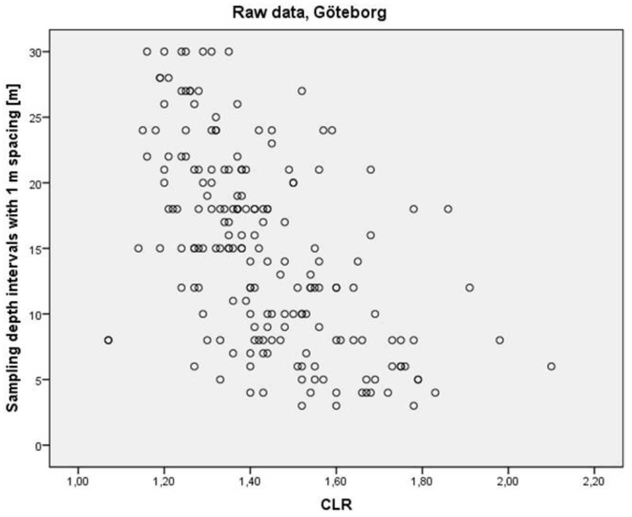


Figure 41: The transformation and normalization of the OCR, All obs. 3-8 meters.

5.1.19 CLR, Göteborg

The scatter plot of the raw data shows the relationship between CLR and the sampling depth, see Figure 42. The histogram of the raw data shows that CLR is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.310. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.113.



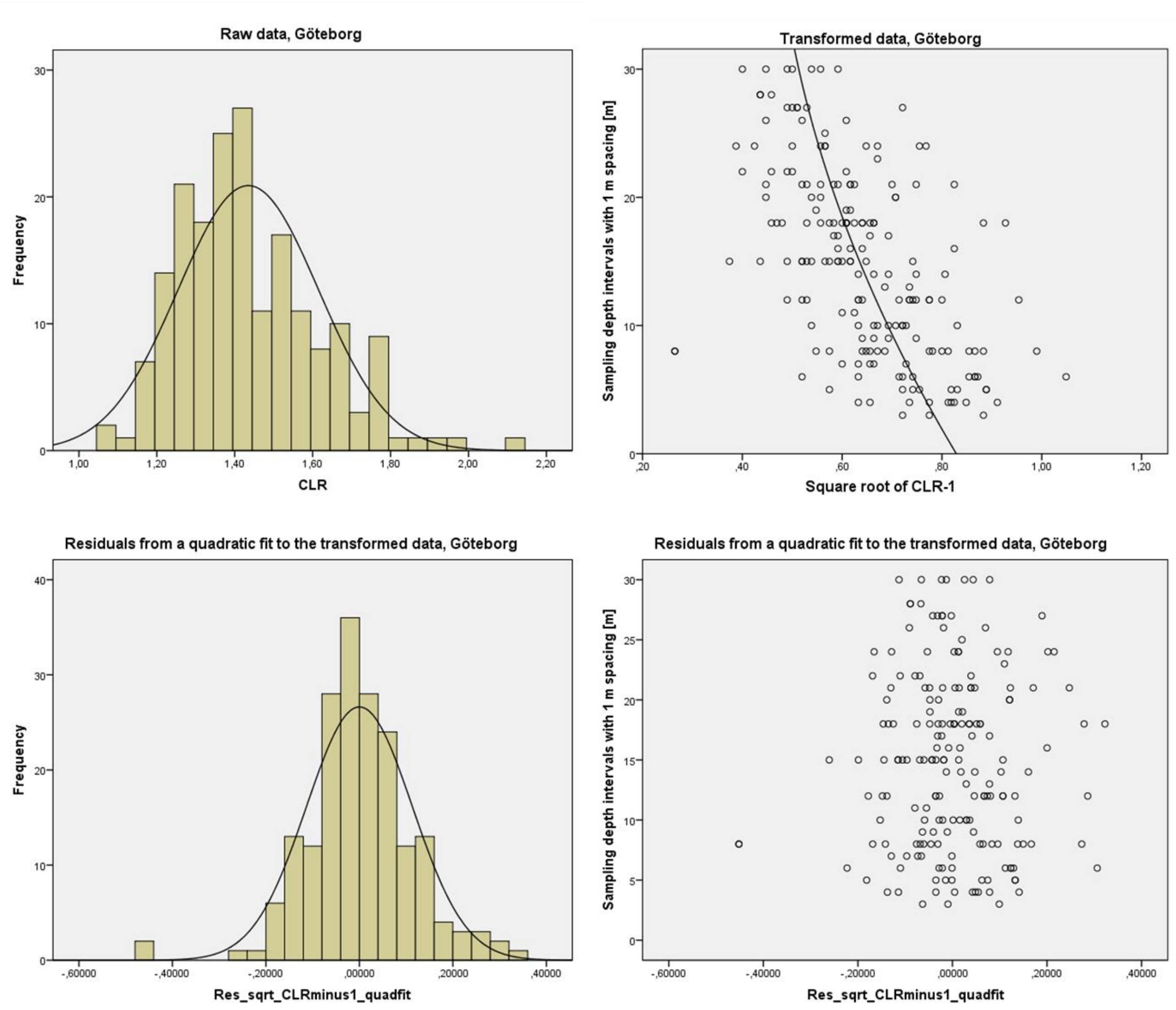
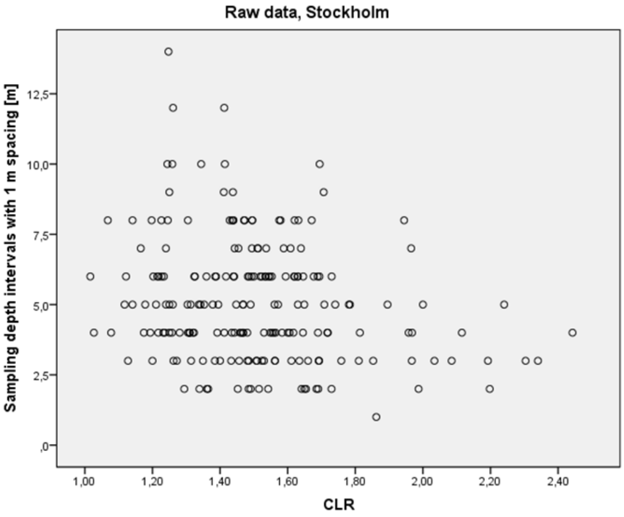


Figure 42: The transformation and normalization of the CLR, Göteborg.

5.1.20 CLR, Stockholm

The scatter plot of the raw data shows the relationship between CLR and the sampling depth, see Figure 43. The histogram of the raw data shows that CLR is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.052. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.175.



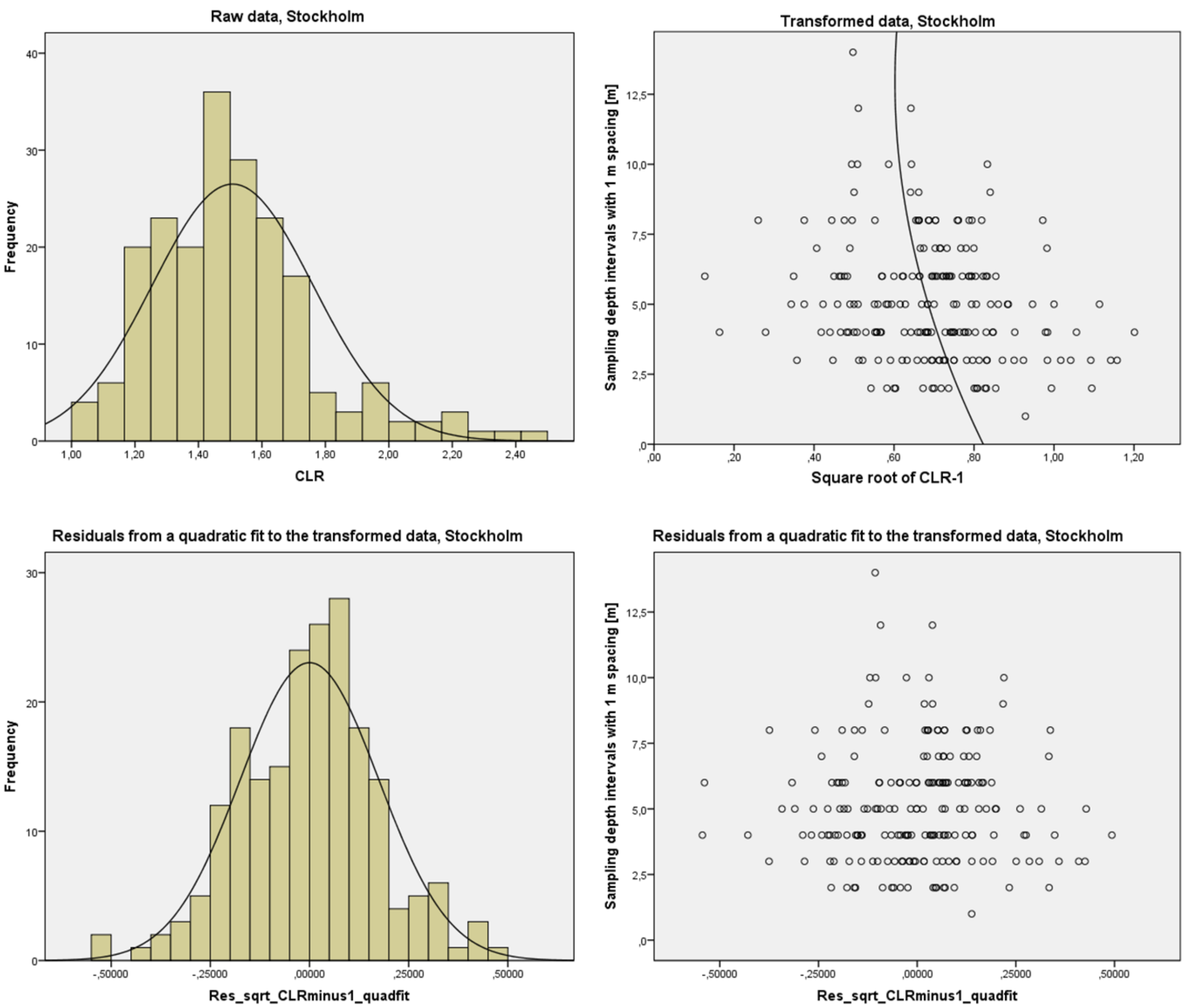
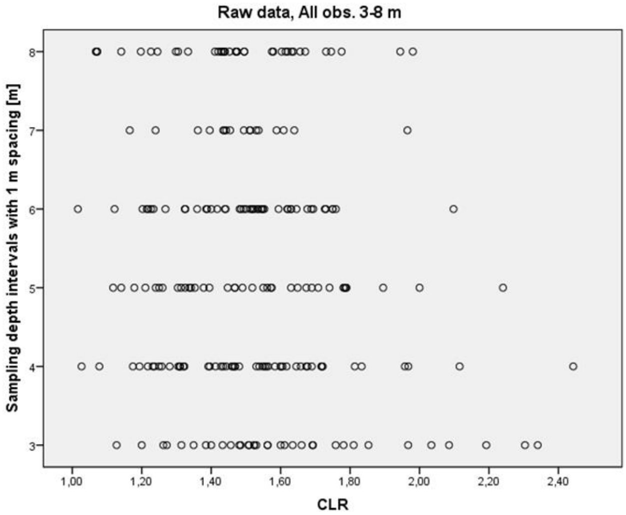


Figure 43: The transformation and normalization of the CLR, Stockholm.

5.1.21 CLR, All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between CLR and the sampling depth, see Figure 44. The histogram of the raw data shows that CLR is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.023. The histogram of the residuals from the regression curve shows that they are a bit closer to be normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.175.



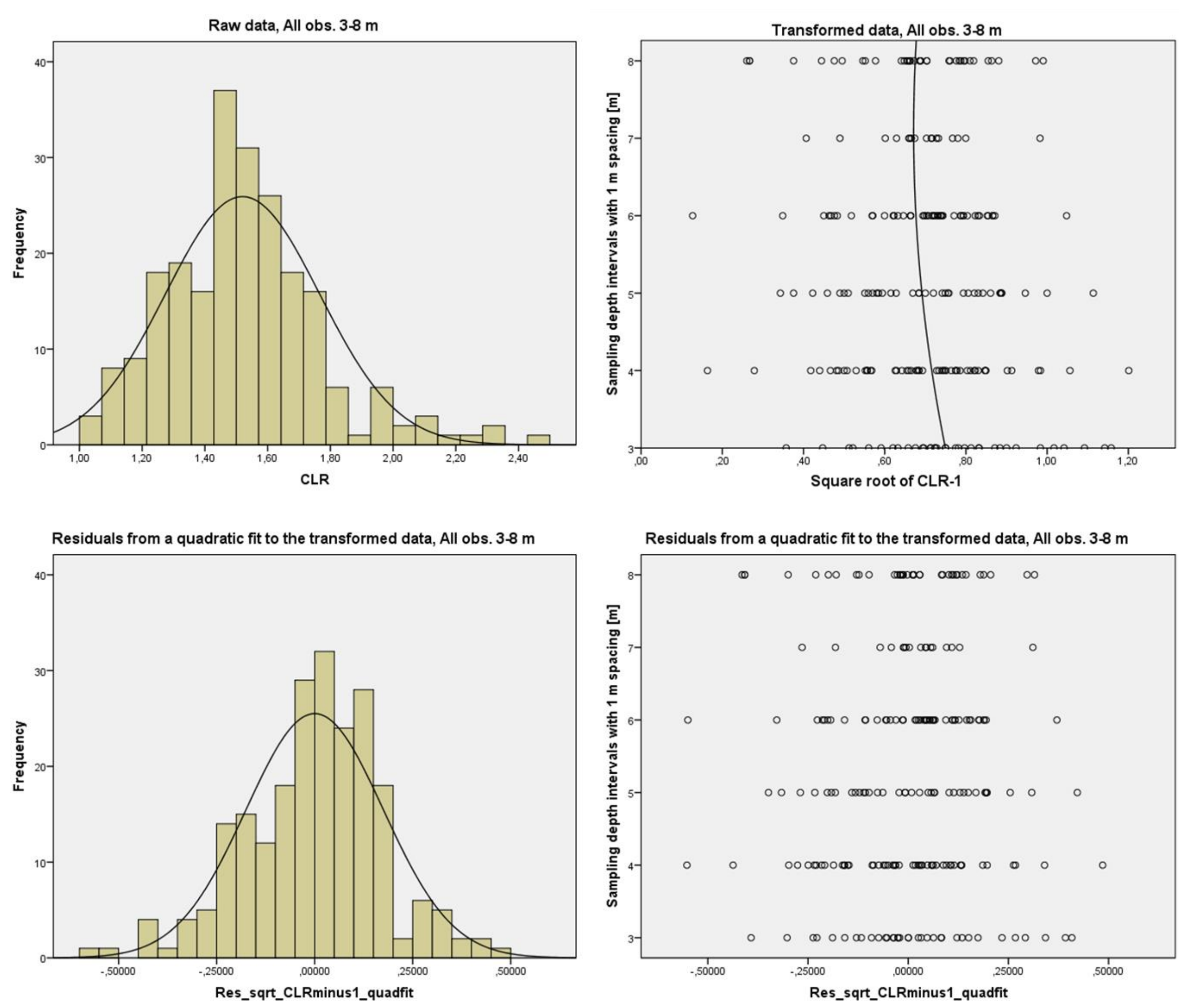
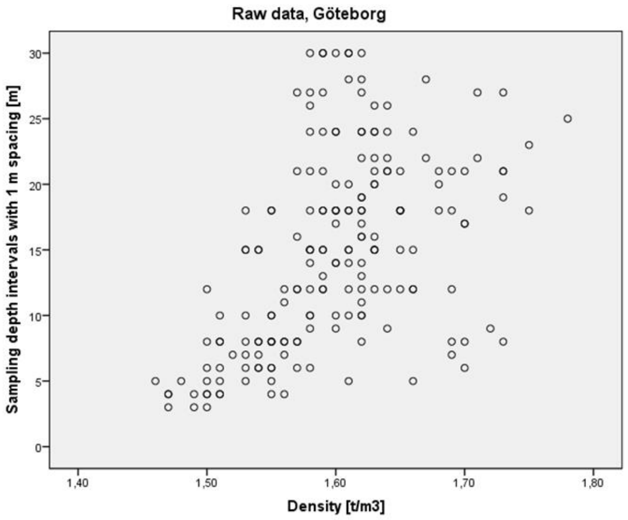


Figure 44: The transformation and normalization of the CLR, All obs. 3-8 meters.

5.1.22 Density (ρ), Göteborg

The scatter plot of the raw data shows the relationship between ρ and the sampling depth, see Figure 45. The histogram of the raw data shows that ρ is already almost normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.350. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.020.



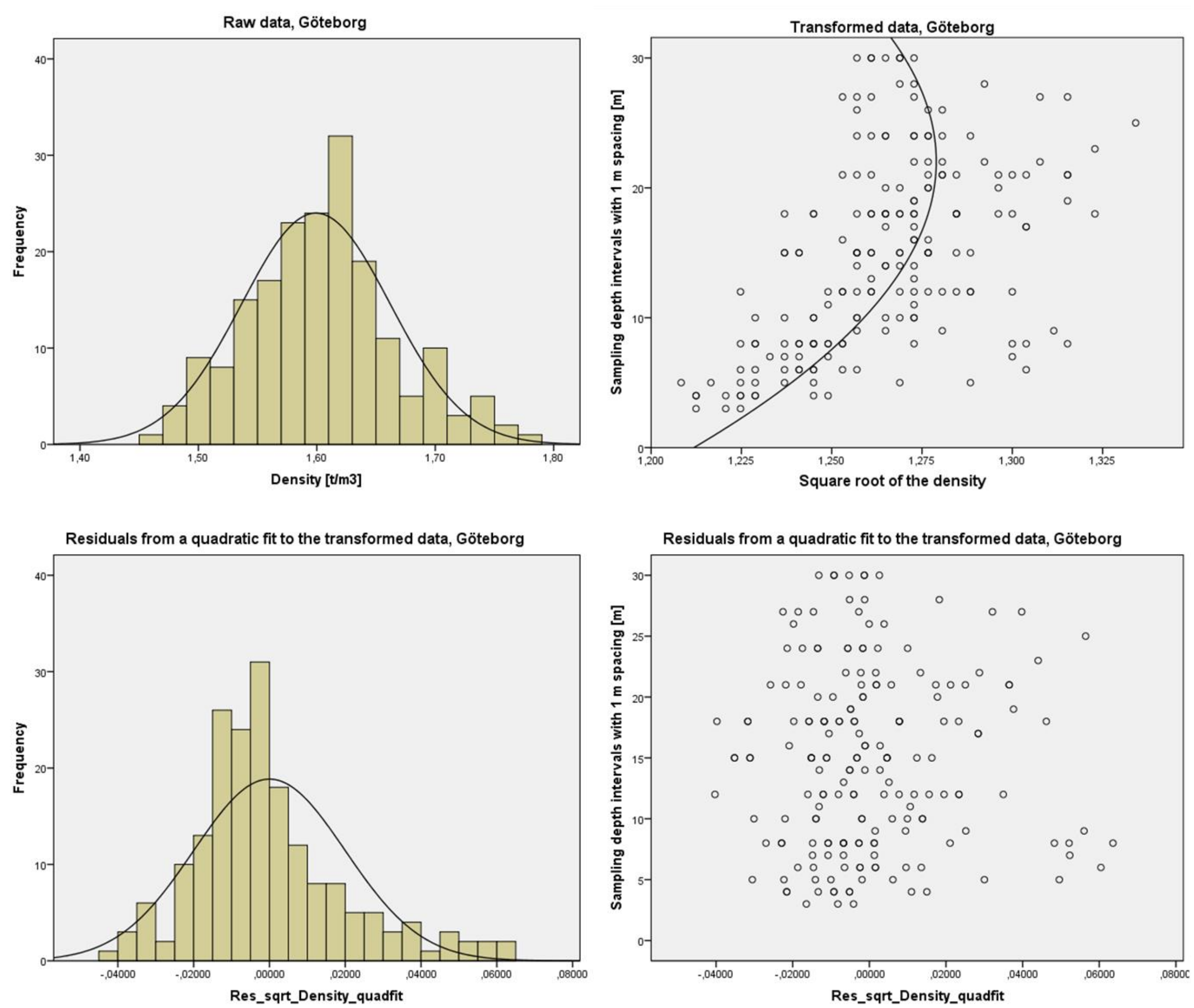
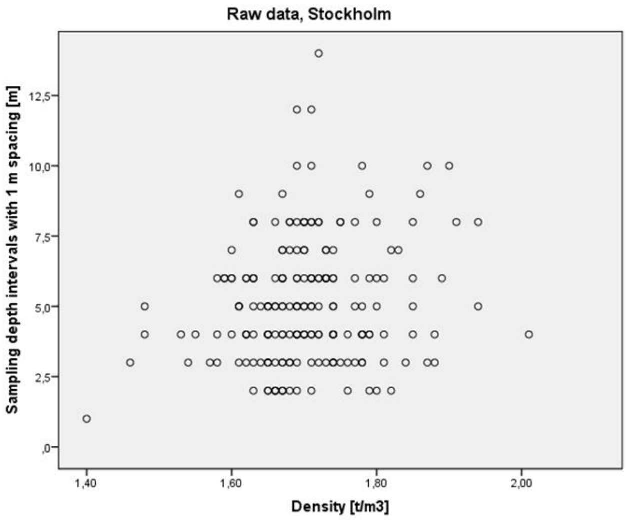


Figure 45: The transformation and normalization of the density, Göteborg.

5.1.23 Density (ρ), Stockholm

The scatter plot of the raw data shows the relationship between ρ and the sampling depth, see Figure 46. The histogram of the raw data shows that ρ is already almost normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.032. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.033.



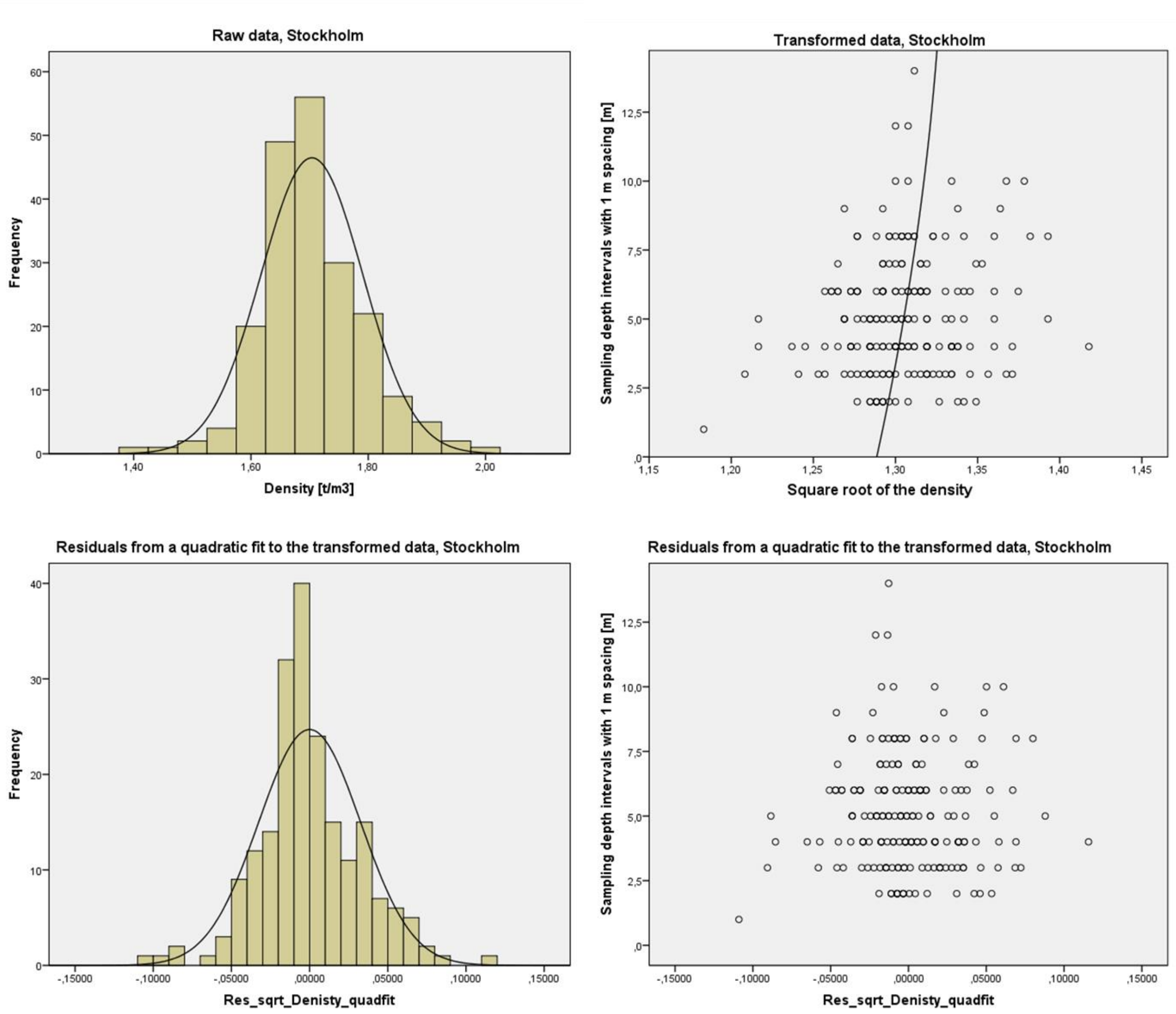
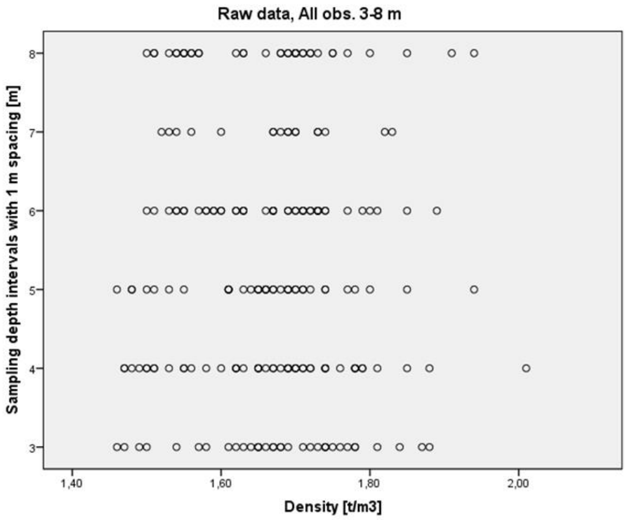


Figure 46: The transformation and normalization of the density, Stockholm.

5.1.24 Density (ρ), All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between ρ and the sampling depth, see Figure 47. The histogram of the raw data shows that ρ is already almost normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.002. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.040.



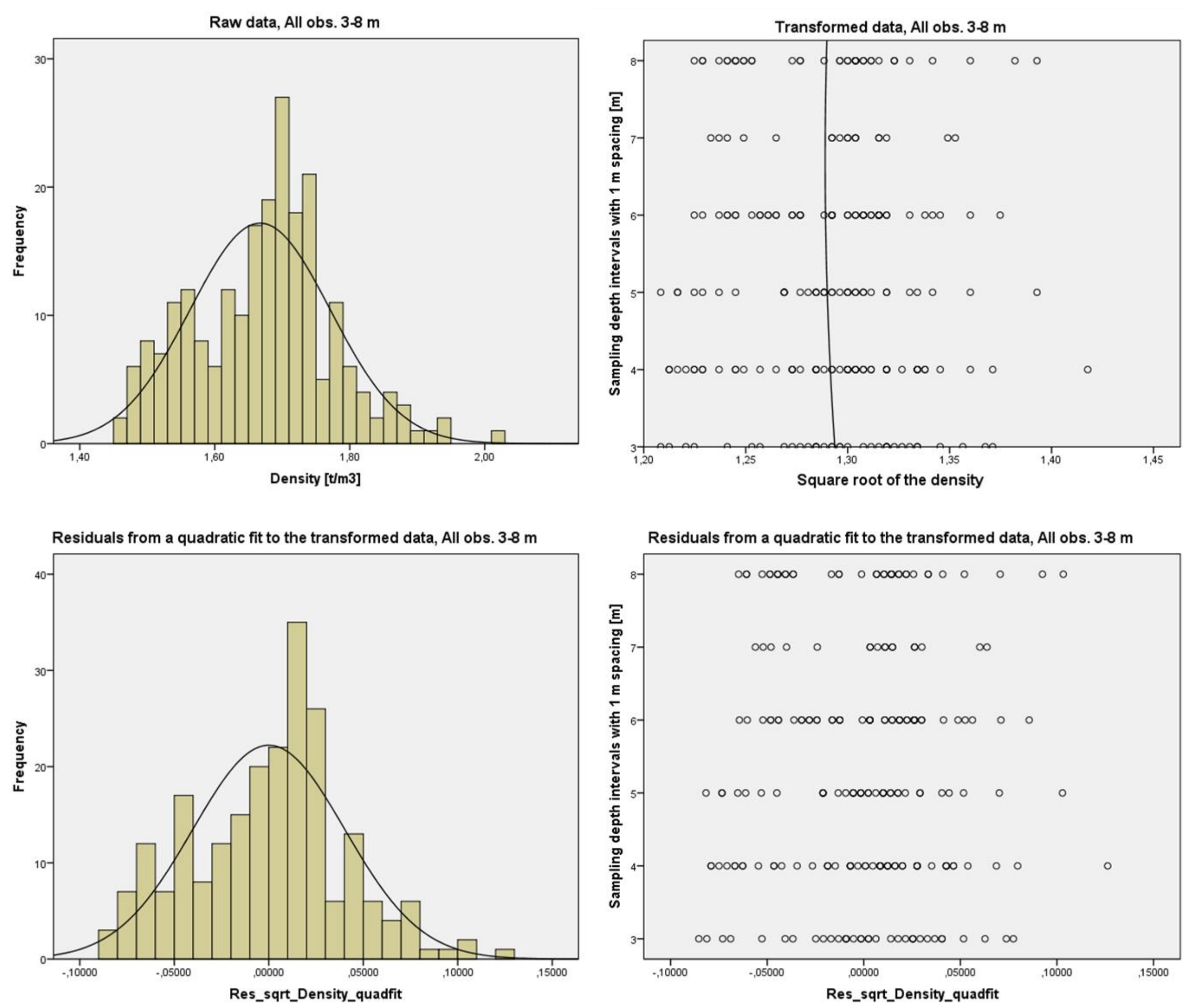
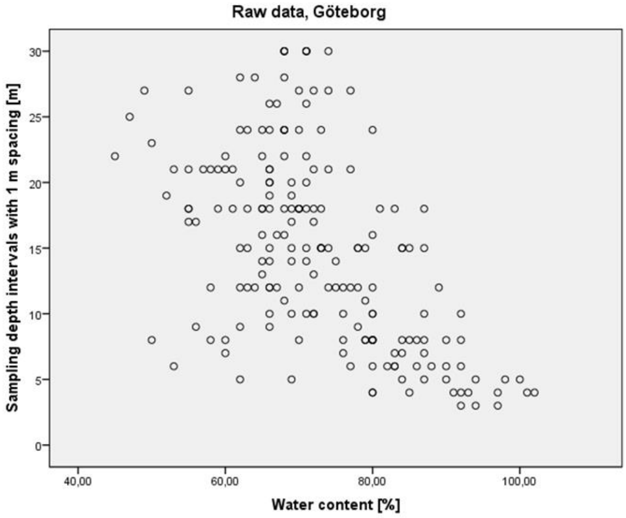


Figure 47: The transformation and normalization of the density, All obs. 3-8 meters.

5.1.25 Water content (w), Göteborg

The scatter plot of the raw data shows the relationship between *w* and the sampling depth, see Figure 48. The histogram of the raw data shows that *w* is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.381. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.531.



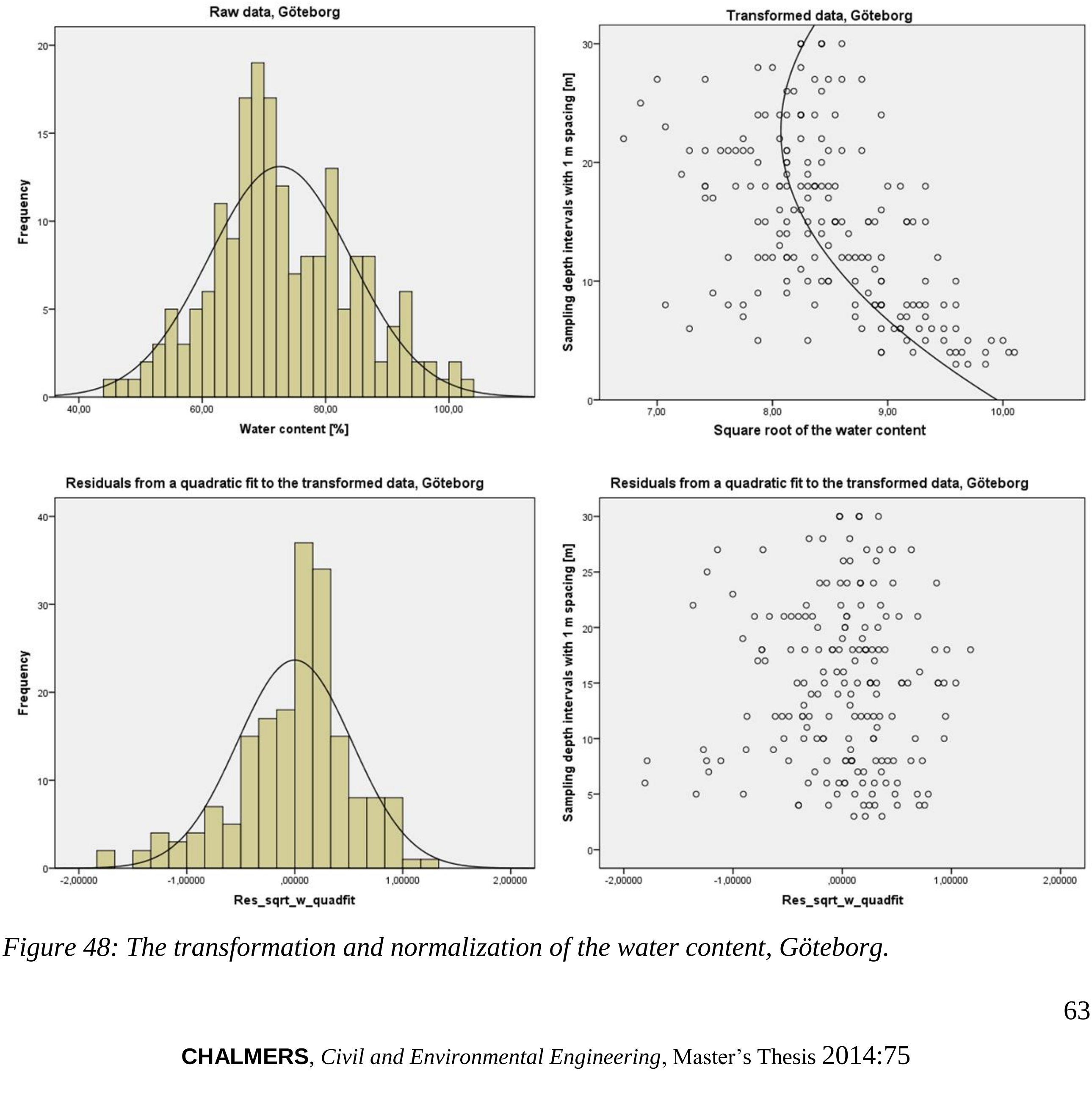
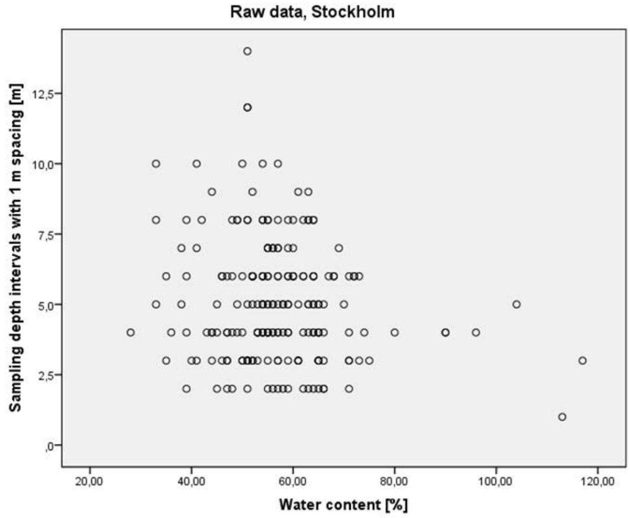


Figure 48: The transformation and normalization of the water content, Göteborg.

5.1.26 Water content (w), Stockholm

The scatter plot of the raw data shows the relationship between w and the sampling depth, see Figure 49. The histogram of the raw data shows that w is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.029. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.764.



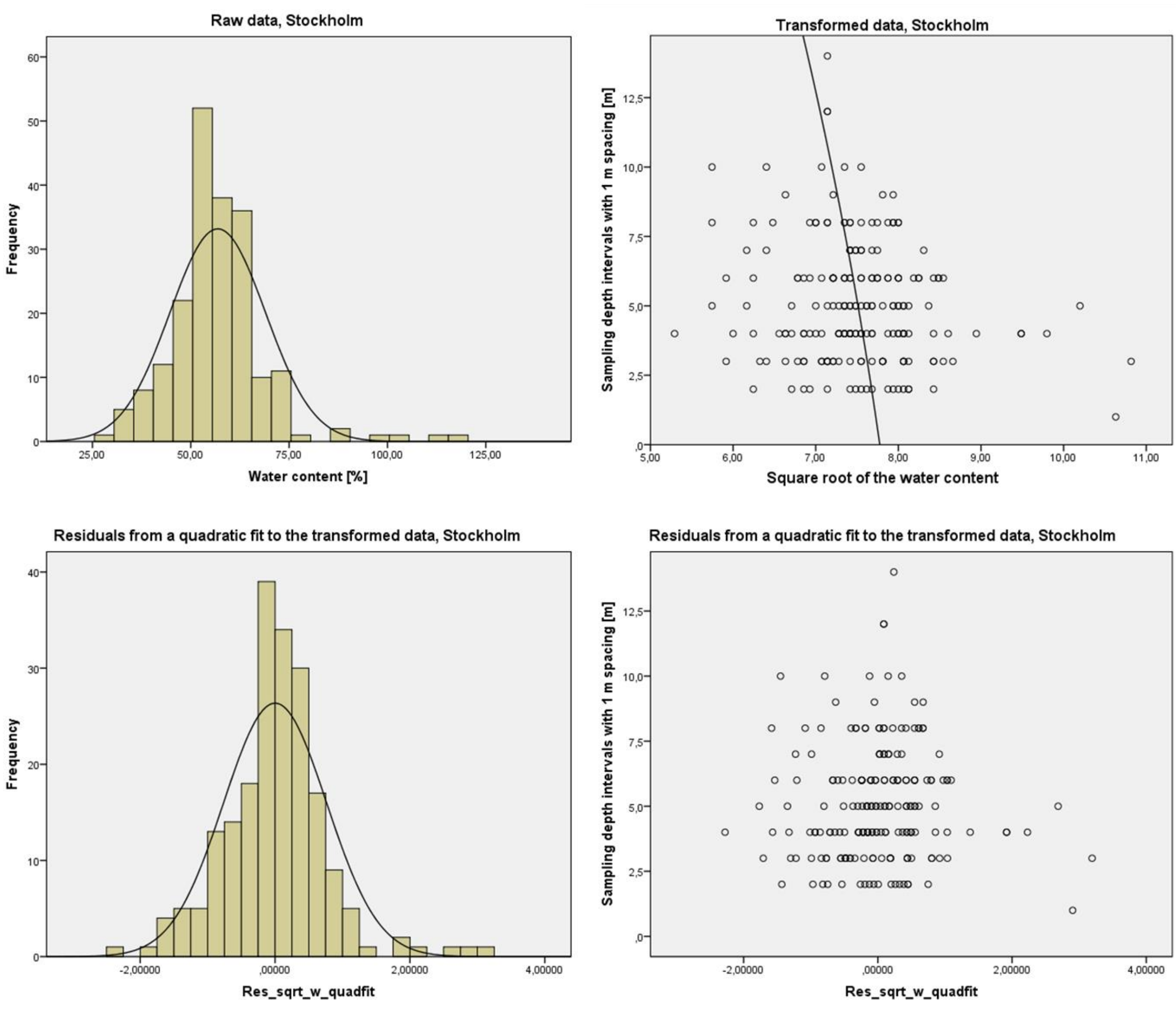
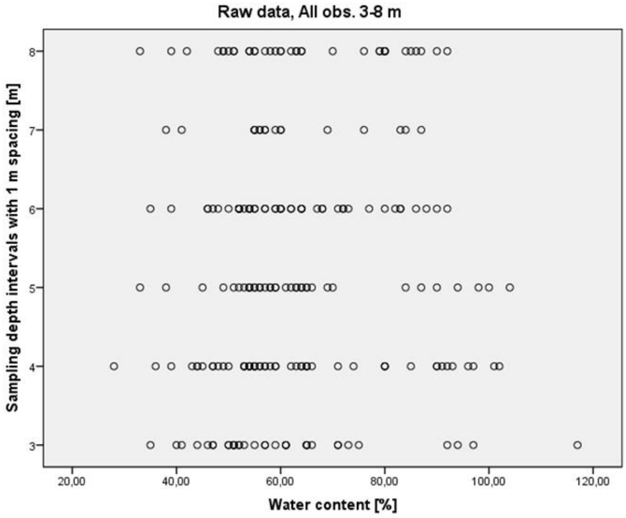


Figure 49: The transformation and normalization of the water content, Stockholm.

5.1.27 Water content (w), All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between *w* and the sampling depth, see Figure 50. The histogram of the raw data shows that *w* is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.003. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.996.



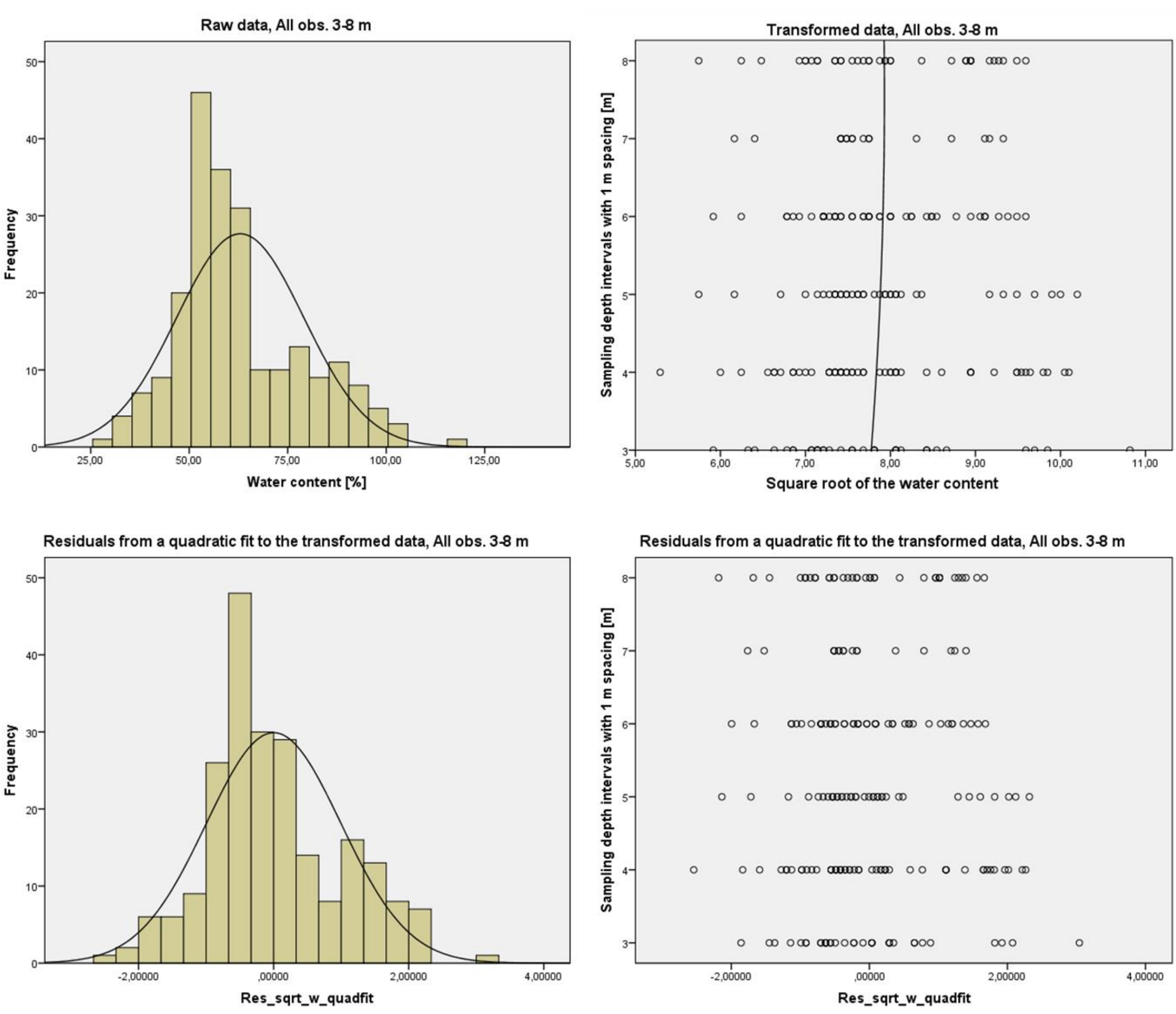
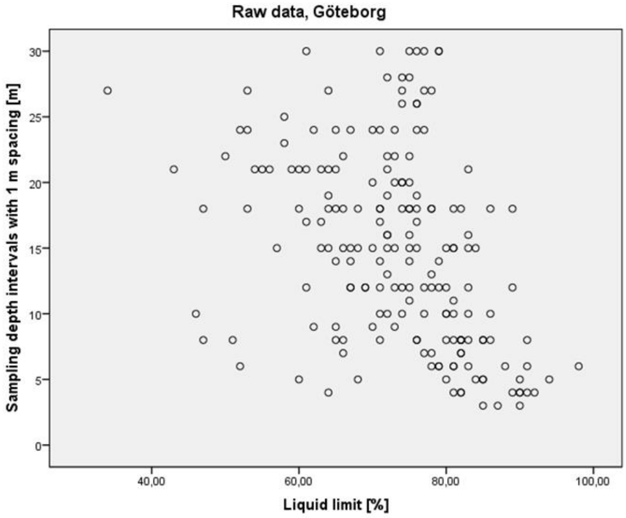


Figure 50: The transformation and normalization of the water content, All obs. 3-8 meters.

5.1.28 Liquid limit (w_L), Göteborg

The scatter plot of the raw data shows the relationship between w_L and the sampling depth, see Figure 51. The histogram of the raw data shows that w_L is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.198. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.583.



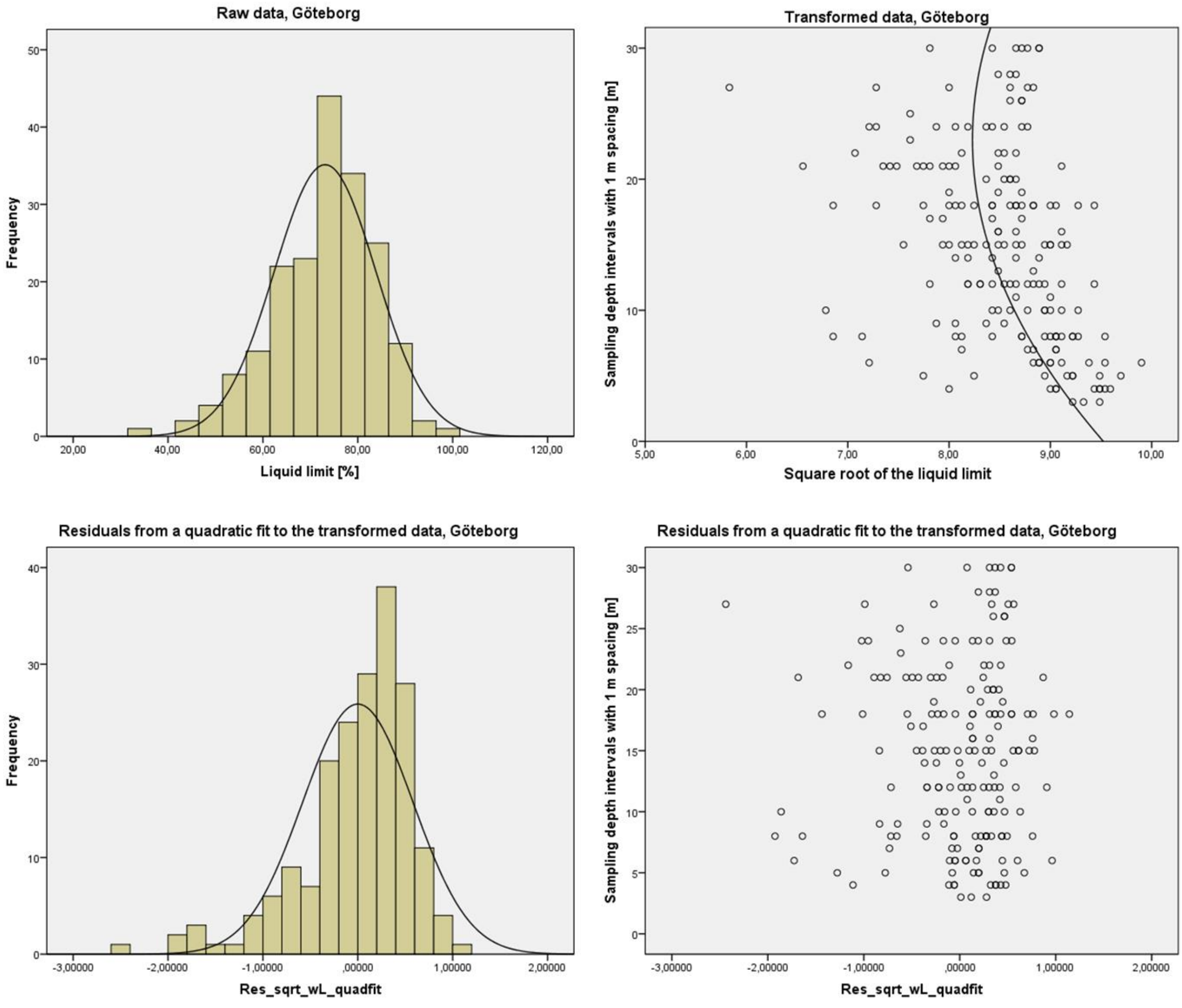
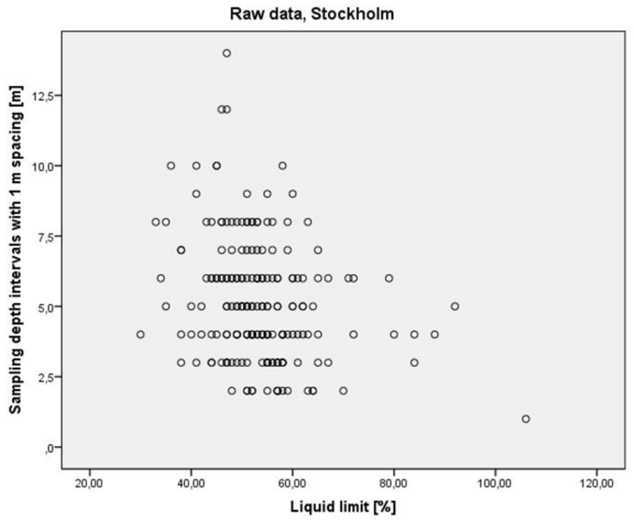


Figure 51: The transformation and normalization of the liquid limit, Göteborg.

5.1.29 Liquid limit (w_L), Stockholm

The scatter plot of the raw data shows the relationship between w_L and the sampling depth, see Figure 52. The histogram of the raw data shows that w_L is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.080. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.624.



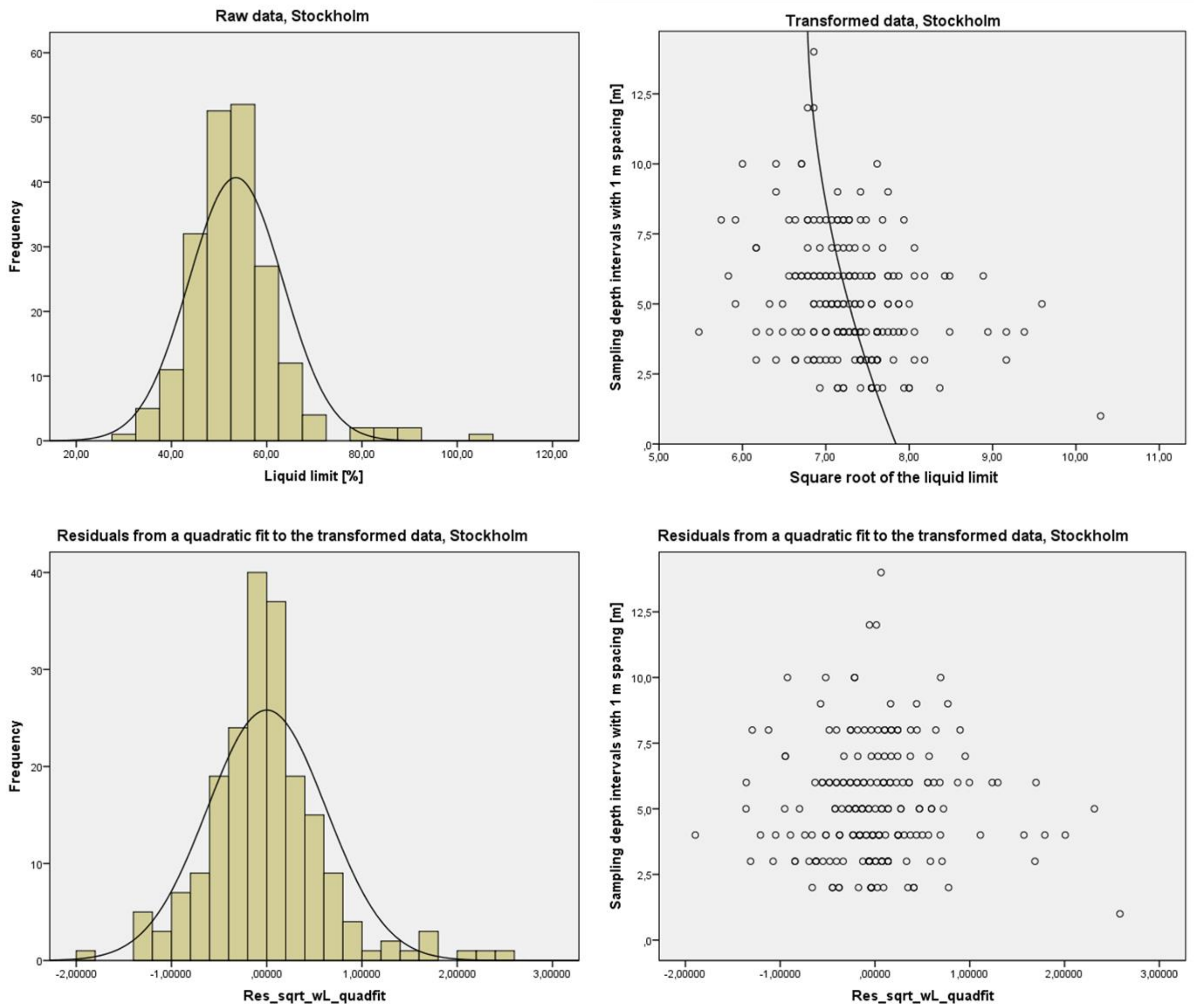
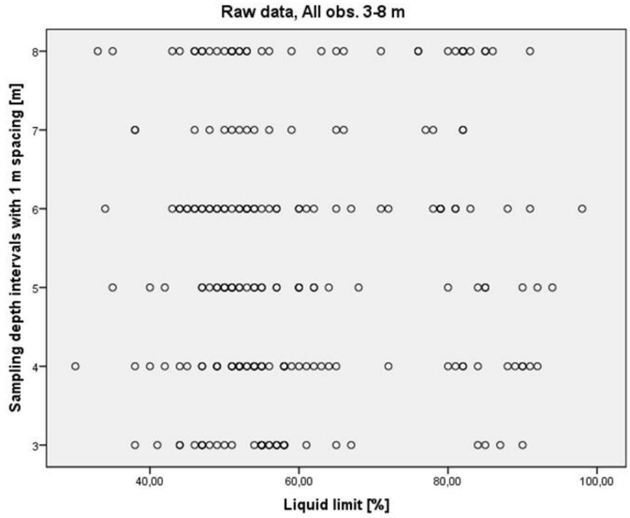


Figure 52: The transformation and normalization of the liquid limit, Stockholm.

5.1.30 Liquid limit (w_L), All observations from 3- 8 m

The scatter plot of the raw data shows the relationship between w_L and the sampling depth, see Figure 53. The histogram of the raw data shows that w_L is not entirely normally distributed. The quadratic regression curve fitted to the scatter plot of the transformed data against depth has an R^2 of 0.003. The histogram of the residuals from the regression curve shows that they are a bit further from being normally distributed than the raw data. The scatter plot of the residuals shows that they are almost completely normalized against depth. The standard deviation of the residuals is 0.938.



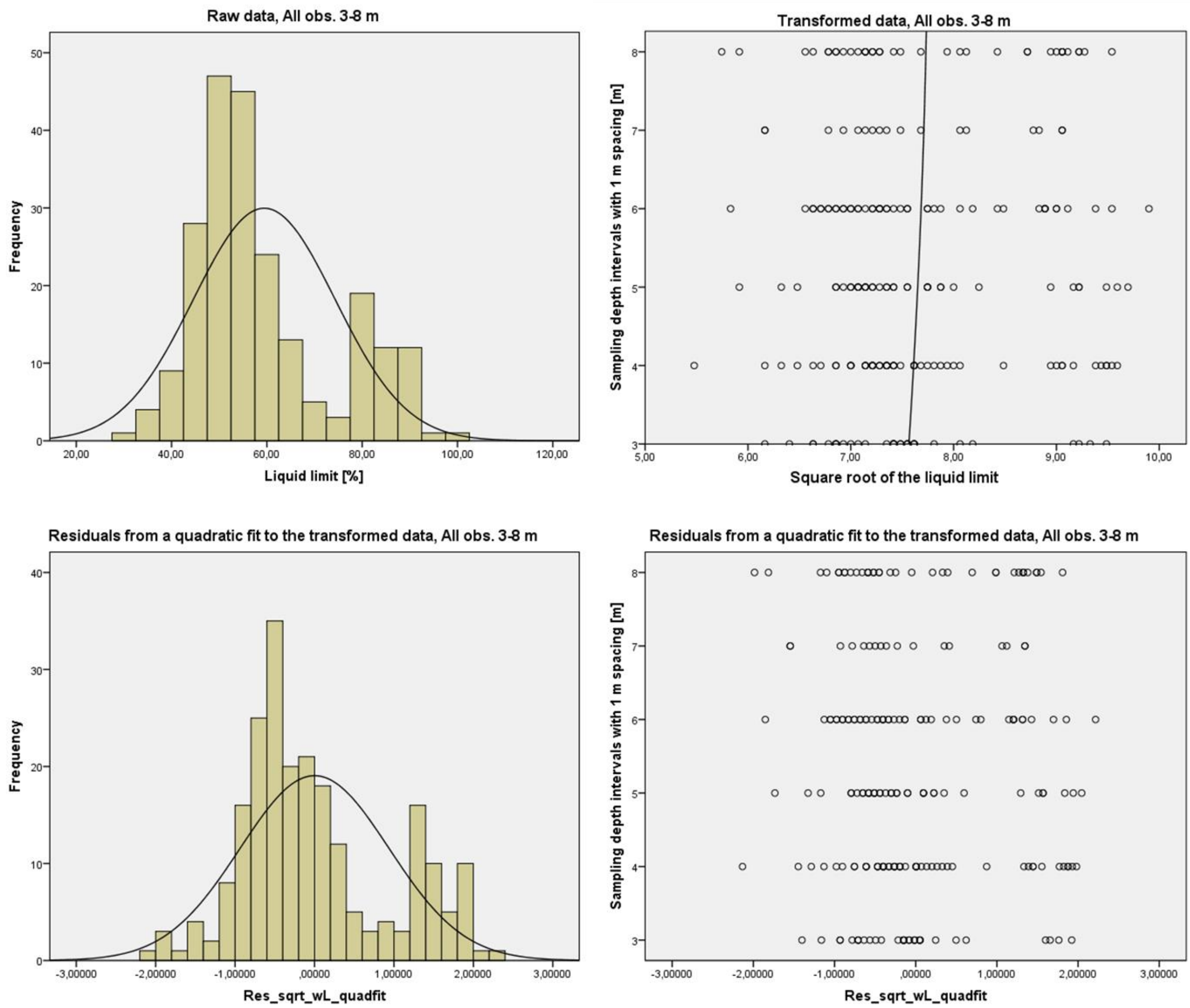


Figure 53: The transformation and normalization of the liquid limit, All obs. 3-8 meters.

5.2 Distribution of independent variables

In this chapter, the distribution of independent variables over the dependent variables is presented. The independent variables are displayed with boxplots against each dependent variable. This means that for one dependent variable there are six boxplots, one for each independent variable. All three data sets are presented in the same boxplot.

The boxplots should be read as follows: within the box, half of the data values are represented (Johnson, Probability and Statistics for Engineers, 2011). The line within the box represents the median and the lines out from the box are drawn to the maximum and minimum values. Outliers are represented as circles.

5.2.1 Boxplots representing the effective stress (σ'$_0$)

In Figure 54 the independent variable sampling depth is plotted against the residuals of $\sqrt{\sigma'_0}$ from a quadratic fit against the sampling depth. The data have a wide range over the residuals, and are more drawn towards depth between three and eight meters.

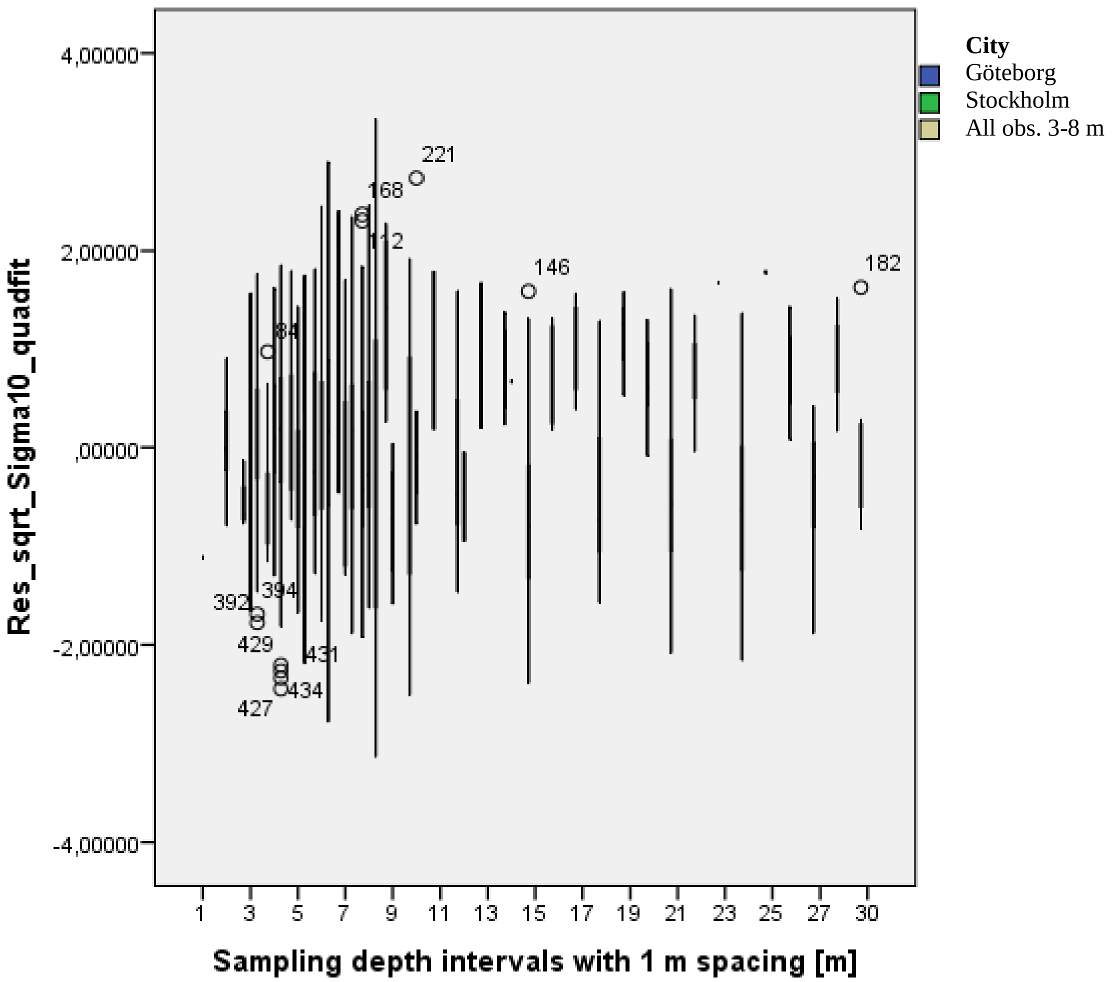


Figure 54: Boxplot showing the distribution of the variable representing the effective stress over the sampling depth.

Figure 55, on the next page, contains the boxplots for the independent variables Grade of urbanization, Soil type according to the geological map, Thickness of the soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. The distribution over the residuals of $\sqrt{\sigma'_0}$ from a quadratic fit against the sampling depth varies depending on which independent variable is observed. For some independent variables, such as Zone, there is not data from all of the three data sets, for each category.

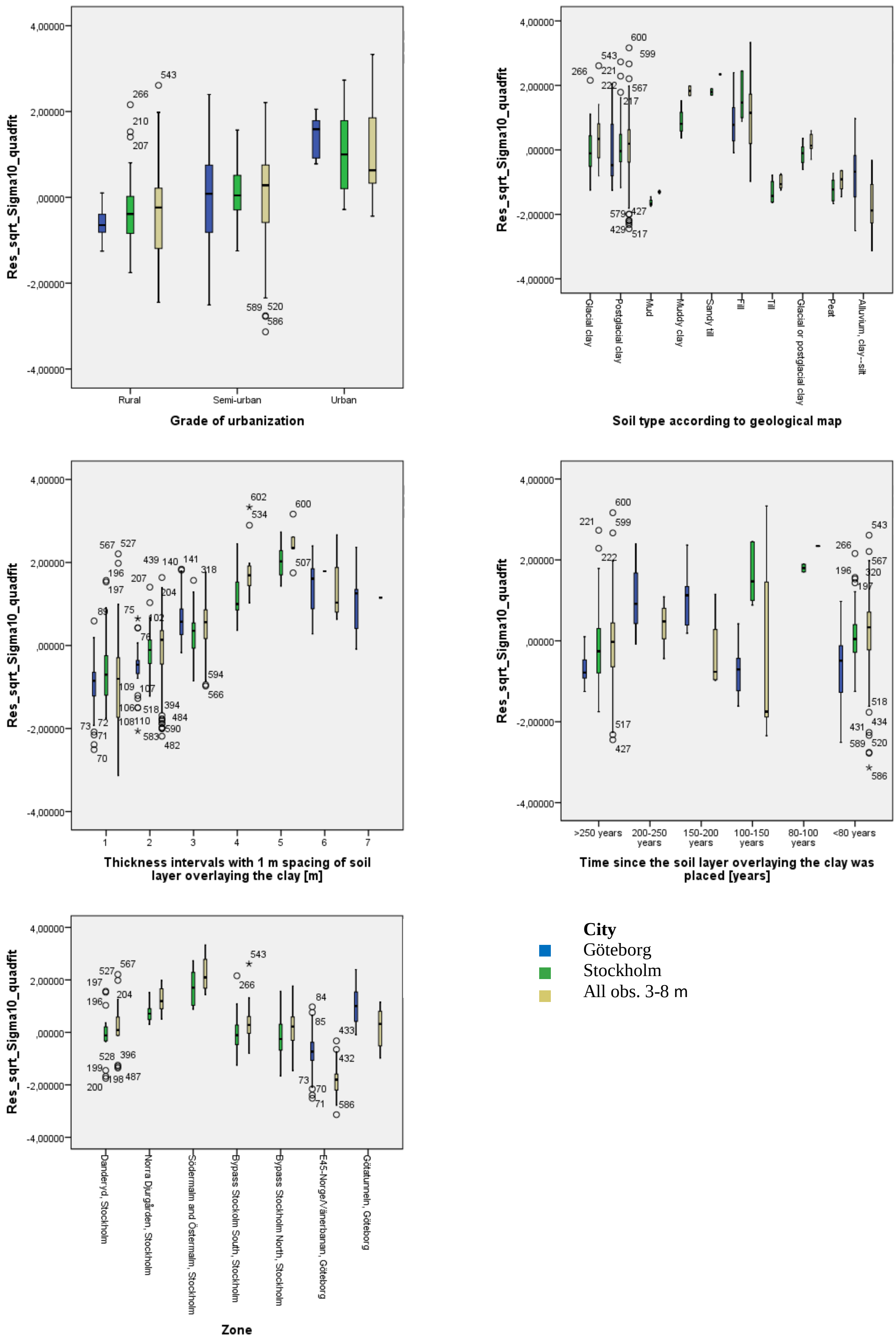


Figure 55: Boxplots showing the distribution of the variable representing the effective stress over the different independent variables.

5.2.2 Boxplots representing the preconsolidation stress (σ'_C)

In Figure 56 the independent variable depth is plot against the residual of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth. The data has a wide range over the residuals, and is more drawn towards depth between three and eight meters.

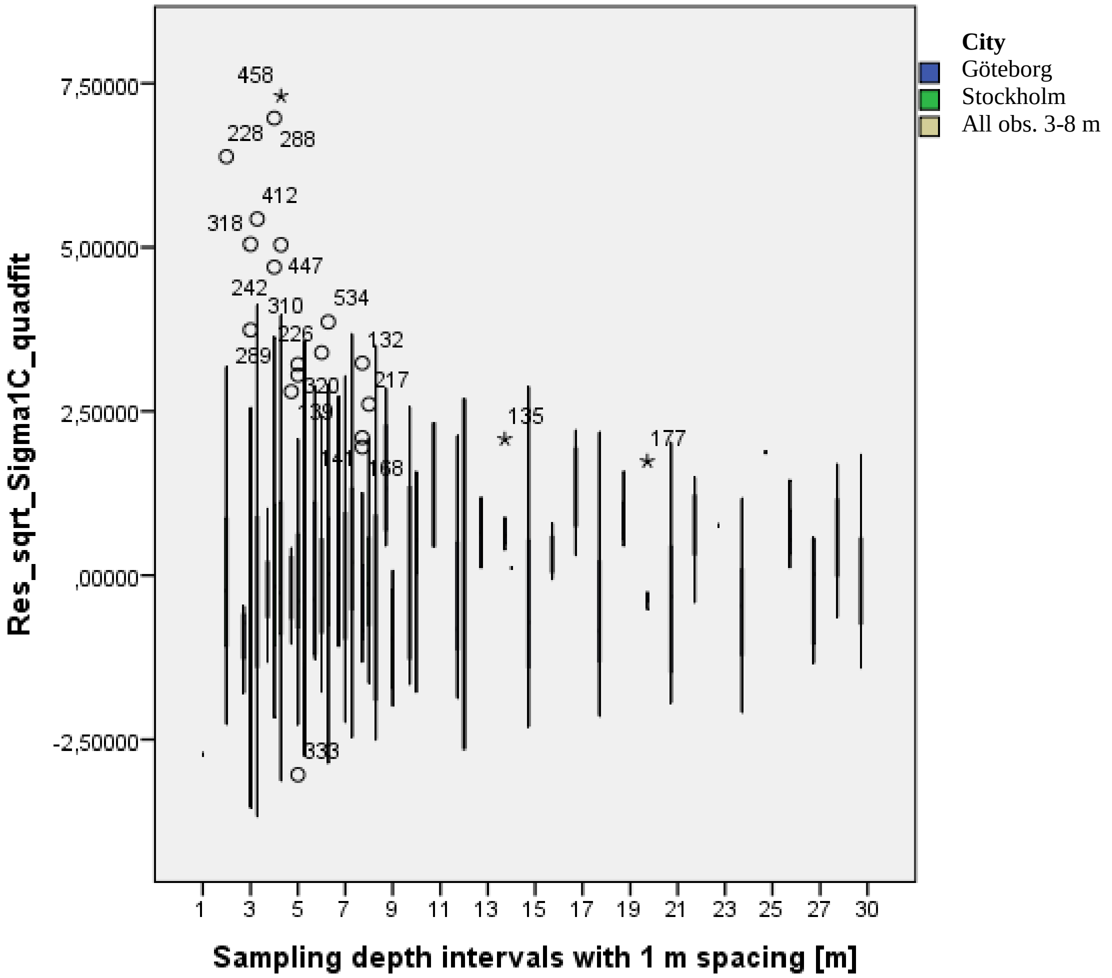


Figure 56: Boxplot showing the distribution of the variable representing the preconsolidation stress over the sampling depth.

Figure 57 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. For the independent variable Soil layer overlaying the clay, a trend of higher residuals values towards thicker soil layer overlaying the clay is seen.

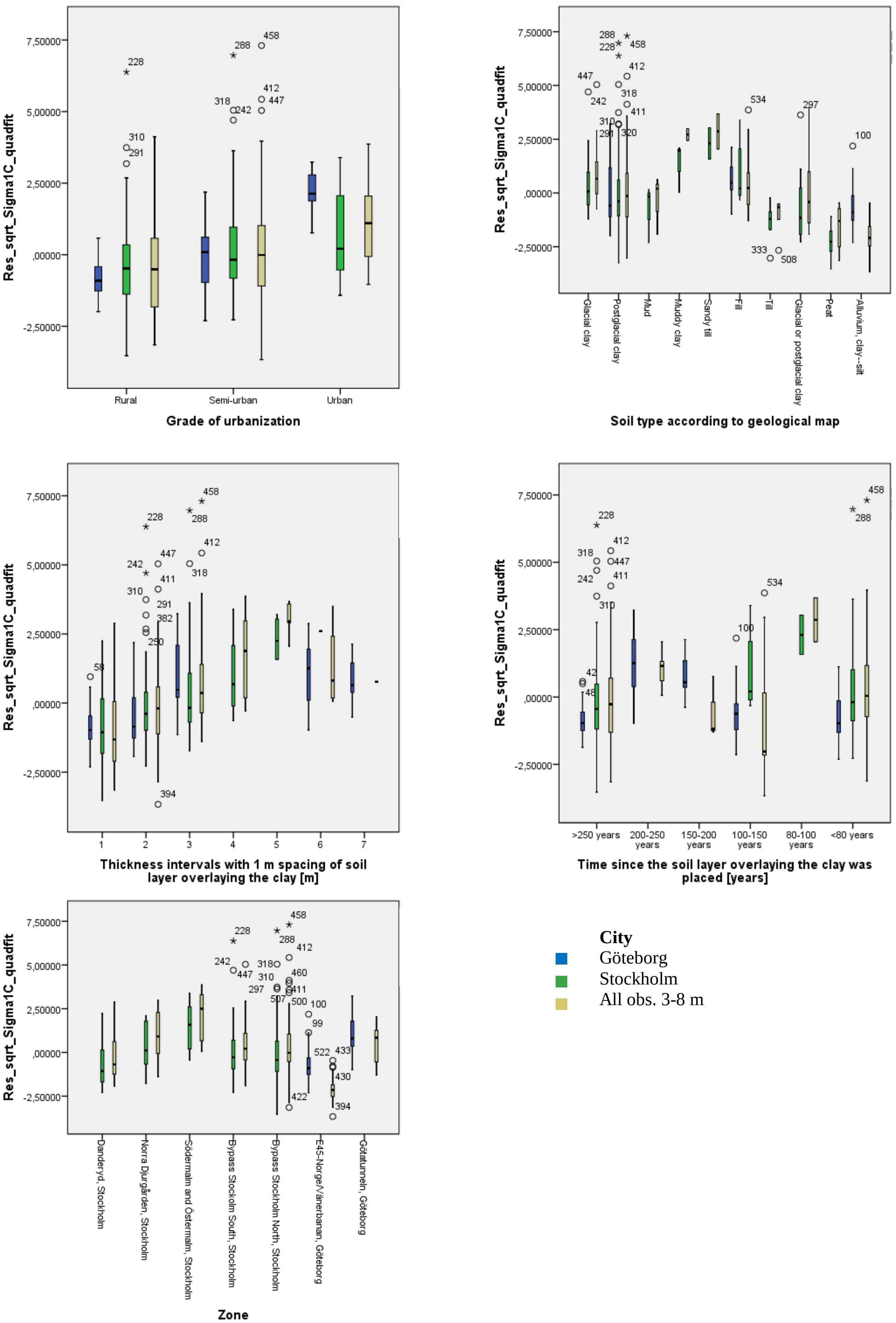


Figure 57: Boxplots showing the distribution of the variable representing the preconsolidation stress over the different independent variables.

5.2.3 Boxplots representing the limit stress (σ'$_L$)

In Figure 58 the independent variable depth is plot against the residual of $\sqrt{\sigma'_L}$ from a quadratic fit against the sampling depth. The data is more drawn towards depth between three and eight meters and the range for this depth is larger than for deeper depth.

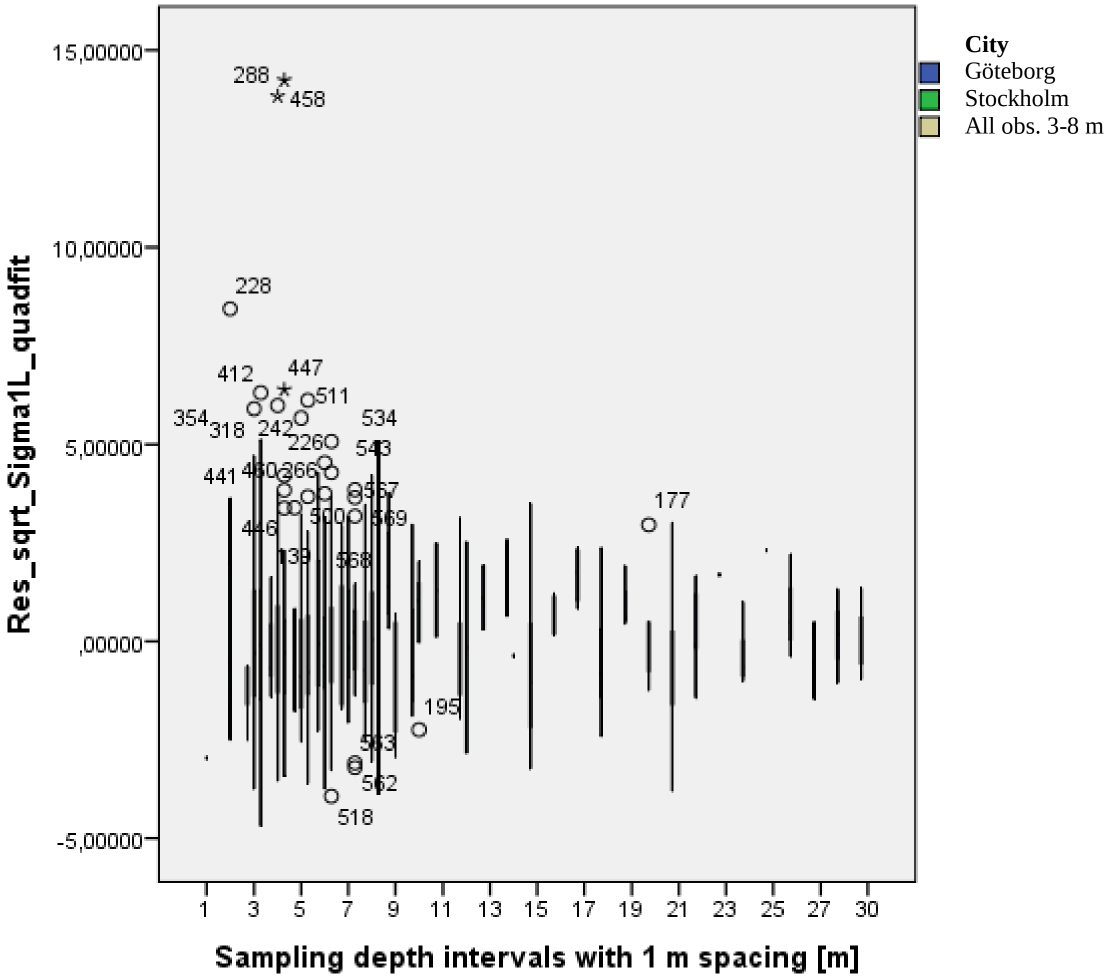


Figure 58: Boxplot showing the distribution of the variable representing the limit stress over the sampling depth.

Figure 59 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. For the independent variable Soil layer overlaying the clay, a trend of higher residuals towards thicker soil layer overlaying the clay is seen, as for the preconsolidation stress in the previously chapter.

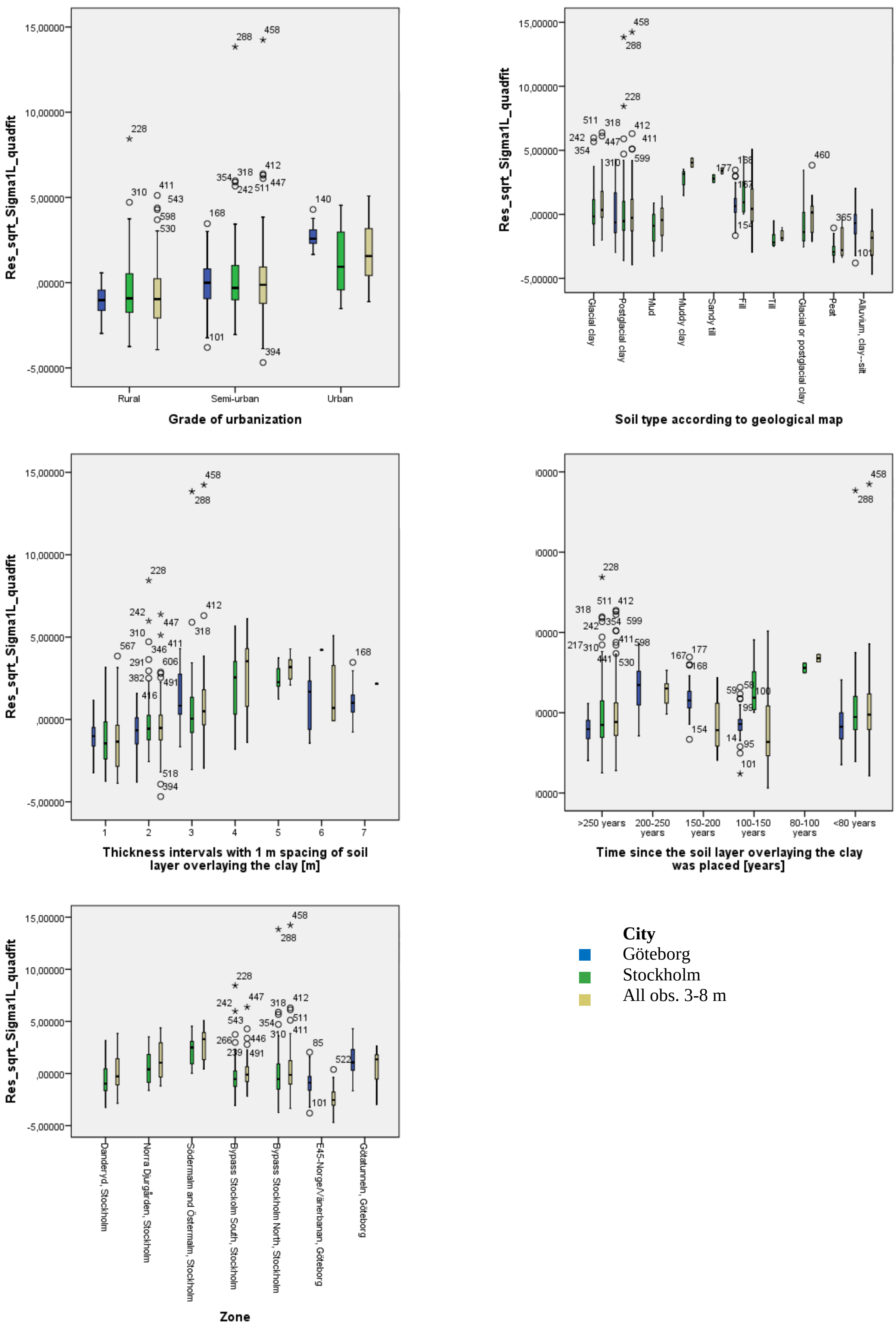


Figure 59: Boxplots showing the distribution of the variable representing the limit stress over the different independent variables.

5.2.4 Boxplots representing the compression modulus M_L

In Figure 60 the independent variable depth is plot against the residual of $\sqrt{M_L}$ from a quadratic fit against the sampling depth. The data has a wide range over the residuals, for the depth between three and eight meters.

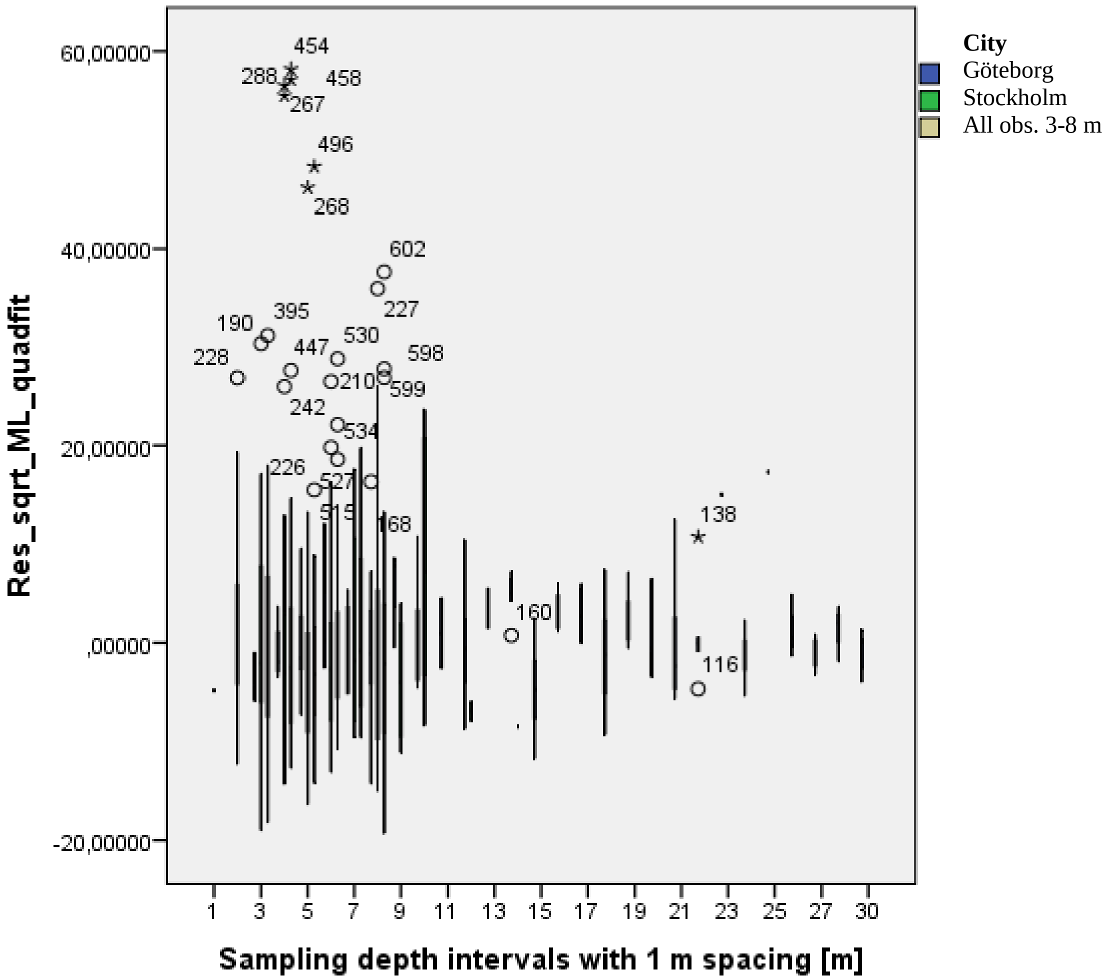


Figure 60: Boxplot showing the distribution of the variable representing M_L over the sampling depth.

Figure 61 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. For the independent variable Soil layer overlaying the clay, a trend of higher residuals values towards thicker soil layer overlaying the clay is seen, as for the preconsolidation stress in the previously chapters.

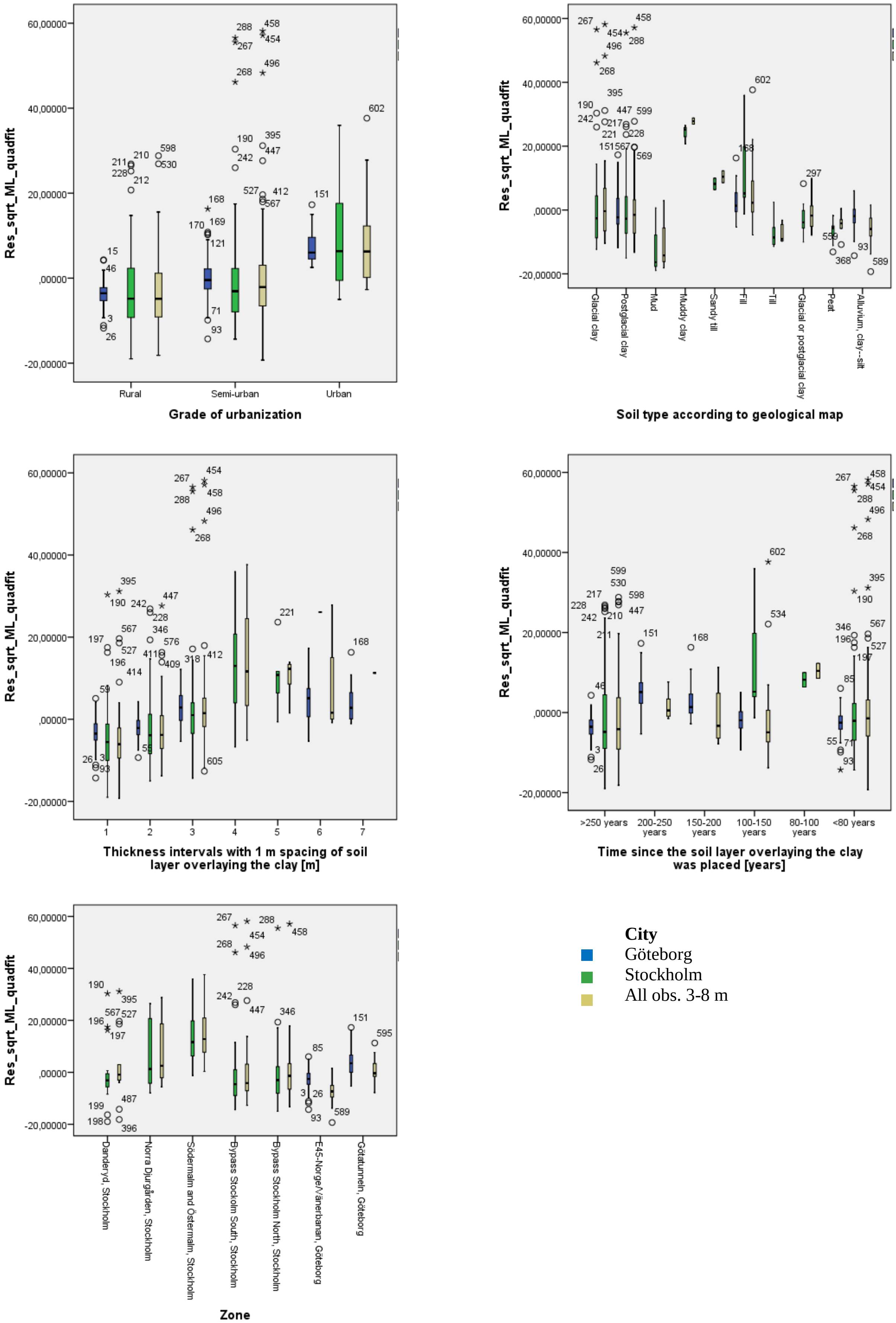


Figure 61: Boxplots showing the distribution of the variable representing the M_L over the different independent variables.

5.2.5 Boxplots representing the compression modulus M'

In Figure 62 the independent variable depth is plot against the residual of $\sqrt{M'}$ from a quadratic fit against the sampling depth. The data is more drawn towards depth between three and eight meters.

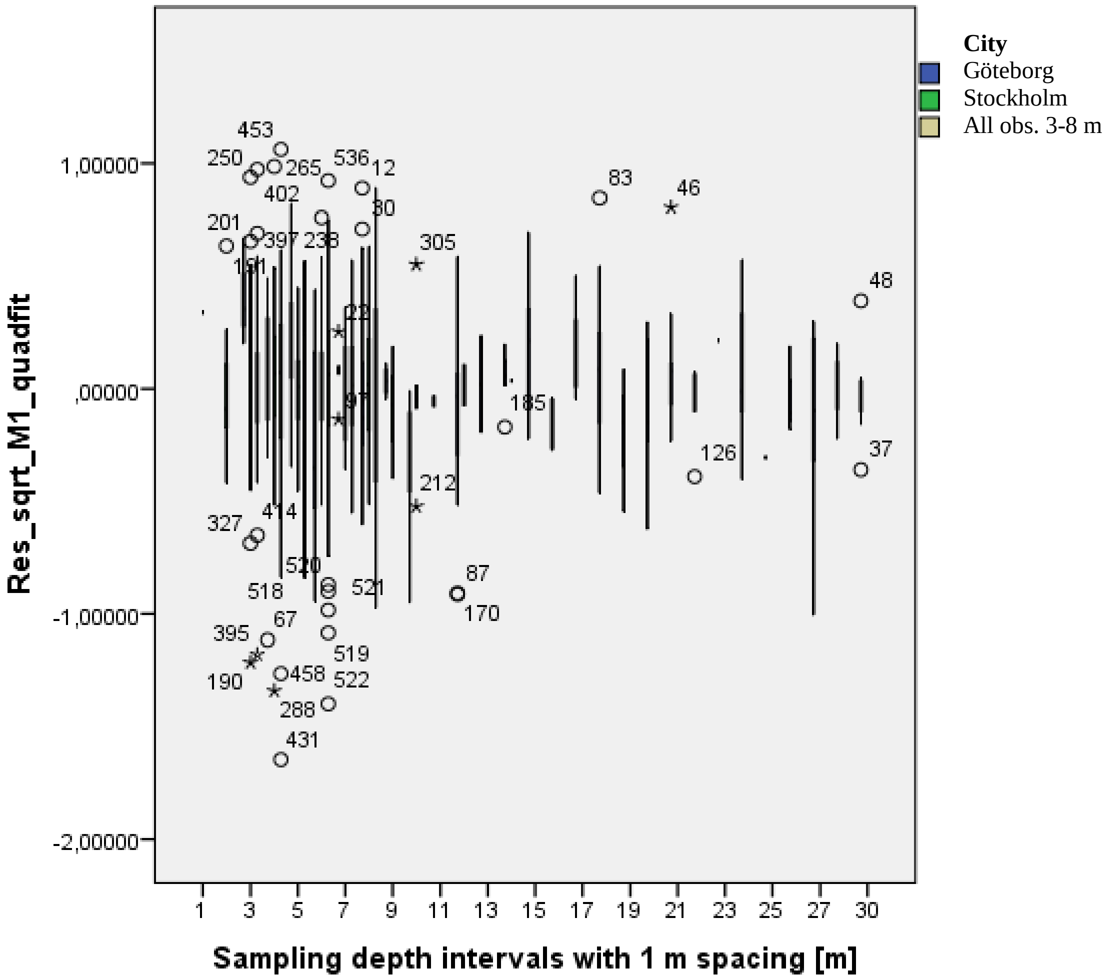


Figure 62: Boxplot showing the distribution of the variable representing M' over the sampling depth.

Figure 63 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. For the five variables there is no trend, and the boxes have values near the values around zero.

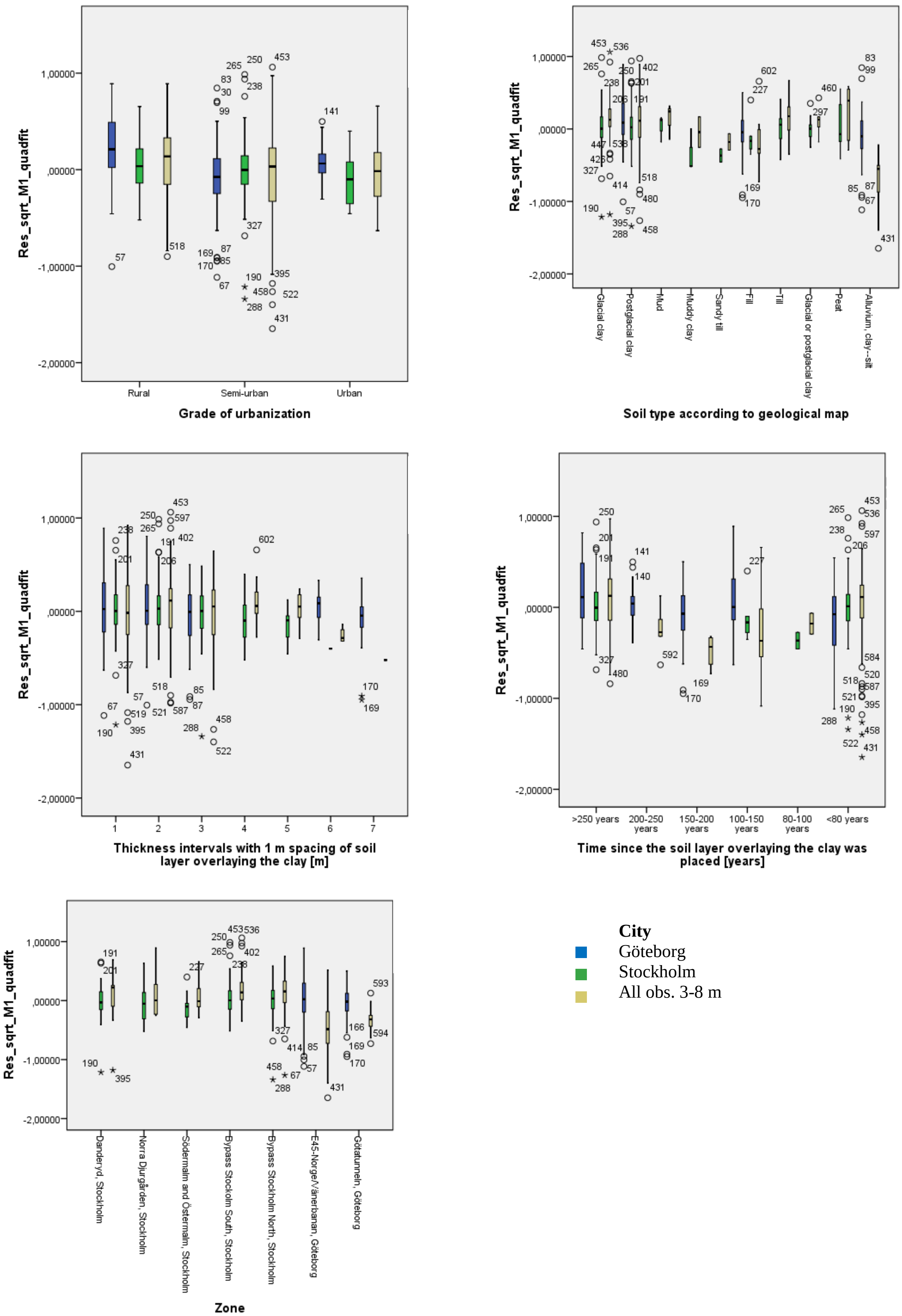


Figure 63: Boxplots showing the distribution of the variable representing the M' over the different independent variables.

5.2.6 Boxplots representing OCR

In Figure 64 the independent variable depth is plot against the residual of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth. The data has a wide range over the residuals for the All observation from 3-8 meters, and is more drawn towards depth between three and eight meters.

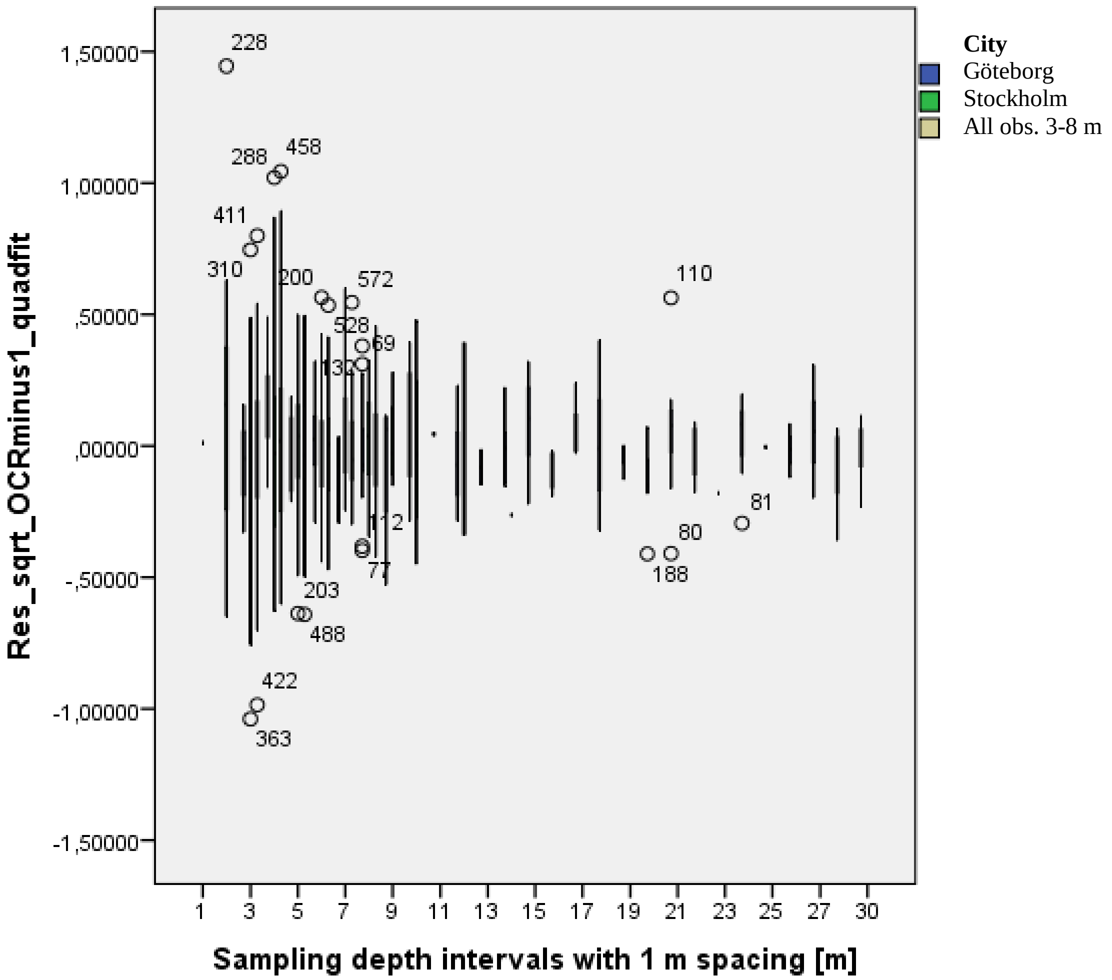


Figure 64: Boxplot showing the distribution of the variable representing OCR over the sampling depth.

Figure 65 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. As for the Compression modulus M', the independent data against the residual of $\sqrt{OCR-1}$ has no trends.

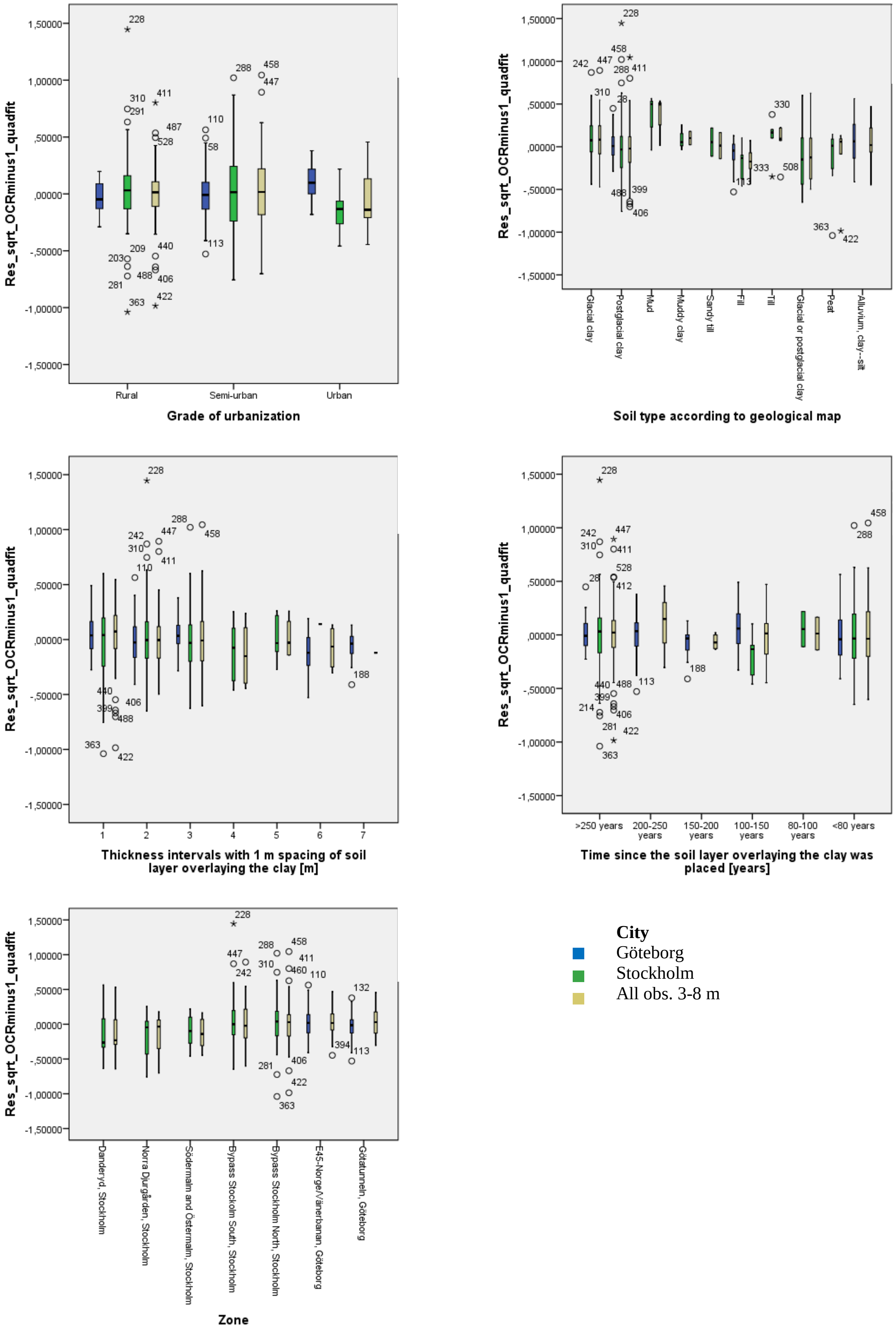


Figure 65: Boxplots showing the distribution of the variable representing the OCR over the different independent variables.

5.2.7 Boxplots representing CLR

In Figure 66 the independent variable depth is plot against the residual of $\sqrt{CLR-1}$ from a quadratic fit against the sampling depth. The data is more drawn towards depth between three and eight meters. The data is more drawn towards depth between three and eight meters.

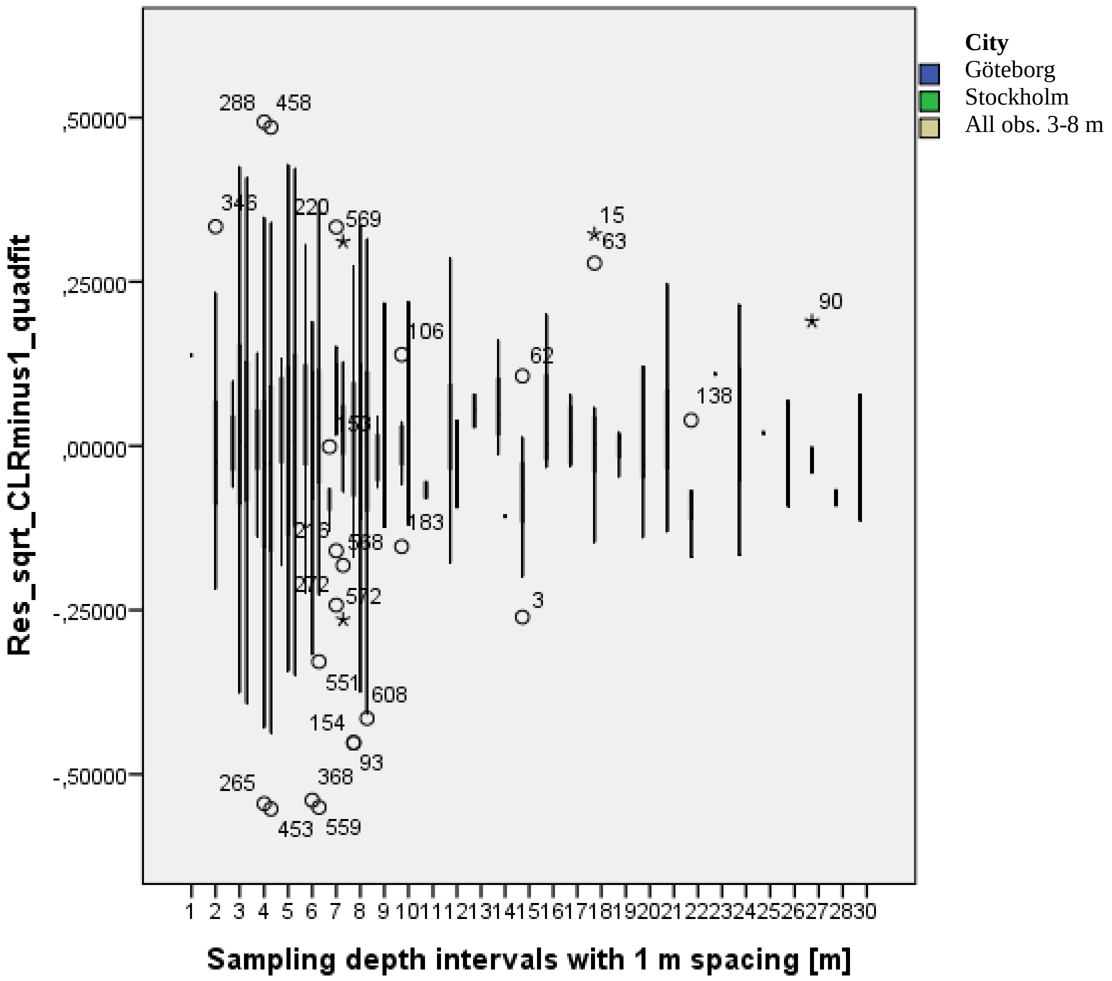


Figure 66: Boxplot showing the distribution of the variable representing CLR over the sampling depth.

Figure 67 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. As for the Compression modulus M' and OCR, the independent data against the residual of $\sqrt{CLR-1}$ has no trends.

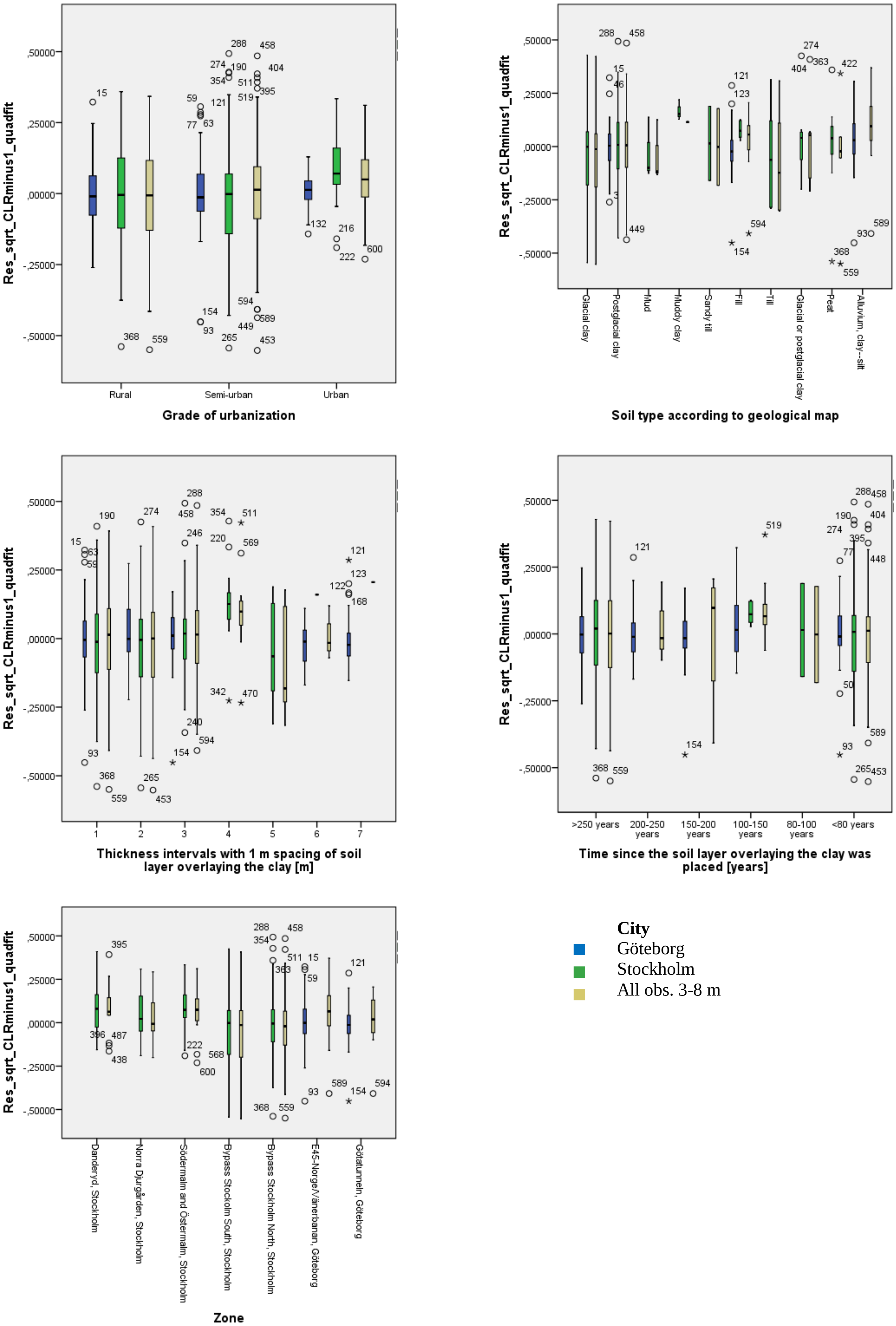


Figure 67: Boxplots showing the distribution of the variable representing the CLR over the different independent variables.

5.2.8 Boxplots representing the density (ρ)

In Figure 68 the independent variable depth is plot against the residual of $\sqrt{Density}$ from a quadratic fit against the sampling depth. The data is more drawn towards depth between three and eight meters. The range for this depth is larger than for deep depth.

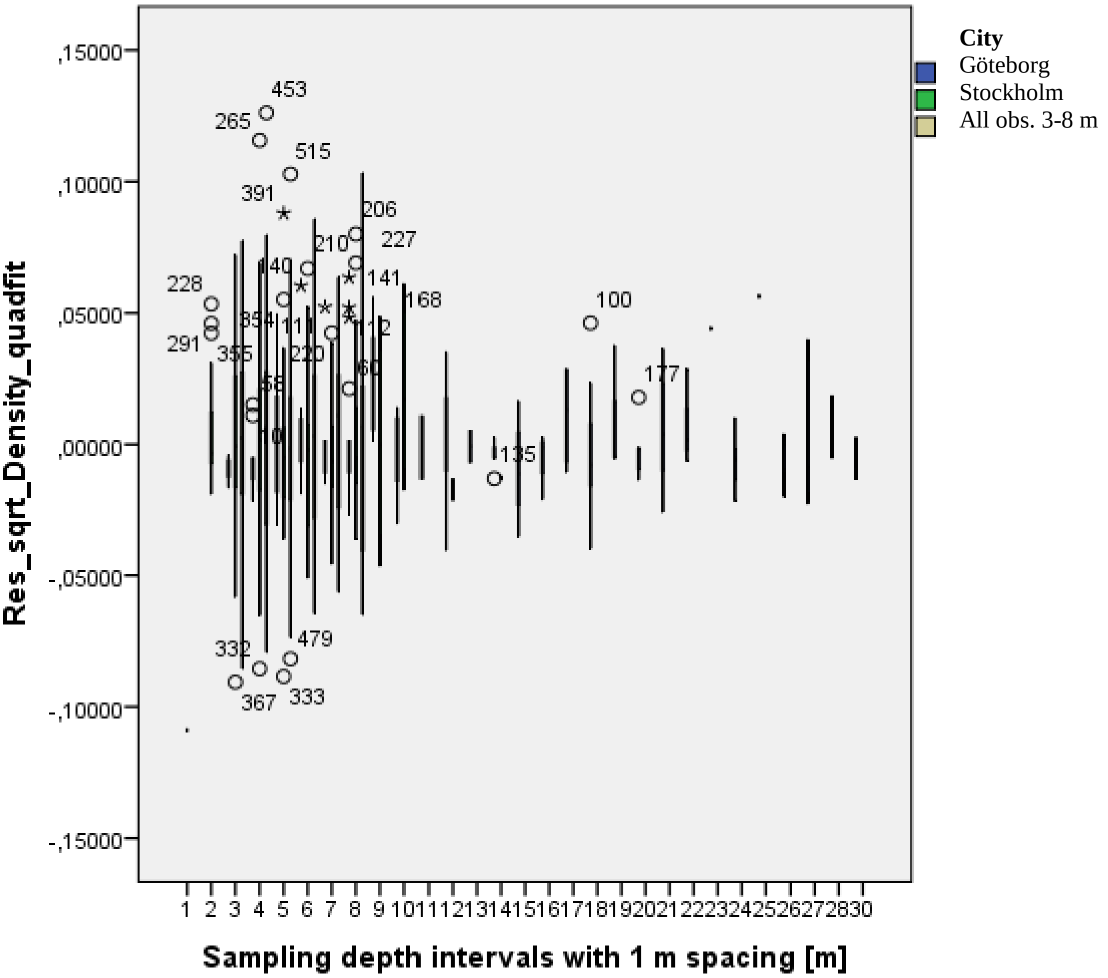


Figure 68: Boxplot showing the distribution of the variable representing the density over the sampling depth.

Figure 69 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. For the independent variable Soil layer overlaying the clay, a trend of higher residuals values towards thicker soil layer overlaying the clay is seen, as for the preconsolidation stress in the previously chapters.

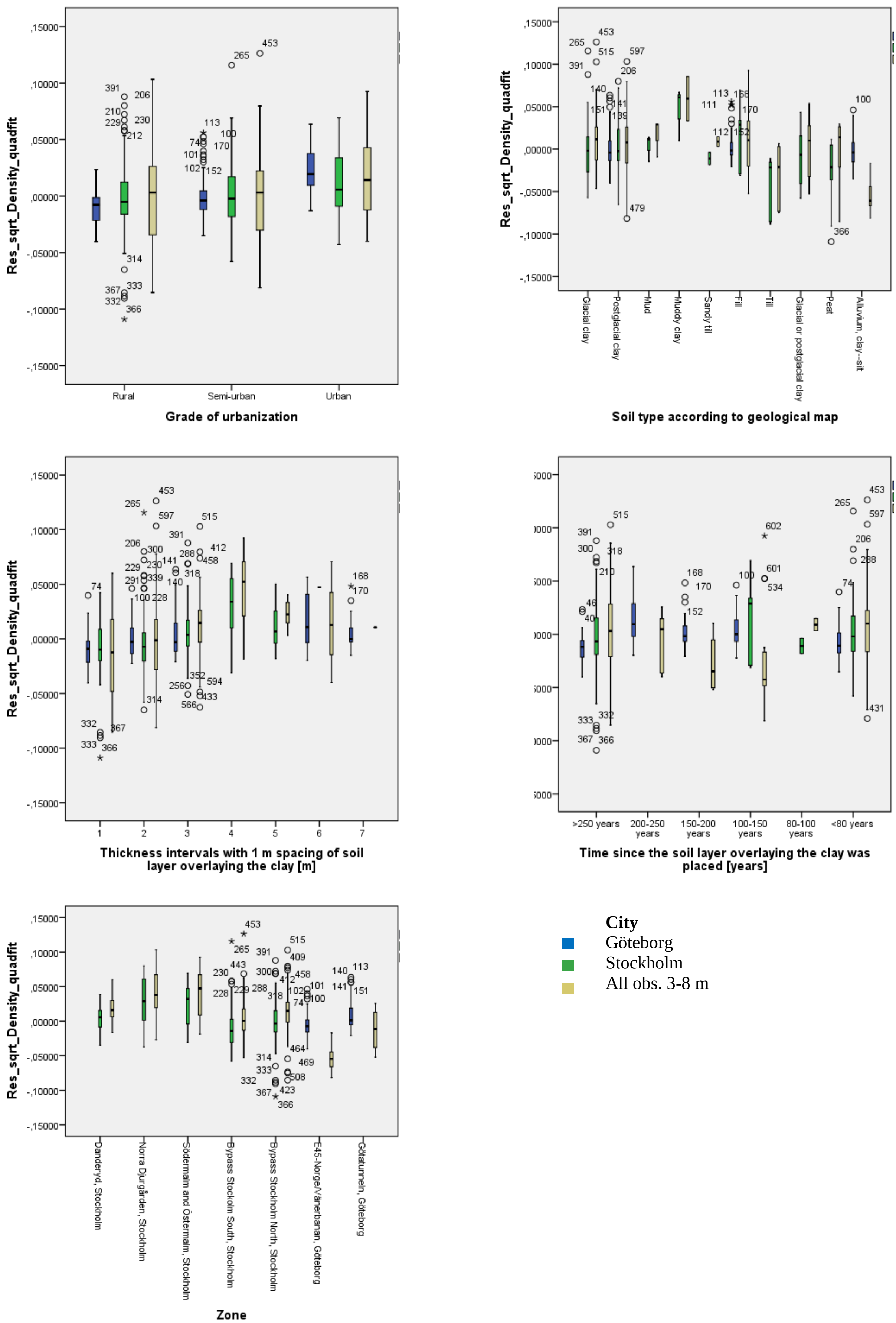


Figure 69: Boxplots showing the distribution of the variable representing the density over the different independent variables.

5.2.9 Boxplots representing the water content (w)

In Figure 70 the independent variable depth is plot against the residual of $\sqrt{w}$ from a quadratic fit against the sampling depth. The data is more drawn towards depth between three and eight meters. The range for this depth is larger than for deep depth.

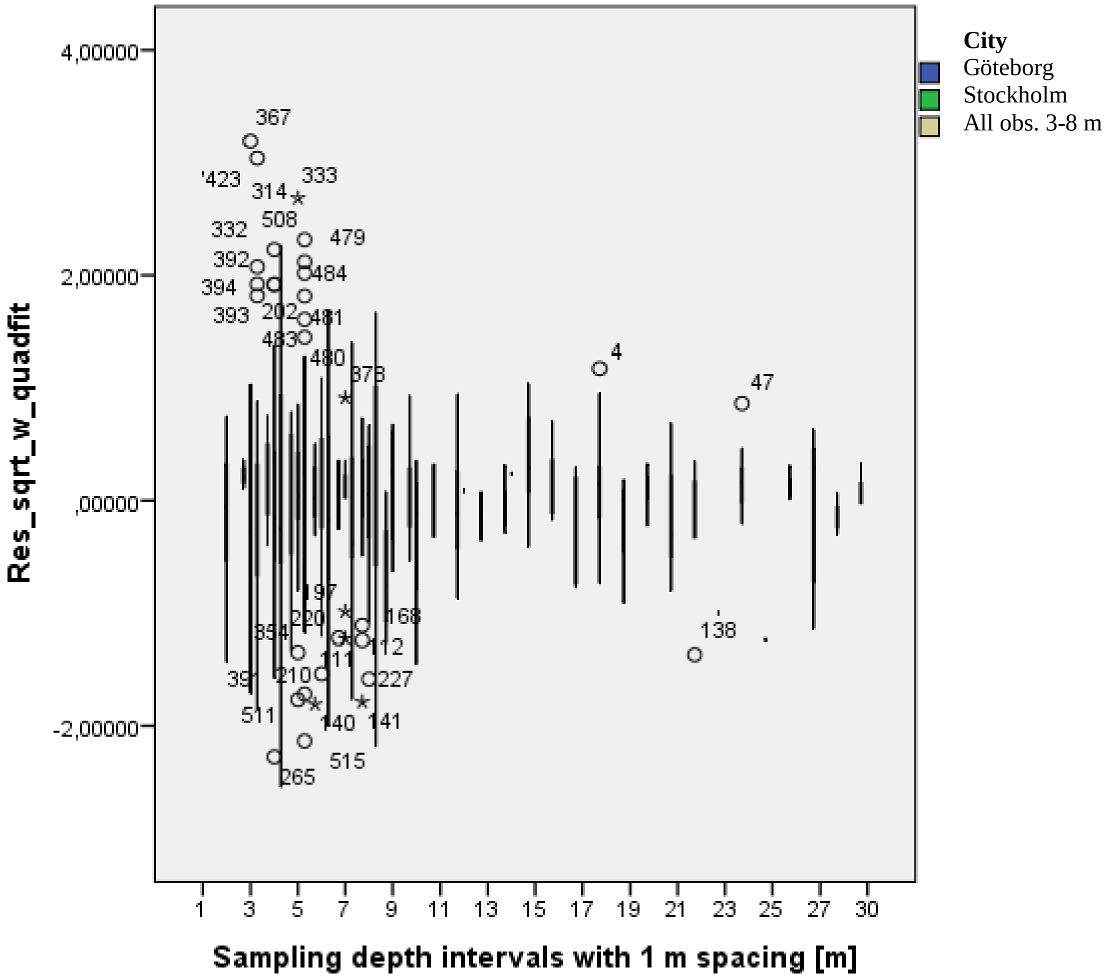


Figure 70: Boxplot showing the distribution of the variable representing the water content over the sampling depth.

Figure 71 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. For the independent variable Grade of urbanization, a trend of lower residuals values towards urbanization is seen.

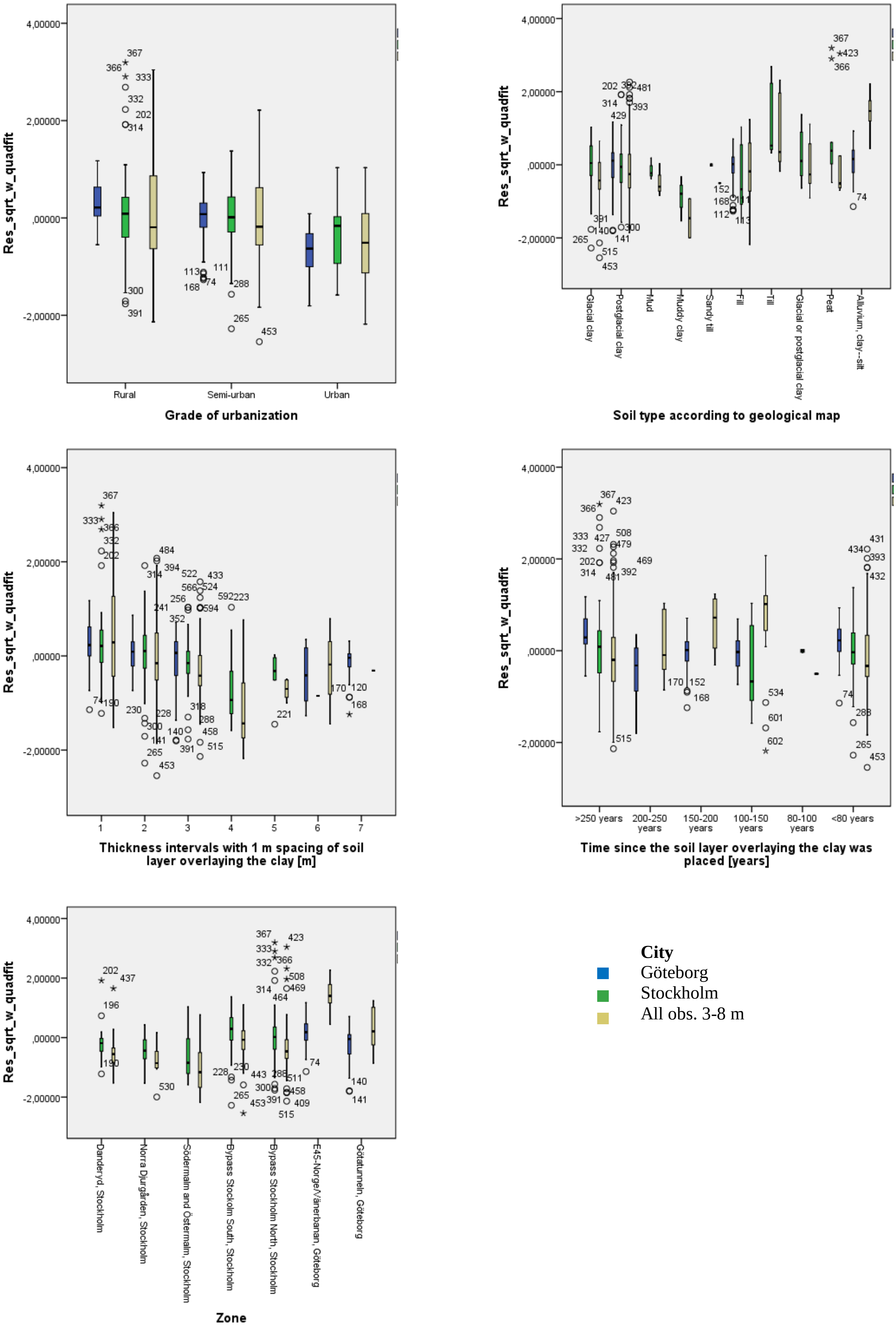


Figure 71: Boxplots showing the distribution of the variable representing the water content over the different independent variables.

5.2.10 Boxplots representing the liquid limit (w_L)

In Figure 72 the independent variable depth is plot against the residual of $\sqrt{w_L}$ from a quadratic fit against the sampling depth.

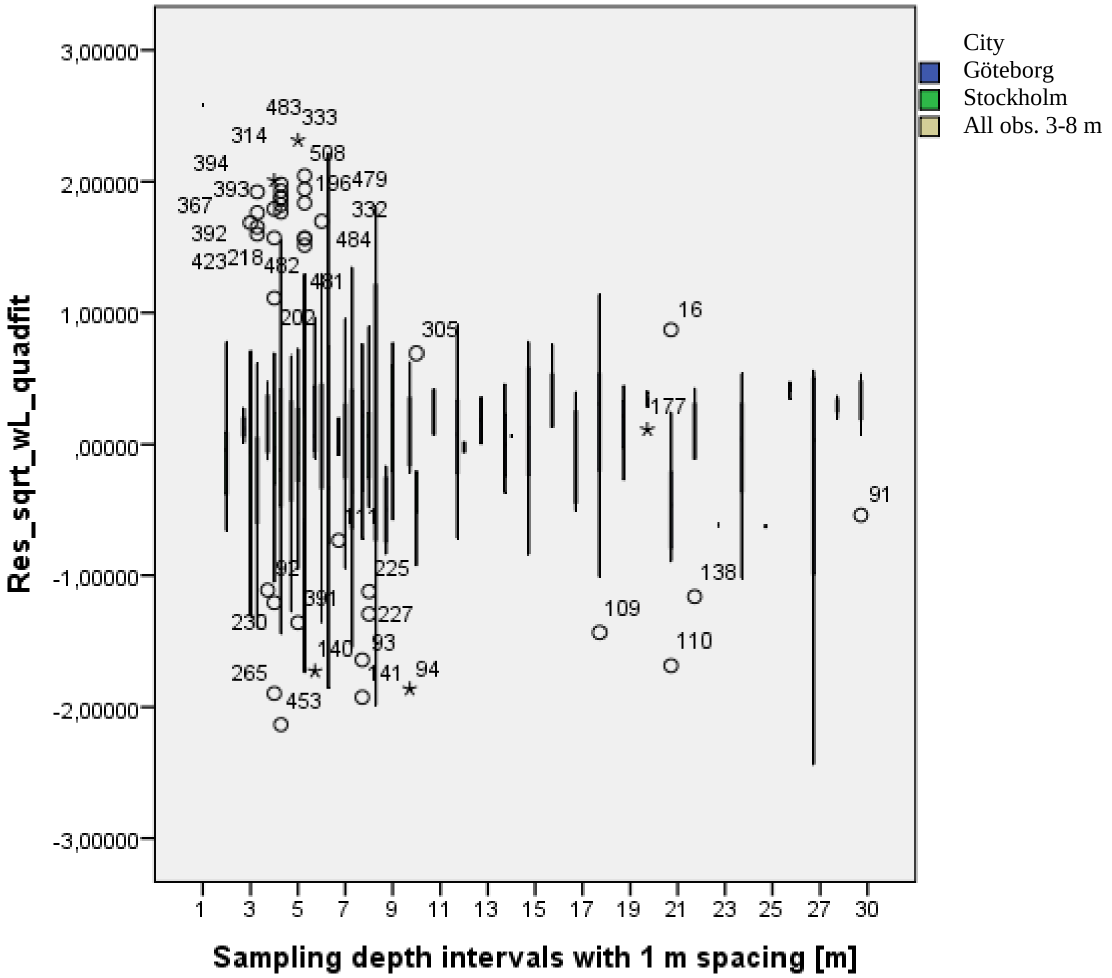


Figure 72: Boxplot showing the distribution of the variable representing the liquid limit over the sampling depth.

Figure 73 on the next page contains the boxplots for the independent variables Grade of urbanization, Soil type according to geological map, Thickness of soil layer overlaying the clay, Time since the soil layer overlaying the clay was placed and Zone. No trends for the independent variables can be seen.

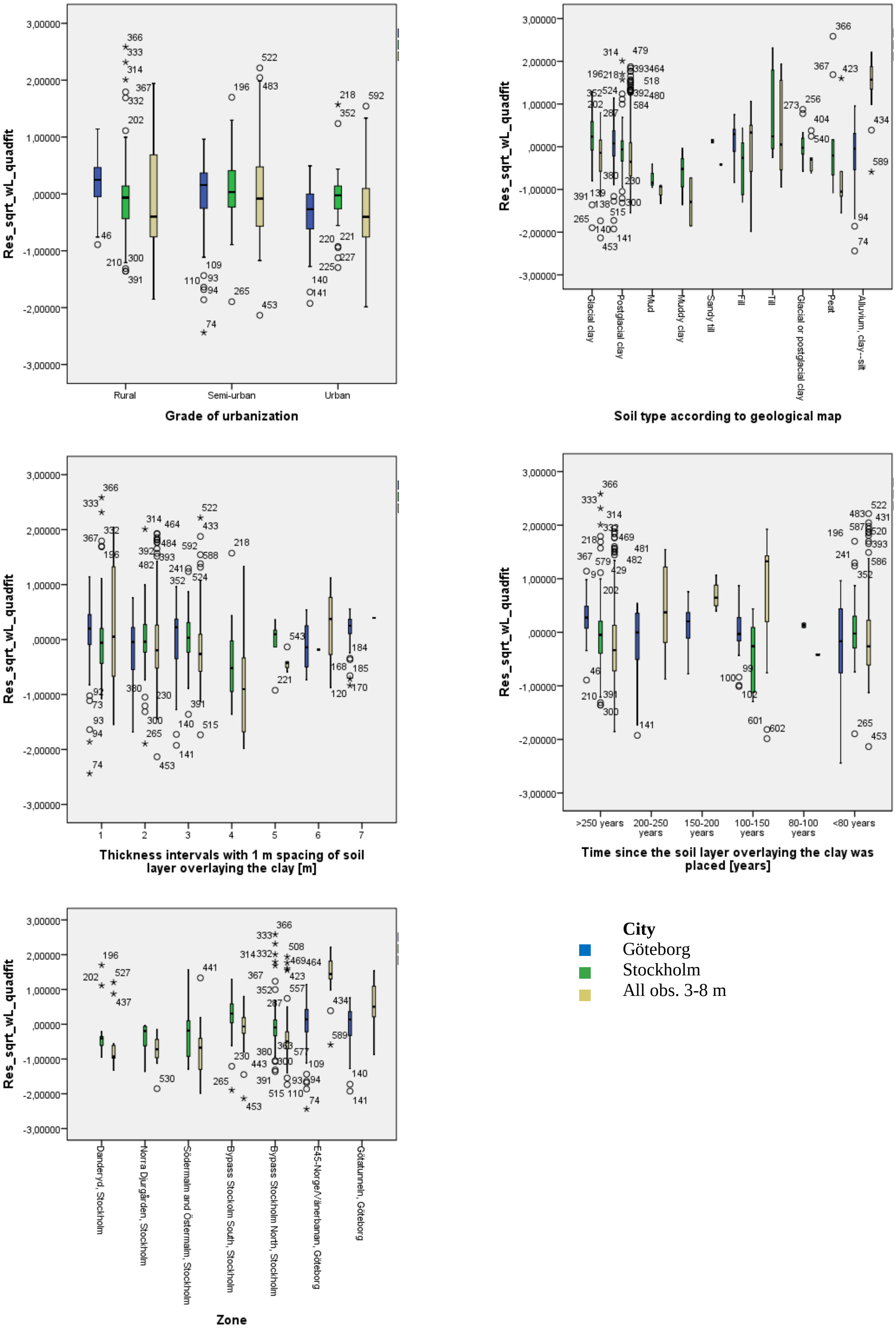


Figure 73: Boxplots showing the distribution of the variable representing the liquid limit over the different independent variables.

6 Results

In this chapter, the results from all statistical analyses and the sensitivity analysis are presented. For each clay parameter, results are presented for the three data sets; Göteborg, Stockholm and All observations from 3-8 meters. The result from a one-way ANOVA is always presented followed by the result from a full-factorial ANOVA, just including main effects showing an *F*-factor higher than one in the one-way ANOVA. In some cases, where not all main effects are significant in the full-factorial ANOVA, the result from a second full-factorial ANOVA excluding the insignificant factors is presented. For factors that have zero degrees of freedom, results from independent groups *T*-tests are presented. All significant results from the full-factorial ANOVA and independent groups *T*-test are plotted and evaluated. A summary of all result is presented in Chapter 6.11. Finally the result from the sensitivity analysis is presented in Chapter 6.12.

To make the results easier to read, only a small part of the total output from SPSS is presented here. From the one-way ANOVA, only the *F*-factors are presented and from the full-factorial ANOVA, the *F*-factors and *p*-values are presented since it is these values that are used to determine how the analysis is performed. The complete outputs from the analysis given from SPSS are presented in Appendix B.

6.1 Effective stress (σ'_0)

In this chapter, the results concerning the effective stress are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.1.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 3. For the complete output from this one-way ANOVA, see Appendix B. page 1.

Table 3: One-way ANOVA, effective stress, Göteborg.

Source	F
Corrected Model	22,638
Intercept	30,613
Depth_INT	2,500
Urbanization	,001
Soil_type_map	3,672
Overlaying_layer__INT	29,916
Time_overlying_layer	11,761

Full-factorial ANOVA

The full-factorial ANOVA is made with all variables since each of them show an *F*-factor higher than 1, see Table 4 for results. For the complete output from this full-factorial ANOVA, see Appendix B. page 2.

Table 4: Full-factorial ANOVA, effective stress, Göteborg.

Source	F	Sig.
Corrected Model	6,540	,000
Intercept	18,868	,000
Depth_INT	2,238	,016
Urbanization	,706	,407
Soil_type_map	.	.
Overlaying_layer__INT	13,393	,000
Time_overlying_layer	13,518	,000

A second full-factorial ANOVA is made carrying along only significant main factors from the first full-factorial ANOVA, see Table 5 for results. For the complete output from this second full-factorial ANOVA, see Appendix B. page 4.

Table 5: Second full-factorial ANOVA, effective stress, Göteborg.

Source	F	Sig.
Corrected Model	8,599	,000
Intercept	21,396	,000
Depth_INT	2,832	,001
Overlaying_layer__INT	16,281	,000
Time_overlying_layer	2,749	,037

The plots from all observations with significant main effects and interactions are presented underneath.

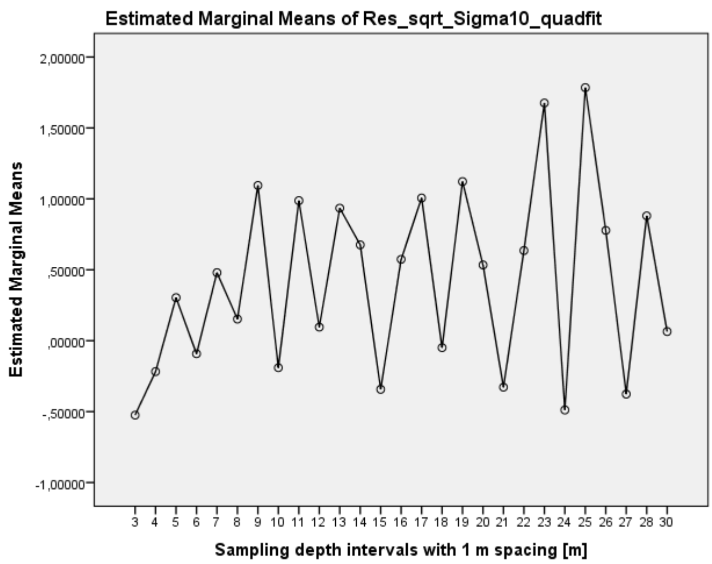


Figure 74: The main effect of Depth_INT on the effective stress in the data set Göteborg.

The value jumps up and down without any clear trend in Figure 74, which indicates that there is no relationship between the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth, and the sampling depth. This indicates that the normalization against depth successfully eliminated the intrinsic relationship between the parameter and the sampling depth.

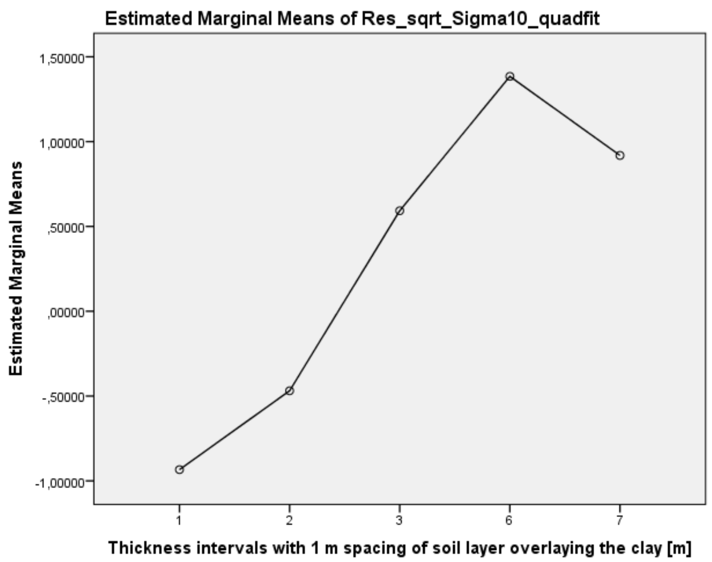


Figure 75: The main effect of Overlaying_layer_INT on the effective stress in the data set Göteborg.

The residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth follows a smooth trend against higher values toward thicker layers of soil overlaying the clay, as can be seen in Figure 75. However, there are no observations of thicknesses between 3 and 6 meters and there is an exception from the trend between a thickness of 6 and 7 meters. The amount of samplings for this interval is 52, therefore the exception from the trend cannot be explained by a few deviating observations. The result is reasonable since the effective stress is directly connected to the current load situation and thicker layers of soil overlaying the clay should result in higher effective stresses. The exception from the trend could be caused either by a generally lower density of the clay or overlaying soil or a generally higher pore water pressure in areas with an overlaying soil cover between 6 and 7 meters. This is, however, not evaluated within this investigation. Notable is that the mean thickness of the soil overlaying the clay is 0.92 meters in the zone E45-Norge/Vänerbanan and 5.05 meters in the zone Götatunneln. Therefore, it is reasonable to believe that it is in fact the difference between these two zones which is causing the clear grouping in this plot.

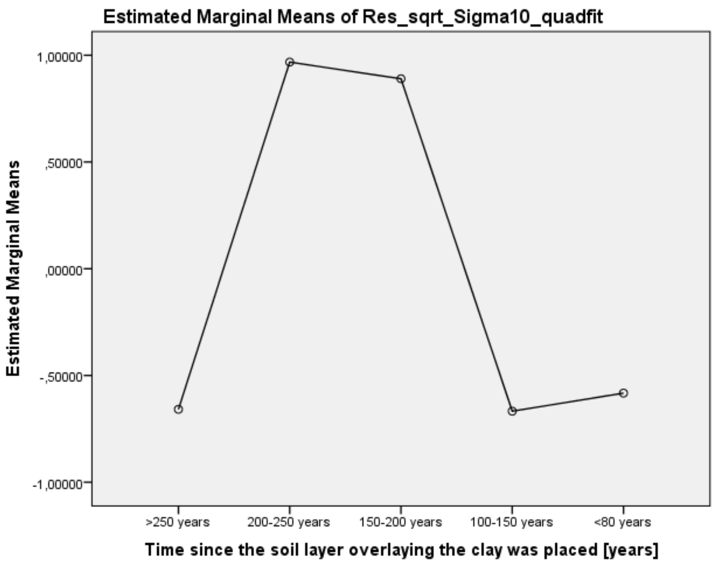


Figure 76: The main effect of Time_overlaying_layer on the effective stress in the data set Göteborg.

The plot in Figure 76 suggests that the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth have higher values for observations in areas where the soil layer overlaying the clay was placed between 150 and 250 years ago. The fact that the value dives for observations in areas where the overlaying soil has been there for 250 years or longer may be due to the fact that all observations in rural areas, that was never subjected to fill material, are sorted into this category. It is reasonable that the effective stresses are lower in these areas and since there are many observations in rural areas, these have a great effect on the estimated marginal mean. Had they been removed, the overall trend would probably have been that of higher values for the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth towards soil layers that was placed earlier in time. However, since σ_0' is evaluated from present conditions, it is not reasonable to believe that the time since the soil layer overlaying the clay was placed has any impact on this parameter. Any grouping or trend in the values may instead be dependent on a lurking variable. The categories 200-250 years and 150-200 years only contain observations from Götatunneln and the rest of the categories only contain observations from E45-Norge/Vänerbanan. The lurking variable seems to be the zone.

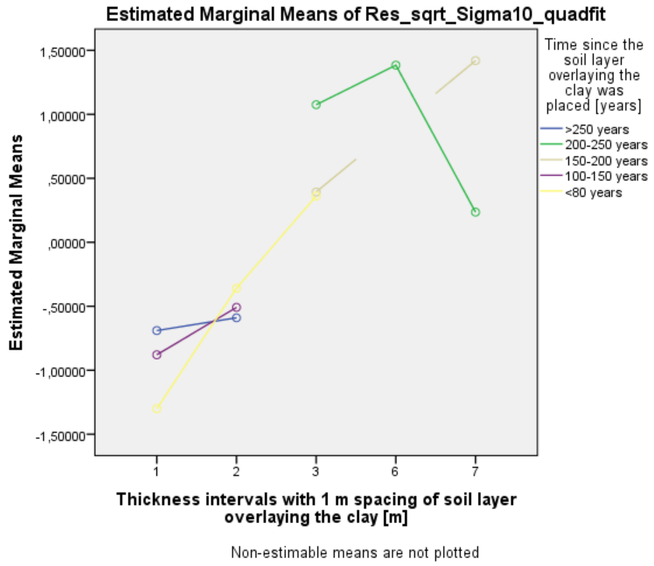


Figure 77: The interaction of Overlaying_layer_INT and Time_overlaying_layer on the effective stress in the data set Göteborg.

The plot in Figure 77 suggests that there is a trend against higher values for the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth towards higher values of the thickness of the soil layer overlaying the clay. On the other hand, there seems to be no clear connection to the time since this layer was placed. This is reasonable since the effective stress is directly connected to the current load situation and is not affected by the time since this load was placed. As mentioned in the previous result evaluations, it is likely the difference between the two specified zones within the Göteborg area which acts as a lurking variable in causing the grouping in this plot. The full-factorial ANOVA has an R^2 of 0.954, giving a good grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 6 and 7.

Table 6: Group Statistics, Zone, effective stress, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,7246840	,64590921	,06158503
Götatunneln, Göteborg	79	1,0090536	,65315097	,07348523

Table 7: Independent Groups T-test output, Zone, effective stress, Göteborg.

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	1,517	,220	-18,116	187	,000	-1,73373761	,09570295	-1,92253380	-1,54494143
Equal variances not assumed			-18,083	167,068	,000	-1,73373761	,09587906	-1,92302829	-1,54444694

The independent groups *T-test* shows that there is a significant difference in the mean values of the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area. Since the Levene's *p*-value (0.220) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 78.

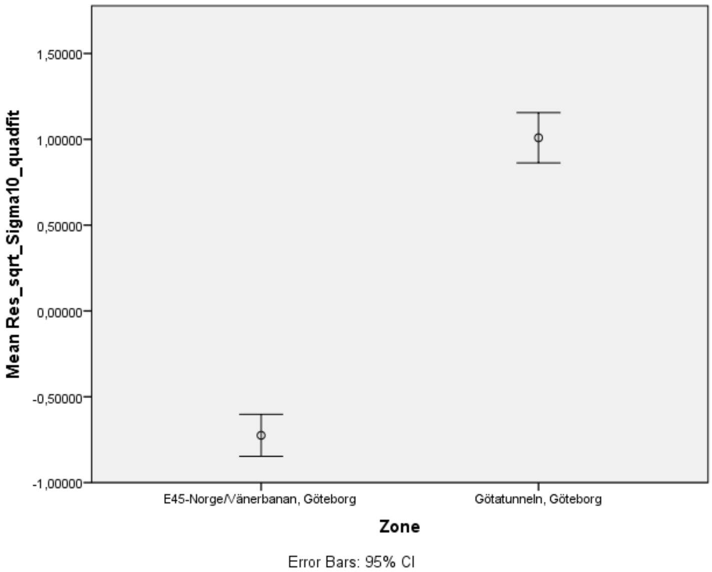


Figure 78: The effect of Zone on the effective stress in the data set Göteborg.

Figure 78 indicates that there is a relationship between the effective stress and the zones that were investigated, where values of σ_0' tend to be lower at E45-Norge/Vänerbanan than at Götatunneln. This could be a result of either higher loads from thicker layers of soil overlaying the clay, higher clay density, lower pore water pressure or a combination of them at the zone Götatunneln compared to the zone E45-Norge/Vänerbanan. Notable is that it is the same grouping of values as in all the previous results for this parameter and since these were hard to explain with the external factor investigated, it is reasonable to believe that it is in fact the difference between the two zones that is causing the grouping in all results.

6.1.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 8. For the complete output from this one-way ANOVA, see Appendix B. page 5.

Table 8: One-way ANOVA, effective stress, Stockholm.

Source	F
Corrected Model	25,433
Intercept	27,095
Depth_INT	7,570
Zone	21,864
Urbanization	5,774
Soil_type_map	7,649
Overlaying_layer__INT	34,739
Time_overlying_layer	,477

Full-factorial ANOVA

The full-factorial ANOVA is made with all variables except Time_overlaying_layer, since each of them show an *F*-factor higher than one, see Table 9 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 6.

Table 9: Full-factorial ANOVA, effective stress, Stockholm.

Source	F	Sig.
Corrected Model	5,522	,000
Intercep	47,243	,000
Depth_INT	4,065	,000
Zone	9,679	,000
Urbanization	1,813	,172
Soil_type_map	3,349	,006
Overlaying_layer__INT	5,309	,000

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 10 for result. For the complete output from the second full-factorial ANOVA, see Appendix B. page 8.

Table 10: Second full-factorial, effective stress, Stockholm.

Source	F	Sig.
Corrected Model	6,941	,000
Intercept	49,140	,000
Depth_INT	3,350	,001
Zone	16,154	,000
Soil_type_map	10,051	,000
Overlaying_layer__INT	19,881	,000
Depth_INT * Zone	1,006	,461

The plots from all observations with significant main effects or interactions are presented below.

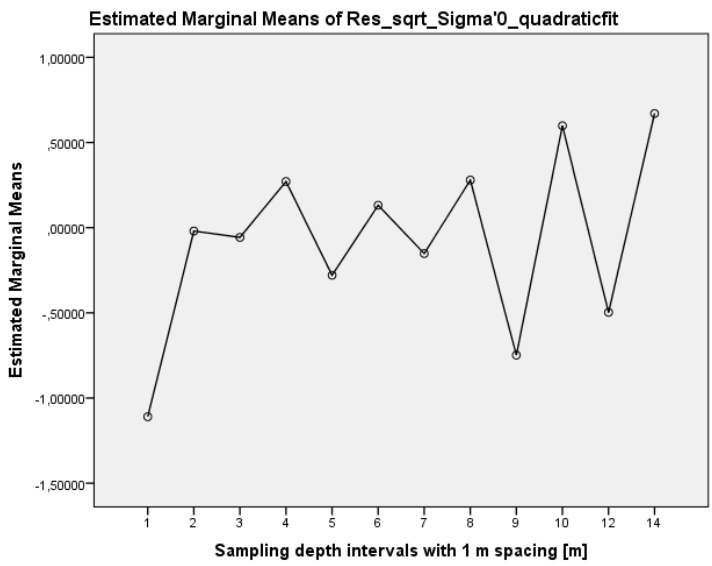


Figure 79: The main effect of Depth_INT on the effective stress in the data set Stockholm.

The value jumps up and down without any clear trend in Figure 79, which indicates that there is no relationship between the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth, and the sampling depth. This indicates that the normalization against depth successfully eliminated the intrinsic relationship between the parameter and the sampling depth.

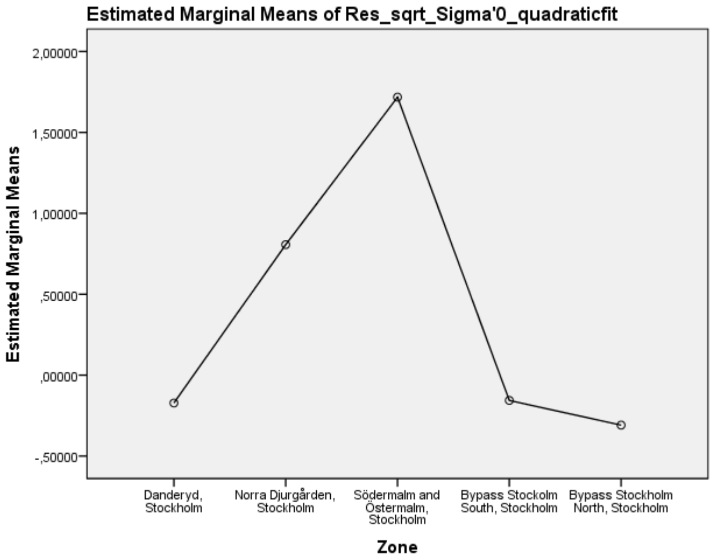


Figure 80: The main effect of Zone on the effective stress in the data set Stockholm.

The plot in Figure 80 indicates that the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth are generally low in the zones Danderyd, Bypass Stockholm-South and Bypass Stockholm-North while they are high in Södermalm and Östermalm and moderate in Norra Djurgården. The differences could be a result of either a differing thickness of the soil layer overlaying the clay, differing clay density, groundwater level or a combination of them. In Table 11, the mean thickness of the soil layer overlaying the clay and the mean clay density are shown for each zone. A mean groundwater level is not evaluated and should also have an impact on the result. For example, the relatively lower values of σ_0' for the zones Bypass Stockholm South and Bypass Stockholm North are not explained by the table values below and may instead be caused by a higher groundwater level compared to the other zones.

Table 11: Mean Thickness and mean Density of the zones in Stockholm.

Zone	Mean thickness of overlaying soil [m]	Mean density [t/m^3]
Danderyd	0,67	1,72
Norra Djurgården	1,64	1,78
Södermalm and Östermalm	4,08	1,77
Bypass Stockholm South	2,13	1,68
Bypass Stockholm North	1,64	1,70

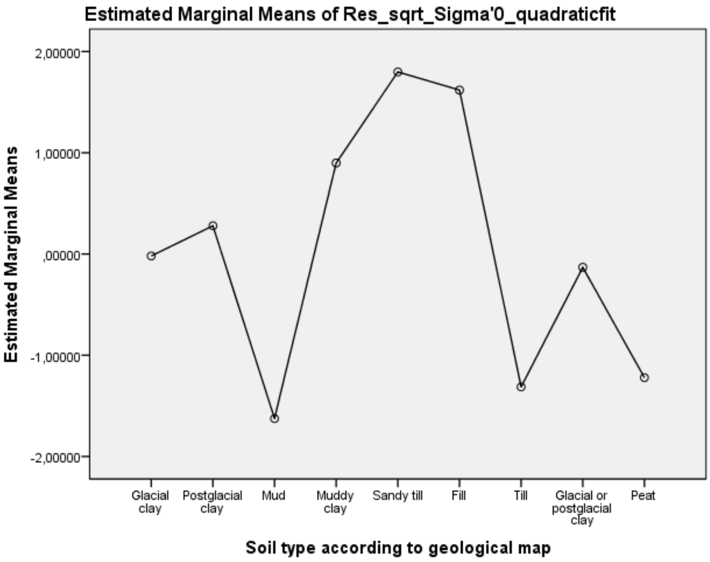


Figure 81: The main effect of Soil_type_map on the effective stress in the data set Stockholm.

The plot in Figure 81 indicates no clear grouping of the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth over the soil type according to the geological map. The result is probably affected by the uneven distribution of observations over the different soil types, see Table 12. With so few observations in some categories, the evidentiary value of this result is very low.

Table 12: Amount of observations for the independent variable Soil type in Stockholm.

Soil type according to the geological map	N
Glacial clay	47
Postglacial clay	116
Mud	3
Muddy clay	3
Sandy till	2
Fill	5
Till	6
Glacial or postglacial clay	11
Peat	9
Alluvium, clay--silt	0

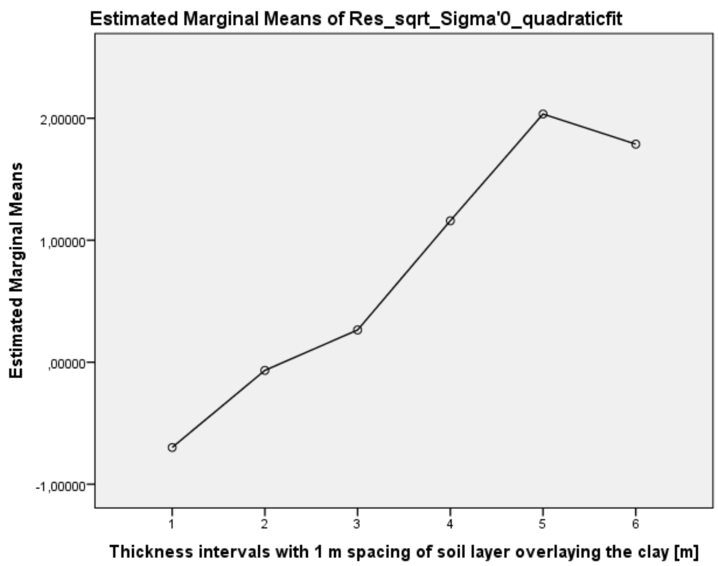


Figure 82: The main effect of Overlaying_layer_INT on the effective stress in the data set Stockholm.

The residuals of $\sqrt{\sigma'_0}$ from a quadratic fit against the sampling depth follows a smooth trend against higher values toward thicker layers of soil overlaying the clay, as can be seen in Figure 82. An exception from the trend occurs between a thickness of 5 and 6 meters. In Table 13, the number of observations within each thickness interval is shown. As can be seen, there is only one single observations of a thickness over 5 meters and this could be an outlier which would substantially affect the estimated marginal mean. The result is reasonable since the effective stress is directly connected to the current load situation and thicker layers of soil overlaying the clay should result in higher effective stresses.

Table 13: Amount of observations of the independent variable Thickness in Stockholm.

Thickness of the soil layer overlaying the clay [m]	N
0 – 1	52
1 – 2	85
2 – 3	45
3 – 4	13
4 – 5	6
5 – 6	1

The full-factorial ANOVA has an R^2 of 0.913, giving a good grade of explanation for these results.

6.1.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 14. For the complete output from this one-way ANOVA, see Appendix B. page 9.

Table 14: One-way ANOVA, effective stress, All obs. 3-8 m.

Source	F
Corrected Model	49,097
Intercept	22,229
Depth_INT	,952
Zone	62,217
Urbanization	2,511
Soil_type_map	7,216
Overlaying_layer__INT	28,901
Time_overlying_layer	5,524

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Depth_INT, since each of them show an *F*-factor higher than 1, see Table 15 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 10.

Table 15: Full-factorial ANOVA, effective stress, All obs. 3-8m.

Source	F	Sig.
Corrected Model	41,119	,000
Intercept	145,064	,000
Zone	73,623	,000
Urbanization	1,234	,294
Soil_type_map	10,207	,000
Overlaying_layer__INT	17,546	,000
Time_overlying_layer	,393	,676

A second full-factorial is made carrying along only significant main factors from the first one, see Table 16 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 12.

Table 16: Second full-factorial, effective stress, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	42,492	,000
Intercept	121,555	,000
Zone	64,985	,000
Urbanization	6,182	,003
Soil_type_map	5,514	,000
Overlaying_layer__INT	15,909	,000
Zone * Urbanization	11,683	,000

The plots from all observations with significant main effects or interactions are presented below.

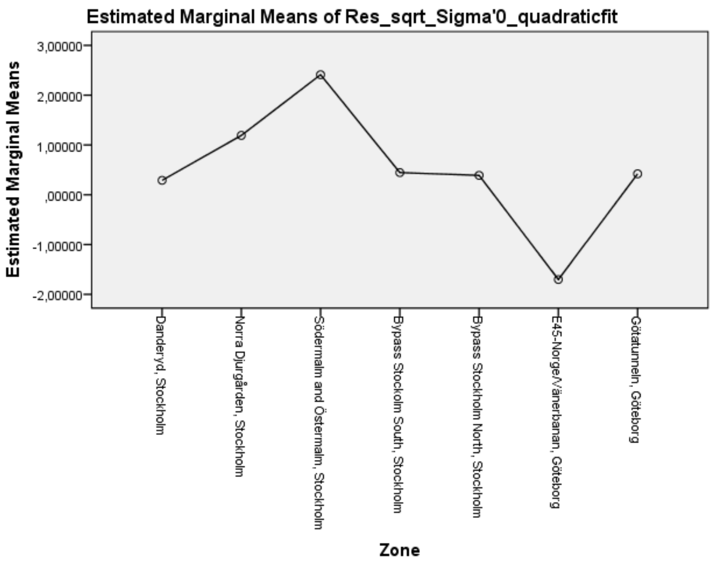


Figure 83: The main effect of Zone on the effective stress in the data set All obs. 3-8 m.

The plot in Figure 83 indicates that the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth are generally very low in the zone E45-Norge/Vänerbanan, low in Danderyd, Bypass Stockholm-South, Bypass Stockholm-North and Götatunneln while they are high in Södermalm and Östermalm and moderate in Norra Djurgården. The differences could be a result of differing thickness of the soil layer overlaying the clay, differing clay density, groundwater level or a combination of them. In Table 17, the mean thickness of the soil layer overlaying the clay and the mean density are shown for each zone. A mean groundwater level is not evaluated and should also have an impact on the result. For example, the relatively lower values of σ_0' for the zones Bypass Stockholm South, Bypass Stockholm North, E45-Norge/Vänerbanan and Götatunneln are not explained by the table values below and may instead be caused by a higher groundwater level compared to the other zones.

Table 17: The mean Thickness and mean Density of the zones in the data set All obs. 3-8.

Zone	Mean thickness of overlaying soil [m]	Mean density [t/m^3]
Danderyd	0,67	1,72
Norra Djurgården	1,64	1,78
Södermalm and Östermalm	4,08	1,77
Bypass Stockholm South	2,13	1,68
Bypass Stockholm North	1,64	1,70
E45-Norge/Vänerbanan	0,92	1,58
Götatunneln	5,05	1,63

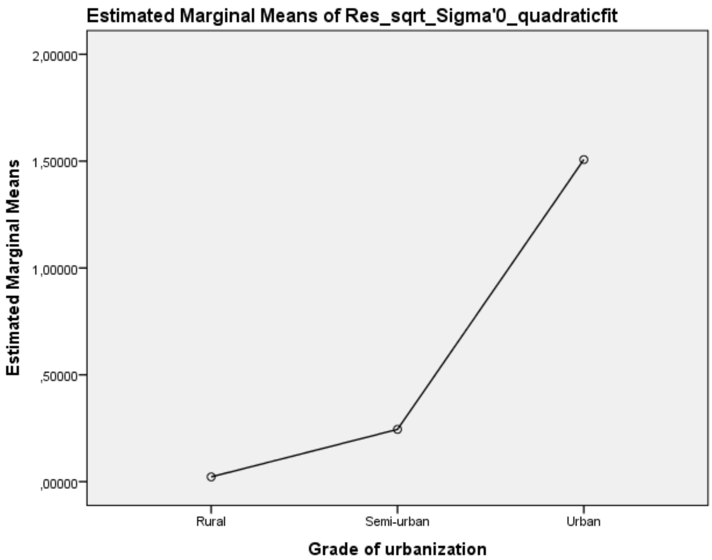


Figure 84: The main effect of Urbanization on the effective stress in the data set All obs. 3-8 m.

The residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth seem to follow a clear trend against higher values towards denser urbanization, as can be seen in Figure 84. The result would be reasonable, had the external loads from buildings been included, since the effective stress is directly connected to the current load situation. The trend may instead be caused by differing thickness of the soil layer overlaying the clay, differing clay density, groundwater level or a combination of them. In Table 18, the mean thickness of the soil layer overlaying the clay and the mean density are shown for each grade of urbanization. They both seem to follow a similar pattern as the plot. That the effective stress follows the same trend as the thickness of the soil layer overlaying the clay is inevitable as mentioned earlier.

Table 18: The mean Thickness and mean Density of Grade of urbanization in the data set All obs. 3-8.

Grade of urbanization	Mean thickness of overlaying soil [m]	Mean density [t/m^3]
Rural	1,30	1,66
Semi urban	1,94	1,66
Urban	3,29	1,71

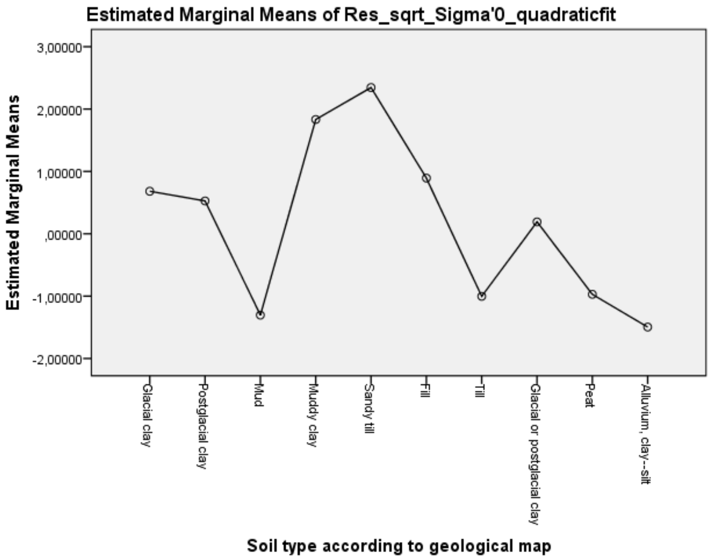


Figure 85: The main effect of Soil_type_map on the effective stress in the data set All obs. 3-8 m.

The plot in Figure 85 indicates no clear grouping of the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth over the soil type according to the geological map. The result may stem from the uneven distribution of observations over the different soil types, see Table 19. With so few observations in some categories, the evidentiary value of this result is very low.

Table 19: The amount of observations of the independent variable Soil type in data set All obs. 3-8 m.

Soil type according to the geological map	N
Glacial clay	44
Postglacial clay	122
Mud	3
Muddy clay	2

Soil type according to the geological map	N
Sandy till	2
Fill	11
Till	5
Glacial or postglacial clay	9
Peat	5
Alluvium, clay--silt	21

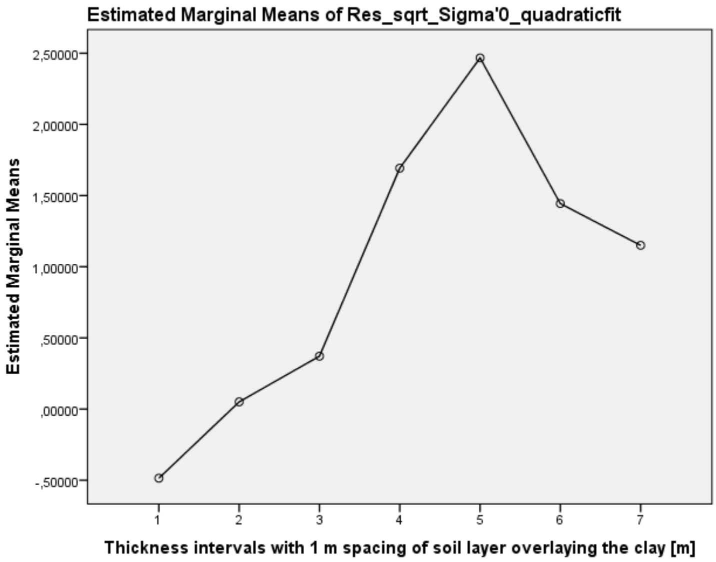


Figure 86: The main effect of Overlaying_layer_INT on the effective stress in the data set All obs. 3-8 m.

The residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth follows a smooth trend against higher values toward thicker layers of soil overlaying the clay, as can be seen in Figure 86. An exception from the trend occurs between a thickness of 5 and 7 meters. This deviation is hard to explain and is not caused by the fact that there are few observations for these categories. The result is reasonable since the effective stress is directly connected to the current load situation and thicker layers of soil overlaying the clay should result in higher effective stresses.

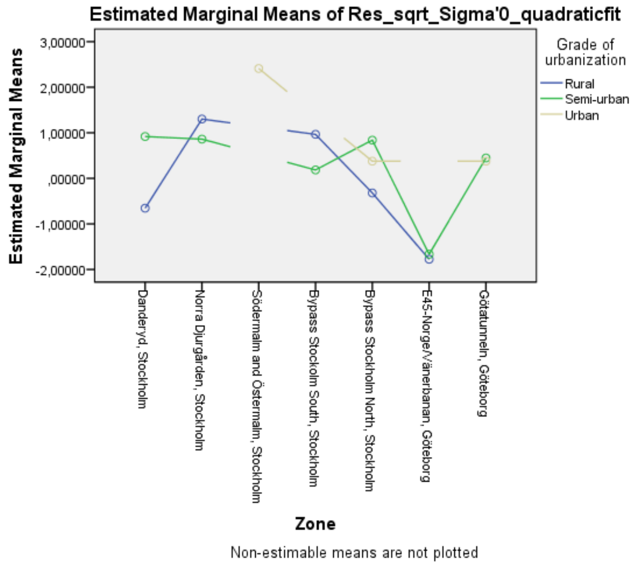


Figure 87: The interaction of Zone and Urbanization on the effective stress in the data set All obs. 3-8 m.

The plot in Figure 87 indicates that the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth are generally very low in the zone E45-Norge/Vänerbanan, low in Danderyd, Bypass Stockholm-South, Bypass Stockholm-North and Götatunneln while they are high in Södermalm and Östermalm and moderate in Norra Djurgården. At the same time, there is no clear grouping of values for the grade of urbanization other than for the zone Södermalm and Östermalm, where it deviates upwards from the other ones. Even though there is a similarity in the behavior of the residuals and the mean grade of urbanization over the zones, as described in the results for the main effect of zones earlier, this result indicates that the interaction between zones and grade of urbanization is diffuse. Once again, the grade of urbanization should not have any effect on the effective stress since house loads are not included in the calculations of the effective stress. The full-factorial ANOVA has an R^2 of 0.938, giving a good grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 20 and 21.

Table 20: Group statistics, City, effective stress, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-1,3393280	1,04534844	,14496375
Stockholm	172	,4049131	,88137494	,06720421

Table 21: Independent Groups T-test output, City, effective stress, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	3,837	,051	-11,959	222	,000	-1,74424114	,14585268	-2,03167409	-1,45680818
Equal variances not assumed			-10,916	74,254	,000	-1,74424114	,15978390	-2,06259937	-1,42588290

The independent groups *T-test* shows that there is a significant difference in the mean values of the residuals of $\sqrt{\sigma_0'}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's *p*-value (0.051) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 88.

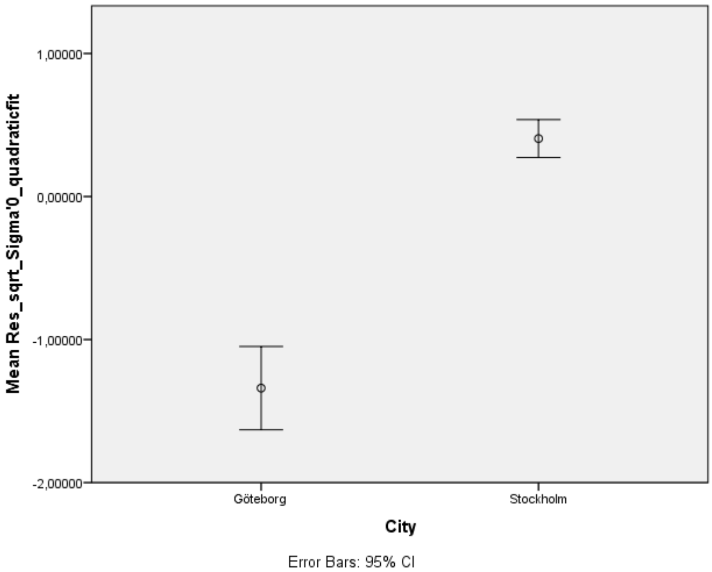


Figure 88: The effect of City on the effective stress in the data set All obs. 3-8 m.

This indicates that there is a relationship between the effective stress and the cities that were investigated, where values of σ_0' tend to be lower in Göteborg than in Stockholm. This may be a result of higher loads in terms of thicker and heavier soil overlaying the clay, from the generally more dense urbanization in Stockholm compared to Göteborg, higher clay density or a lower ground water table.

6.2 Preconsolidation stress (σ'_c)

In this chapter, the results from the analysis of the preconsolidation stress are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.2.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 22. For the complete output from this one-way ANOVA, see Appendix B. page 14.

Table 22: One-way ANOVA, preconsolidation stress, Göteborg.

Source	F
Corrected Model	13,267
Intercept	10,713
Depth_INT	1,869
Urbanization	1,450
Soil_type_map	1,317
Overlaying_layer__INT	8,406
Time_overlying_layer	4,460

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 23 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 15.

Table 23: Full-factorial ANOVA, preconsolidation stress, Göteborg.

Source	F	Sig.
Corrected Model	3,023	,000
Intercept	6,584	,015
Depth_INT	1,434	,165
Urbanization	,658	,423
Soil_type_map	.	.
Overlaying_layer__INT	4,932	,003

Source	F	Sig.
Time_overlying_layer	2,914	,049
Depth_INT * Urbanization	1,444	,229

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 24 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 17.

Table 24: Second full-factorial ANOVA, preconsolidation stress, Göteborg.

Source	F	Sig.
Corrected Model	28,423	,000
Intercept	3,020	,084
Overlaying_layer__INT	6,051	,000
Time_overlying_layer	5,779	,000
Overlaying_layer__INT * Time_overlying_layer	13,235	,000

The plots from all observations with significant main effects or interactions are presented below.

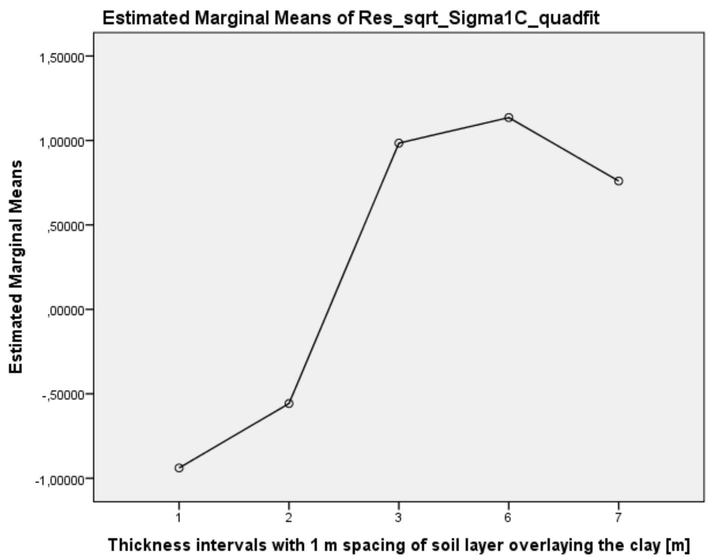


Figure 89: The main effect of Overlaying_layer_INT on the preconsolidation stress in the data set Göteborg.

The residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth are clearly grouped into low values in areas with an overlaying soil cover with a thickness up to 2 meters and high values in areas with an overlaying soil cover with a thickness over 3 meters, as can be seen in Figure 89. However, there are no observations of thicknesses between 3 and 6 meters. The result is reasonable since σ'_C is connected to the highest stress under which the clay once consolidated. If the present soil cover is generally also the thickest that has ever been, thicker layers of soil overlaying the clay would generally result in higher values of σ'_C. If so, OCR-values higher than one are the effect of either aging, as described in the theory chapter, or a higher pore water pressure today than when the clay consolidated. The grouping may also be explained by differences between the two zones E45-Norge/Vänerbanan and Götatunneln. The mean thickness of the soil layer overlaying the clay is 0.92 meters in the zone E45-Norge/Vänerbanan and 5.05 meters in the zone Götatunneln.

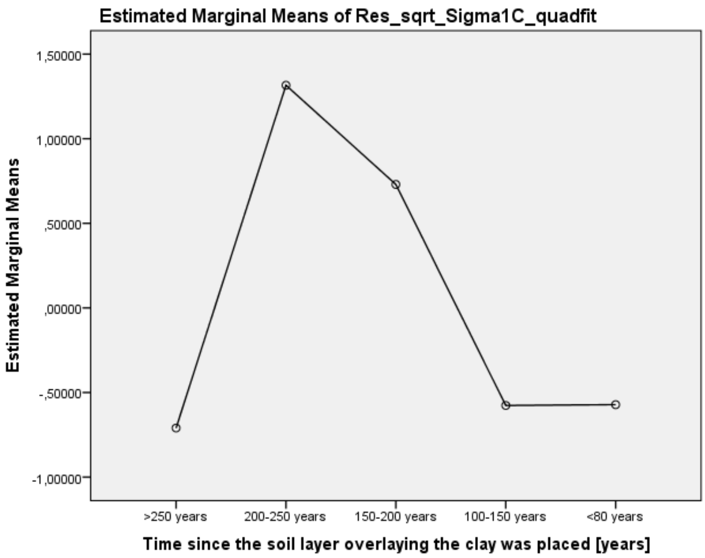


Figure 90: The main effect of Time_overlaying_layer on the preconsolidation stress in the data set Göteborg.

The residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth are clearly grouped into low values in areas where the soil layer overlaying the clay was placed earlier than 250 years ago and later than 150 years ago and into high values where the soil layer overlaying the clay was placed between 150 and 250 years ago, as can be seen in Figure 90. It would be more reasonable if there was a trend of higher values of the residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth towards overlaying soil covers that were placed further back in time. The logic behind this is that the aging process, as described in the theory chapter, is speeded up by external loads and longer time spans would thus result in higher values. However, since all areas where the soil layer overlaying the clay was placed earlier than 250 years ago and later than 150 years ago are located in the zone E45-Norge/Vänerbanan and all observations where the soil layer overlaying the clay was placed between 150 and 250 years ago are located in the zone Götatunneln, the difference between zones is probably causing this clear grouping.

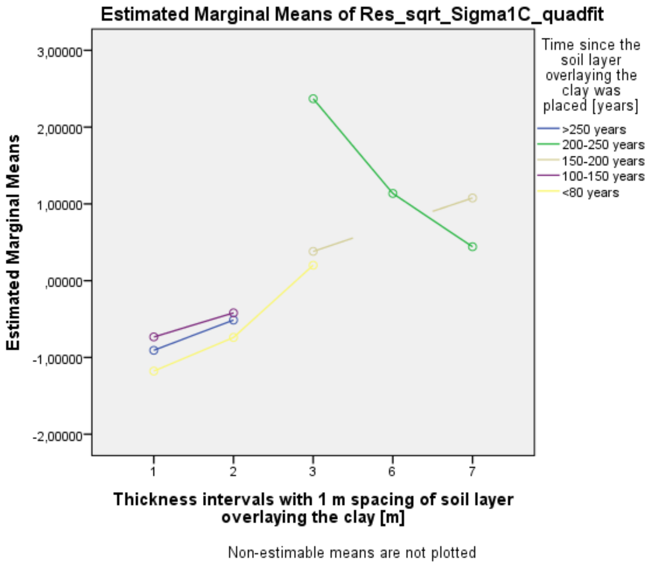


Figure 91: The interaction of Overlaying_layer_INT and Time_overlaying_layer on the preconsolidation stress in the data set Göteborg.

The residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth are clearly grouped into low values in areas with an overlaying soil cover with a thickness up to 2 meters which was placed earlier than 250 years ago and later than 150 years ago and into high values in areas with an overlaying soil cover with a thickness over 3 meters which was placed between 150 and 250 years ago, as can be seen in Figure 92. All observations from areas with an overlaying soil cover with a thickness between 2 and 3 meters which was placed later than 80 years ago stem from one single sampling point in the zone E45-Norge/Vänerbanan. With reference to the evaluation of the main effect of the thickness of the soil layer overlaying the clay and the time since this layer was placed, it seems as if differences between the two zones are the reason for the grouping in this result. The full-factorial ANOVA has an R^2 of 0.639, giving a moderate grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 25 and 26.

Table 25: Group statistics, Zone, preconsolidation stress, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,7484229	,80880748	,07711677
Götatunneln, Göteborg	79	1,0421079	,98243276	,11053232

Table 26: Independent Groups T-test output, Zone, preconsolidation stress, Göteborg.

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	7,425	,007	-13,713	187	,000	-1,79053080	,13057184	-2,04811391	-1,53294769
Equal variances not assumed			-13,285	147,421	,000	-1,79053080	,13477533	-2,05687199	-1,52418961

The independent group's *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area. Since the Levene's *p*-value (0.007) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 92.

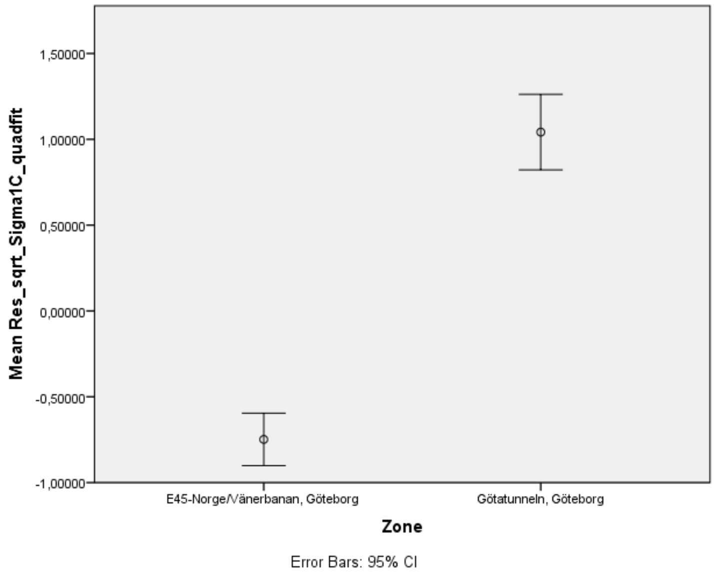


Figure 92: The effect of Zone on the preconsolidation stress in the data set Göteborg.

This indicates that there is a relationship between the residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth and the zones that were investigated, where the values tend to be lower at E45-Norge/Vänerbanan than at Götatunneln. This confirms all other results presented for this clay parameter for the data set Göteborg and means that the area around Götatunneln has either experienced a higher maximum stress at some point in time, been subjected to more extensive aging or a combination of them compared to the vicinity of E45-Norge/Vänerbanan. Notable is that the mean thickness of the soil layer overlaying the clay is 0.92 meters in the zone E45-Norge/Vänerbanan and 5.05 meters in the zone Götatunneln.

6.2.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 27. For the complete output from this one-way ANOVA, see Appendix B. page 18.

Table 27: One-way ANOVA, preconsolidation stress, Stockholm.

Source	F
Corrected Model	2,757
Intercept	1,976
Depth_INT	1,066
Zone	1,435
Soil_type_map	2,816
Overlaying_layer__INT	3,939
Urbanization	2,578
Time_overlying_layer	,674

Full-factorial ANOVA

The full-factorial is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 28 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 19.

Table 28: Full-factorial ANOVA, preconsolidation stress, Stockholm.

Source	F	Sig.
Corrected Model	1,479	,042
Intercept	1,362	,248
Depth_INT	,753	,684
Zone	2,487	,069
Soil_type_map	,608	,723
Overlaying_layer__INT	,478	,792
Urbanization	2,219	,117

The result of the full-factorial ANOVA shows that none of the factors or the model itself is significant.

6.2.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 29. For the complete output from this one-way ANOVA, see Appendix B. page 21.

Table 29: One-way ANOVA, preconsolidation stress, All obs. 3-8 m.

Source	F
Corrected Model	8,278
Intercept	2,553
Zone	11,093
Urbanization	4,050
Soil_type_map	2,600
Overlaying_layer__INT	3,983
Depth_INT	,477
Time_overlying_layer	2,543

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Depth_INT, since each of them show an *F*-factor higher than 1, see Table 30 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 21.

Table 30: Full-factorial ANOVA, preconsolidation stress, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	6,639	,000
Intercept	15,455	,000
Zone	6,745	,000
Urbanization	7,071	,001
Soil_type_map	1,078	,374
Overlaying_layer__INT	1,796	,103
Time_overlying_layer	1,377	,255
Zone * Urbanization	1,470	,227
Zone * Soil_type_map	11,447	,001

Source	F	Sig.
Zone * Overlaying_layer__INT	1,230	,300

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 31 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 24.

Table 31: Second full-factorial ANOVA, preconsolidation stress, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	16,370	,000
Intercept	,659	,418
Zone	17,941	,000
Urbanization	,097	,907
Zone * Urbanization	6,794	,000

The plots from all observations with significant main effects or interactions are presented below.

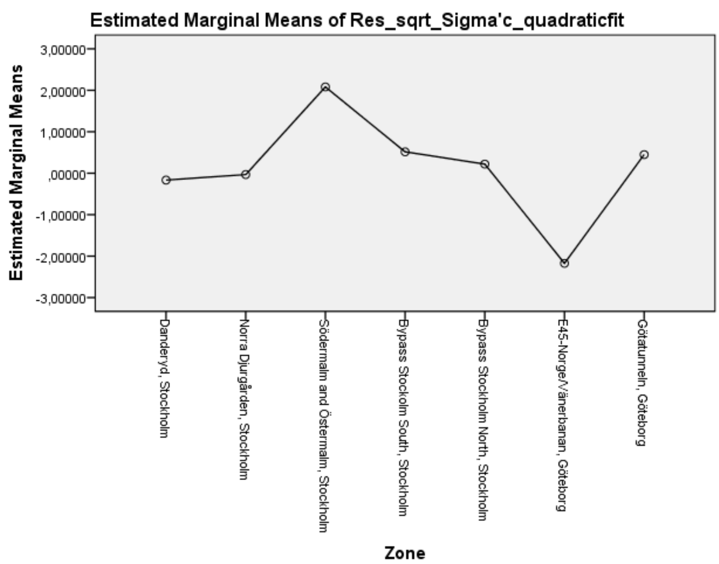


Figure 93: The main effect of Zone on the preconsolidation stress in the data set All obs. 3-8 m.

The plot in Figure 93 indicates that the residuals of $\sqrt{\sigma_C'}$ from a quadratic fit against the sampling depth generally have similar values in all the specified zones except for two of them; they deviate upwards in Södermalm and Östermalm and downwards in E45-Norge/Vänerbanan. This means that the area around Södermalm and Östermalm has either experienced a higher maximum stress at some point in time, been subjected to more extensive aging or a combination of them compared to the other zones, while the opposite applies for the zone E45-Norge/Vänerbanan.

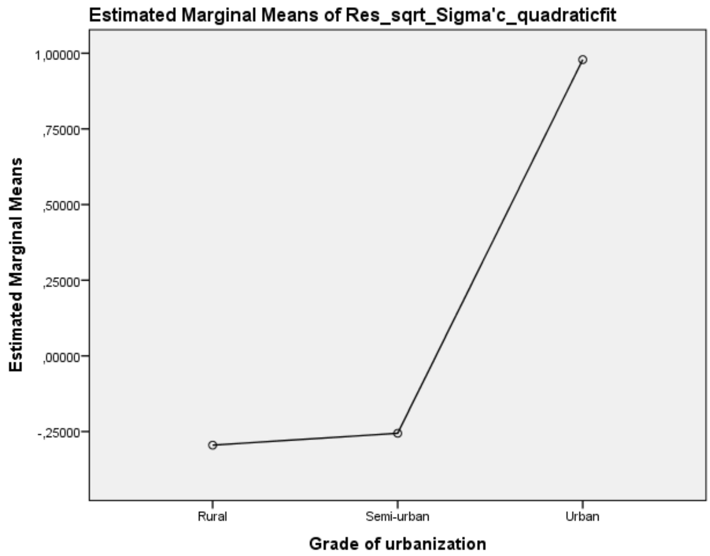


Figure 94: The main effect of Urbanization on the preconsolidation stress in the data set All obs. 3-8 m.

The plot in Figure 94 indicates that the residuals of $\sqrt{\sigma_C'}$ from a quadratic fit against the sampling depth have higher values for observations in areas that are classified as urban. The result is reasonable since higher values of σ_C' could stem from a higher grade of aging caused by higher loads due to denser urbanization.

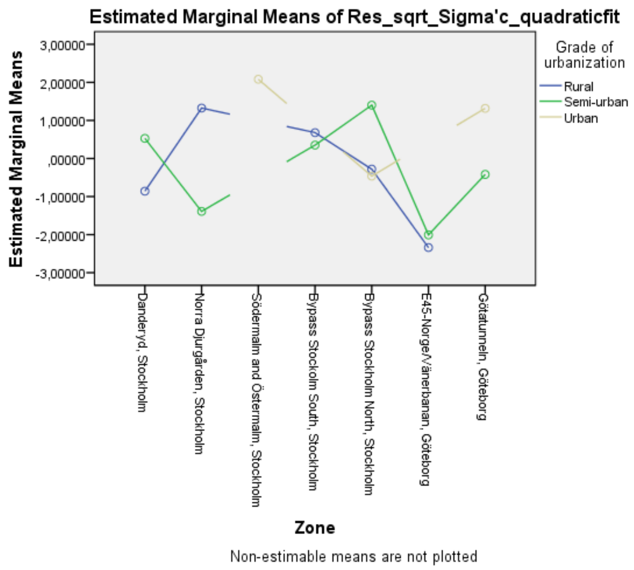


Figure 95: The interaction of Zone and Urbanization on the preconsolidation stress in the data set All obs. 3-8 m.

The plot in Figure 95 indicates that the residuals of $\sqrt{\sigma_C'}$ from a quadratic fit against the sampling depth generally have similar values in all the specified zones except for two of them; they deviate upwards in Södermalm and Östermalm and downwards in E45-Norge/Vänerbanan. At the same time, there is no clear grouping of values for the grade of urbanization other than for the zone Södermalm and Östermalm, where it deviates upwards and the zone E45-Norge/Vänerbanan where it deviates downwards from the other ones. As can be seen in Table 32, there are some similarities between the deviation from the mean grade of urbanization and the deviation from the mean value of σ_C' within the zones. For example, the mean grade of urbanization in the zone Danderyd is 18 % lower than the grand mean while the mean value of σ_C' is 13 % lower. On the other hand, the mean grade of urbanization in the zone Norra Djurgården is 40 % lower than the grand mean while the mean value of σ_C' is 12 % higher. The overall effect on σ_C' of the interaction between zones and the grade of urbanization is a bit diffuse. The full-factorial ANOVA has an R^2 of 0.503, giving a moderate grade of explanation for these results.

Table 32: Deviations from mean values of the zones in data set All obs. 3-8 m.

Zone	Dev. from mean urb.	Direction	Dev. from mean σ'$_C$	Direction
Danderyd	-18%	↓	-13%	↓
Norra Djurgården	-40%	↓↓	+12%	↑
Södermalm and Östermalm	+59%	↑↑	+45%	↑↑
Bypass Stockholm South	0%	-	-3%	↓
Bypass Stockholm North	-19%	↓	-4%	↓
E45_Norge/Vänerbanan	-15%	↓	-46%	↓↓
Götatunneln	+33%	↑↑	+8%	↑

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 33 and 34.

Table 33: Group statistics, City, preconsolidation stress, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-1,5422987	1,34570611	,18661586
Stockholm	172	,4662764	1,59553759	,12165860

Table 34: Independent Groups T-test output, City, preconsolidation stress, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1,060	,304	-8,232	222	,000	-2,00857509	,24398685	-2,48940179	-1,52774839
Equal variances not assumed			-9,016	98,268	,000	-2,00857509	,22276960	-2,45063904	-1,56651114

The independent groups *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{\sigma'_C}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's *p*-value (0.304) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 96.

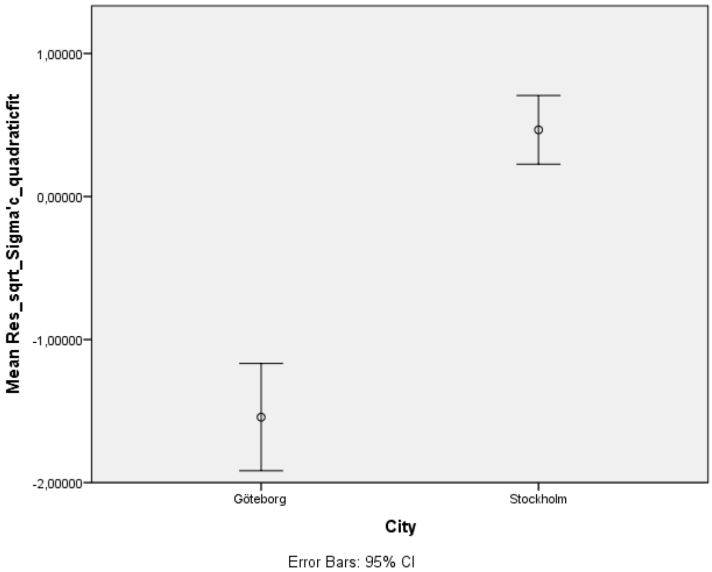


Figure 96: The effect of City on the preconsolidation stress in the data set All obs. 3-8 m.

This indicates that there is a relationship between σ'_C and the cities that were investigated, where values of σ'_C tend to be lower in Göteborg than in Stockholm. This means that the clay in Stockholm has generally either experienced a higher maximum stress at some point in time, been subjected to more extensive aging or a combination of them compared to the clay in Göteborg. The difference between the two cities is likely caused by the difference between the zones Södermalm and Östermalm in Stockholm and E45-Norge/Vänerbanan in Göteborg, since the rest of the zones have similar estimated marginal means.

6.3 Limit stress (σ'_L)

In this chapter, the results from the analysis of the limit stress are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.3.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 35. For the complete output from this one-way ANOVA, see Appendix B. page 25.

Table 35: One-way ANOVA, limit stress, Göteborg.

Source	F
Corrected Model	10,842
Intercept	11,474
Depth_INT	1,513
Urbanization	,950
Soil_type_map	,315
Overlaying_layer__INT	7,421
Time_overlying_layer	2,704

Full-factorial ANOVA

The full-factorial ANOVA is made with all variables except for Urbanization and Soil_type_map, since each of them show an *F*-factor higher than 1, see Table 36 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 26.

Table 36: Full-factorial ANOVA, limit stress, Göteborg.

Source	F	Sig.
Corrected Model	3,242	,000
Intercept	7,590	,008
Depth_INT	1,717	,047
Overlaying_layer__INT	7,915	,000
Time_overlying_layer	4,321	,004

The plots from all observations with significant main effects or interactions are presented below.

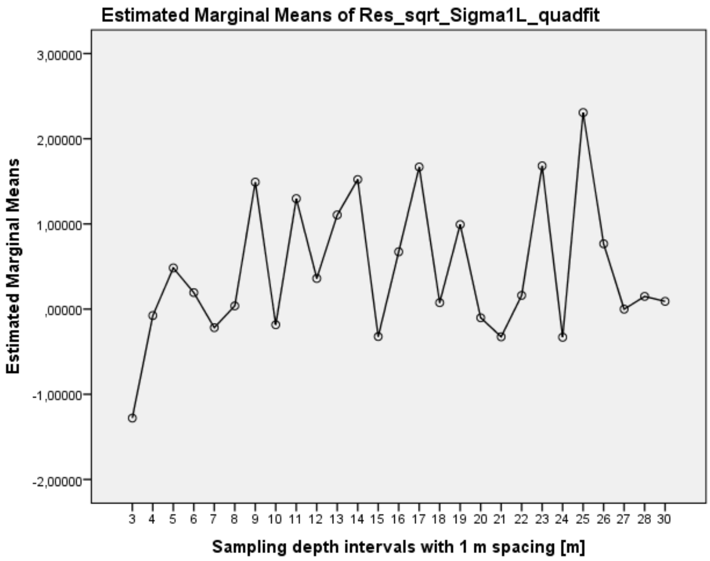


Figure 97: The main effect of Depth_INT on the limit stress in the data set Göteborg.

The value jumps up and down without any clear trend in Figure 97, which indicates that there is no relationship between the residuals of $\sqrt{\sigma_L'}$ from a quadratic fit against the sampling depth and the sampling depth. This indicates that the normalization against depth successfully eliminated the intrinsic relationship between the parameter and the sampling depth.

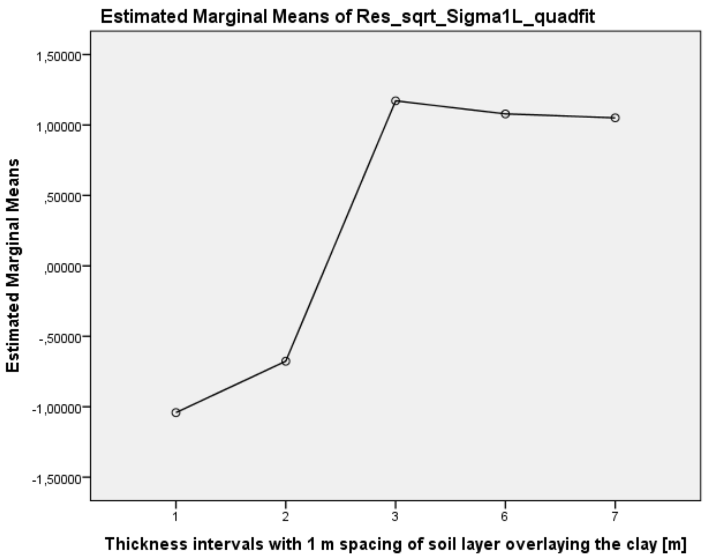


Figure 98: The main effect of Overlaying_layer_INT on the limit stress in the data set Göteborg.

The residuals of $\sqrt{\sigma_L'}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ_C' regarding this factor, as can be seen in Figure 98. The result is reasonable since σ'_L is connected to σ'_C in the way that σ'_L can never be exceeded by σ'_C. It is reasonable to believe that σ'_L is affected by the same factors as σ'_C.

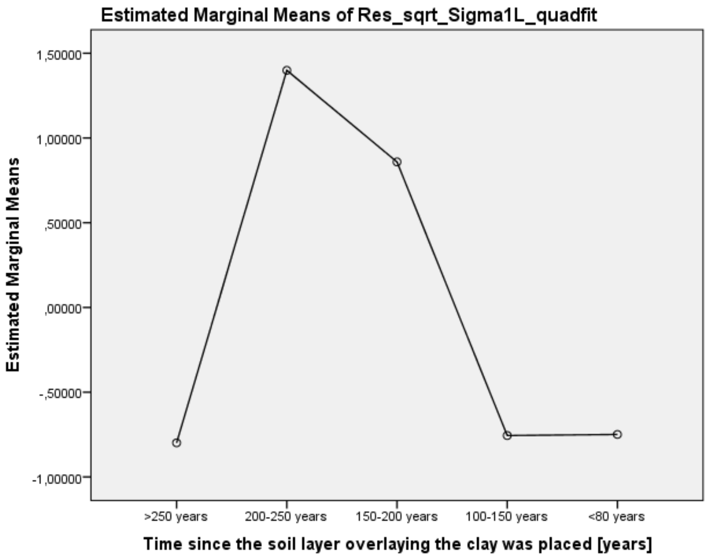


Figure 99: The main effect of Time_overlaying_layer on the limit stress in the data set Göteborg.

The residuals of $\sqrt{\sigma'_L}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ'_C regarding this factor, as can be seen in Figure 99. The result is reasonable since σ'_L is connected to σ'_C in the way that σ'_L can never be exceeded by σ'_C. It is reasonable to believe that σ'_L is affected by the same factors as σ'_C.

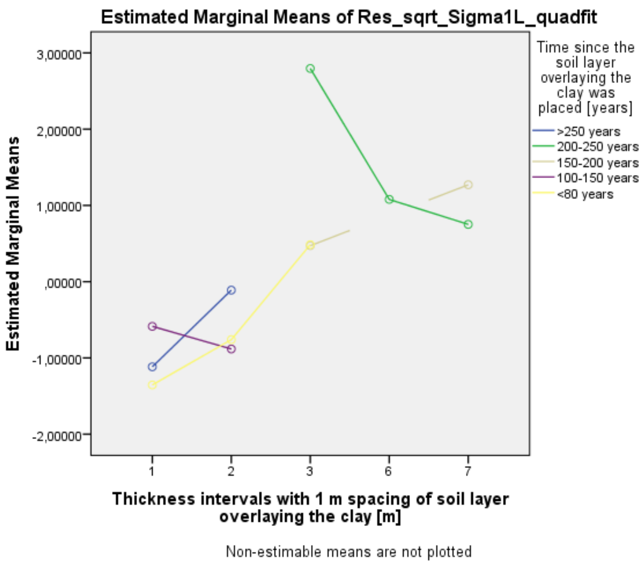


Figure 100: The interaction of Overlaying_layer_INT and Time_overlaying_layer on the limit stress in the data set Göteborg.

The residuals of $\sqrt{\sigma'_L}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ'_C regarding this factors, as can be seen in Figure 100. The result is reasonable since σ'_L is connected to σ'_C in the way that σ'_L can never be exceeded by σ'_C. It is reasonable to believe that σ'_L is affected by the same factors as σ'_C. The full-factorial ANOVA has an R^2 of 0.887, giving a high grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 37 and 38.

Table 37: Groups statistics, Zone, limit stress, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,8754667	1,01360359	,09664331
Götatunneln, Göteborg	79	1,2190042	1,33259576	,14992874

Table 38: Independent Groups T-test output, Zone, limit stress, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	9,071	,003	-12,271	187	,000	-2,09447093	,17068810	-2,43119265	-1,75774922
Equal variances not assumed			-11,742	139,100	,000	-2,09447093	,17837756	-2,44715286	-1,74178901

The independent group's *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{\sigma'_L}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area. Since the Levene's *p*-value (0.003) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 101.

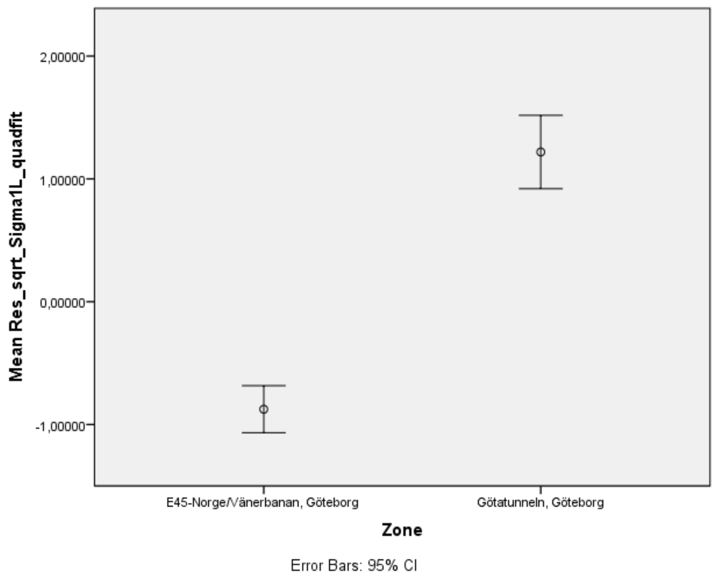


Figure 101: The effect of Zone on the limit stress in the data set Göteborg.

The residuals of $\sqrt{\sigma_L'}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ_C' regarding this factor. The result is reasonable since σ_L' is connected to σ_C' in the way that σ_L' can never be exceeded by σ_C'. It is reasonable to believe that σ_L' is affected by the same factors as σ_C'.

6.3.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 39. For the complete output from this one-way ANOVA, see Appendix B. page 27.

Table 39: One-way ANOVA, limit stress, Stockholm.

Source	F
Corrected Model	2,569
Intercept	3,236
Depth_INT	1,088
Zone	1,139
Soil_type_map	2,073
Overlaying_layer__INT	4,129
Urbanization	,726
Time_overlying_layer	,290

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Urbanization and Soil_type_map, since each of them show an *F*-factor higher than 1, see Table 40 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 28.

Table 40: Full-factorial ANOVA, limit stress, Stockholm.

Source	F	Sig.
Corrected Model	1,329	,086
Intercept	4,361	,040
Depth_INT	,198	,997
Zone	,373	,773
Soil_type_map	1,897	,091
Overlaying_layer__INT	2,097	,074

The result of the full-factorial ANOVA shows that none of the factors or the model itself is significant.

6.3.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 41. For the complete output from this one-way ANOVA, see Appendix B. page 29.

Table 41: One-way ANOVA, limit stress, All obs. 3-8 m.

Source	F
Corrected Model	6,279
Intercept	6,308
Depth_INT	,328
Zone	7,765
Urbanization	2,129
Soil_type_map	2,010
Overlaying_layer__INT	4,448
Time_overlying_layer	1,369

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Depth_INT, since each of them show an *F*-factor higher than 1, see Table 42 for result. For the complete output from this one-way ANOVA, see Appendix B. page 30.

Table 42: Full-factorial ANOVA, limit stress, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	5,182	,000
Intercept	20,894	,000
Zone	6,115	,000
Urbanization	5,060	,007
Soil_type_map	,125	,987
Overlaying_layer__INT	1,888	,086
Time_overlying_layer	3,629	,029

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 43 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 32.

Table 43: Second full-factorial ANOVA, limit stress, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	6,264	,000
Intercept	2,903	,090
Zone	12,948	,000
Urbanization	,292	,747
Time_overlying_layer	,200	,938
Zone * Urbanization	2,712	,046

The plots from all observations with significant main effects or interactions are presented below.

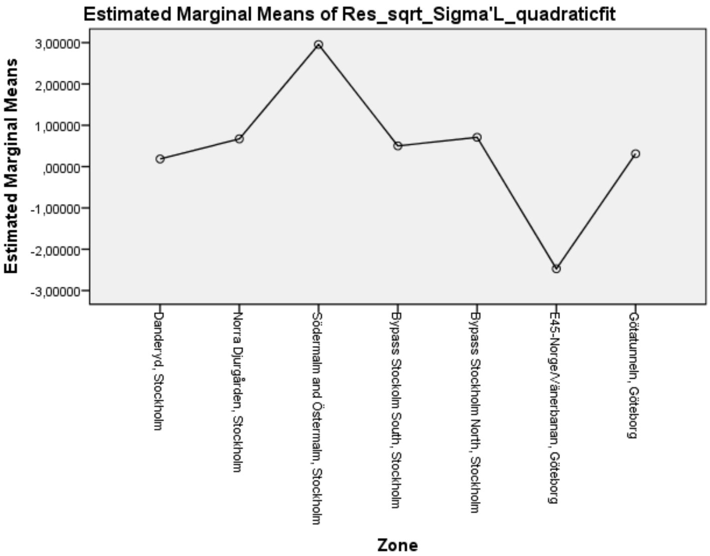


Figure 102: The main effect of Zone on the limit stress in the data set All obs. 3-8 m.

The residuals of $\sqrt{\sigma_L'}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ_C' regarding this factor, as can be seen in Figure 102. The result is reasonable since σ_L' is connected to σ_C' in the way that σ_L' can never be exceeded by σ_C'. It is reasonable to believe that σ_L' is affected by the same factors as σ_C'.

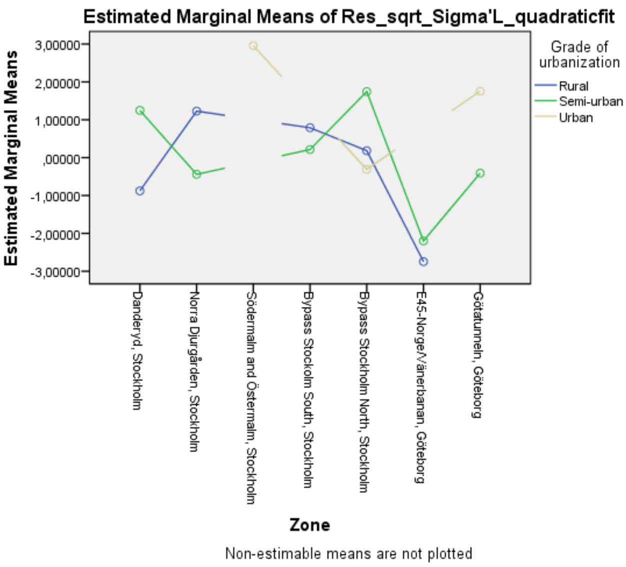


Figure 103: The interaction of Zone and Urbanization on the limit stress in the data set All obs. 3-8 m.

The residuals of $\sqrt{\sigma_L'}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ_C' regarding this factor, as can be seen in Figure 103. The result is reasonable since σ_L' is connected to σ_C' in the way that σ_L' can never be exceeded by σ_C'. It is reasonable to believe that σ_L' is affected by the same factors as σ_C'. Notable is though that the main factor for the grade of urbanization fell out as insignificant for σ_L' while it shows to be significant for σ'_C. The full-factorial ANOVA has an R^2 of 0.442, giving a low grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 44 and 45.

Table 44: Group statistics, City, limit stress, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-1,6806186	1,74452468	,24192205
Stockholm	172	,5080940	2,18735924	,16678458

Table 45 independent Groups T-test output, City, limit stress, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,704	,402	-6,605	222	,000	-2,18871264	,33137534	-2,84175646	-1,53566881
Equal variances not assumed			-7,449	103,994	,000	-2,18871264	,29384243	-2,77141357	-1,60601170

The independent groups *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{\sigma'_L}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's *p*-value (0.402) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 104.

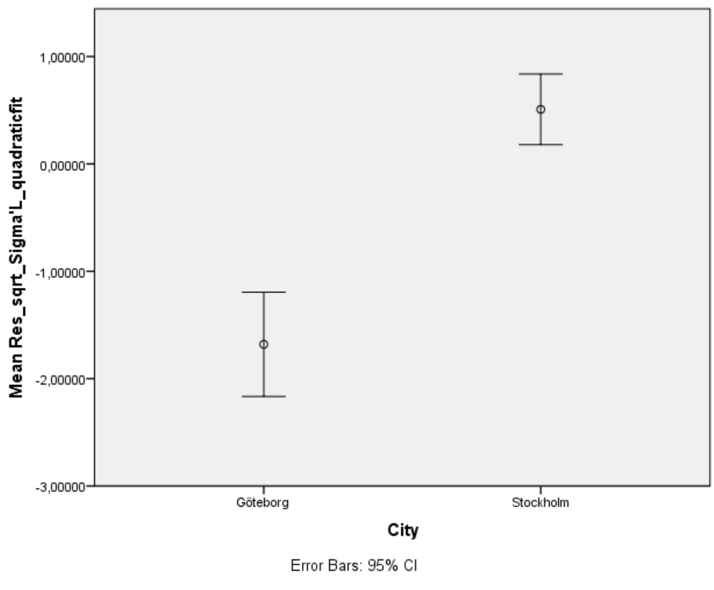


Figure 104: The effect of City on the limit stress in the data set All obs. 3-8 m.

The residuals of $\sqrt{\sigma'_L}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ'_C regarding this factor. The result is reasonable since σ'_L is connected to σ'_C in the way that σ'_L can never be exceeded by σ'_C. It is reasonable to believe that σ'_L is affected by the same factors as σ'_C.

6.4 The compression modulus M_L

In this chapter, the results from the analysis of the compression modulus M_L are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.4.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 46. For the complete output from this one-way ANOVA, see Appendix B. page 34.

Table 46: One-way ANOVA, M_L, Göteborg.

Source	F
Corrected Model	7,827
Intercept	9,180
Depth_INT	2,262
Urbanization	1,828
Soil_type_map	,471
Overlaying_layer__INT	4,934
Time_overlying_layer	2,915

Full-factorial ANOVA

The full-factorial ANOVA is made with all variables except Soil_type_map, since each of them show an *F*-factor higher than 1, see Table 47 for result. For the complete output from this one-way ANOVA, see Appendix B. page 34.

Table 47: Full-factorial ANOVA, M_L, Göteborg.

Source	F	Sig.
Corrected Model	2,828	,000
Intercept	8,924	,005

Source	F	Sig.
Depth_INT	2,221	,016
Urbanization	1,547	,228
Overlaying_layer__INT	6,129	,001
Time_overlying_layer	1,523	,219

A second full-factorial ANOVA is made with only significant main factors from the first one, see Table 48 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 36.

Table 48: Second full-factorial ANOVA, M_L, Göteborg.

Source	F	Sig.
Corrected Model	4,495	,000
Intercept	21,407	,000
Depth_INT	3,211	,000
Overlaying_layer__INT	28,669	,000
Depth_INT * Overlaying_layer__INT	1,807	,006

The plots from all observations with significant main effects or interactions are presented below.

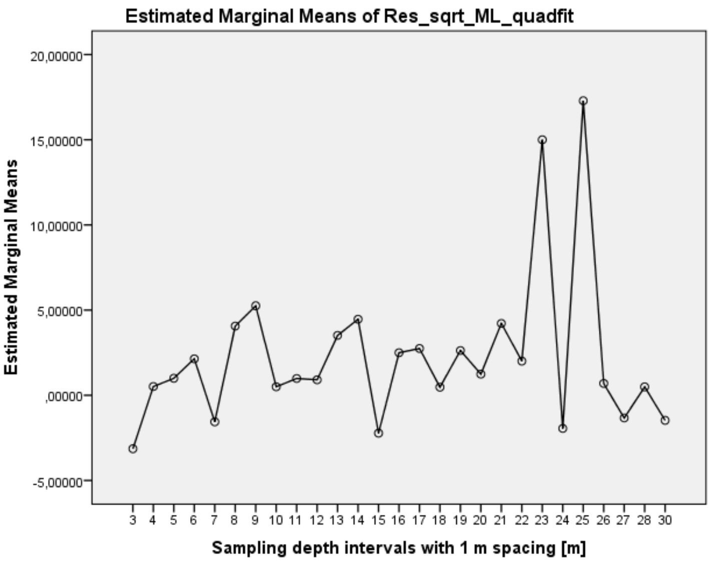


Figure 105: The main effect of Depth_INT on the compression modulus M_L in the data set Göteborg.

The value jumps up and down without any clear trend in Figure 105, which indicates that there is no relationship between the residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth and the sampling depth. This indicates that the normalization against depth successfully eliminated any intrinsic relationship between the parameter and the sampling depth.

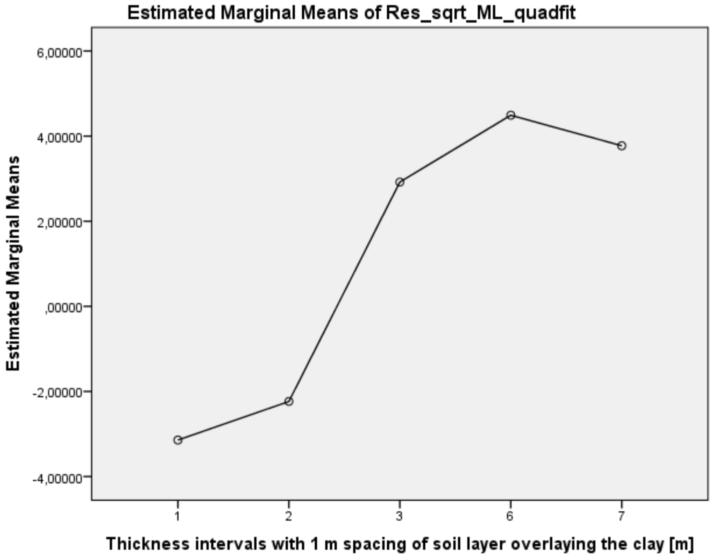


Figure 106: The main effect of Overlaying_layer_INT on the compression modulus M_L in the data set Göteborg.

The residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth follow the same general behavior as those representing σ'_C and σ'_L regarding this factor, as can be seen in Figure 106. The grouping may be explained by differences between the two zones E45-Norge/Vänerbanan and Götatunneln. The mean thickness of the soil layer overlaying the clay is 0.92 meters in the zone E45-Norge/Vänerbanan and 5.05 meters in the zone Götatunneln.

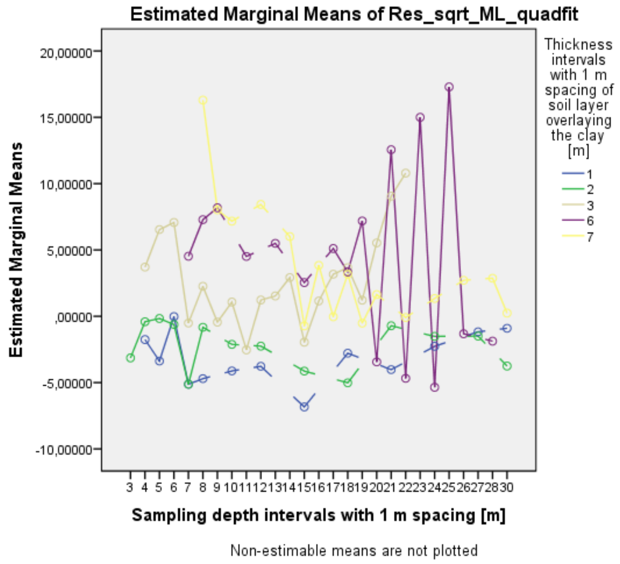


Figure 107: The interaction of Depth_INT and Overlaying_layer_INT on the compression modulus M_L in the data set Göteborg.

The interaction between the sampling depth and the thickness of the soil layer overlaying the clay is apparently significant according to the full-factorial ANOVA but it is not reasonable that this in fact has an effect on M_L, as can be seen in Figure 107. The full-factorial ANOVA has an R^2 of 0.761, giving a relatively high grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 49 and 50.

Table 49: Group statistics, Zone, M_L, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-2,7229669	3,53328426	,33688544
Götatunneln, Göteborg	79	3,7914729	4,72143398	,53120282

Table 50: Independent Groups T-test, Zone, M_L, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	8,793	,003	-10,850	187	,000	-6,51443985	,60041106	-7,69888938	-5,32999032
Equal variances not assumed			-10,356	137,450	,000	-6,51443985	,62902165	-7,75825061	-5,27062909

The independent group's *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area. Since the Levene's *p*-value (0.003) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 108.

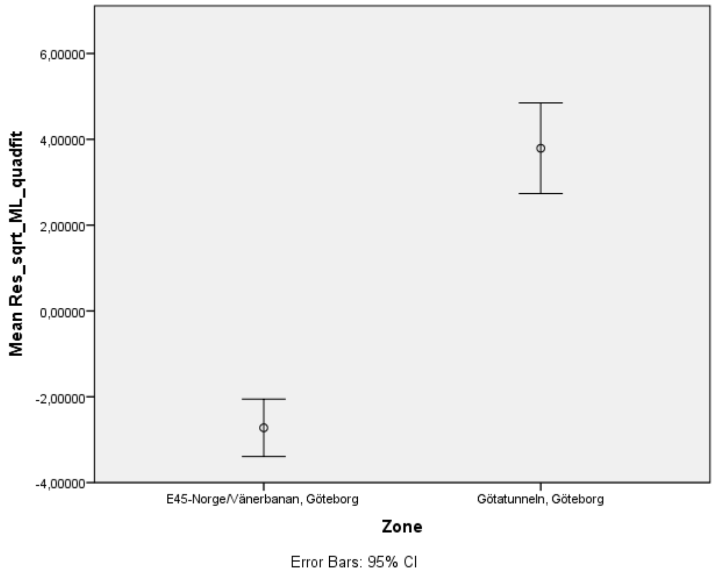


Figure 108: The effect of Zone on the compression modulus M_L in the data set Göteborg.

This indicates that there is a relationship between the compression modulus M_L and the zones that were investigated, where values of M_L tend to be lower at E45-Norge/Vänerbanan than at Götatunneln. This confirms the result of the factor representing the thickness of the soil layer overlaying the clay presented for this clay parameter for the data set Göteborg.

6.4.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 51. For the complete output from this one-way ANOVA, see Appendix B. page 37.

Table 51: One-way ANOVA, M_L, Stockholm.

Source	F
Corrected Model	2,847
Intercept	1,565
Depth_INT	1,252
Zone	3,108
Soil_type_map	3,435
Overlaying_layer__INT	4,501

Source	F
Urbanization	,573
Time_overlying_layer	1,587

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Urbanization, since each of them show an *F*-factor higher than 1, see Table 52 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 37.

Table 52: Full-factorial ANOVA, M_L, Stockholm.

Source	F	Sig.
Corrected Model	,925	,652
Intercept	5,429	,023
Depth_INT	,262	,990
Zone	1,606	,197
Soil_type_map	1,052	,396
Overlaying_layer__INT	1,264	,291
Time_overlying_layer	,029	,865

The result of the full-factorial ANOVA shows that none of the factors or the model itself is significant.

6.4.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 53. For the complete output from this one-way ANOVA, see Appendix B. page 40.

Table 53: One-way ANOVA, M_L, All obs. 3-8 m.

Source	F
Corrected Model	4,061
Intercept	4,634
Zone	5,682
Urbanization	,198

Source	F
Time_overlying_layer	,880
Depth_INT	,706
Soil_type_map	3,481
Overlaying_layer__INT	4,681

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along the variables Zone and Soil_type_map, since both of them show an *F*-factor higher than 1, see Table 54 for result. The variable Time_overlaying_layer is accidently carried along instead of Overlaying_layer_INT. This mistake was found late in the process and therefore, no changes have been made. For the complete output from this one-way ANOVA, see Appendix B. page 41.

Table 54: Full-factorial ANOVA, M_L, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	3,525	,000
Intercept	7,008	,009
Zone	7,245	,000
Time_overlying_layer	,055	,983
Soil_type_map	2,924	,004

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 55 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 41.

Table 55: Second full-factorial ANOVA, M_L, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	4,814	,000
Intercept	7,543	,007
Zone	7,711	,000
Soil_type_map	3,824	,000
Zone * Soil_type_map	1,513	,200

The plots from all observations with significant main effects or interactions are presented below.

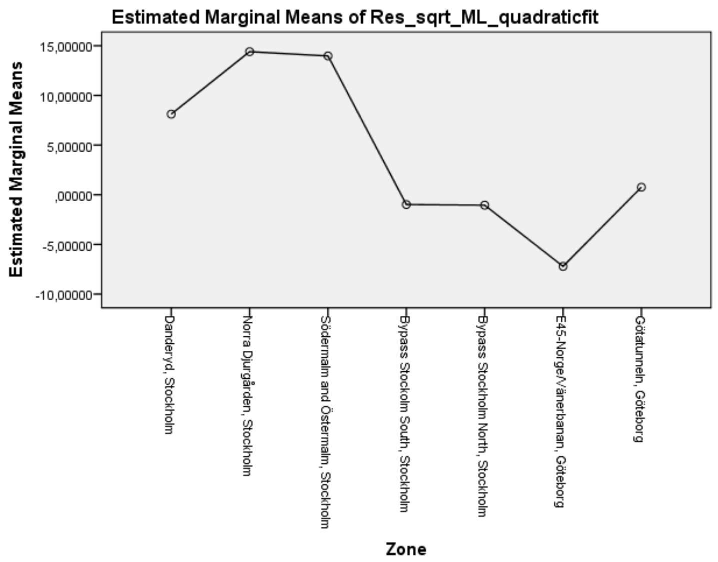


Figure 109: The main effect of Zone on the compression modulus M_L in the data set All obs. 3-8 m.

The plot indicates that the residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth are grouped into four groups with the highest values in the zones Norra Djurgården and Södermalm and Östermalm, the second highest values in Danderyd, the second lowest values in Bypass Stockholm South, Bypass Stockholm North and Götatunneln and the lowest values in E45-Norge/Vänerbanan, as can be seen in Figure 109. It is hard to say what is causing this grouping. The value of M_L is probably dependent on the local clay structure rather than any of the external factors. Notable is that the full-factorial ANOVA has an R^2 of 0.310, giving a low grade of explanation for these results. The behavior is somewhat similar to the one for σ'_0, σ'_C and σ'_L.

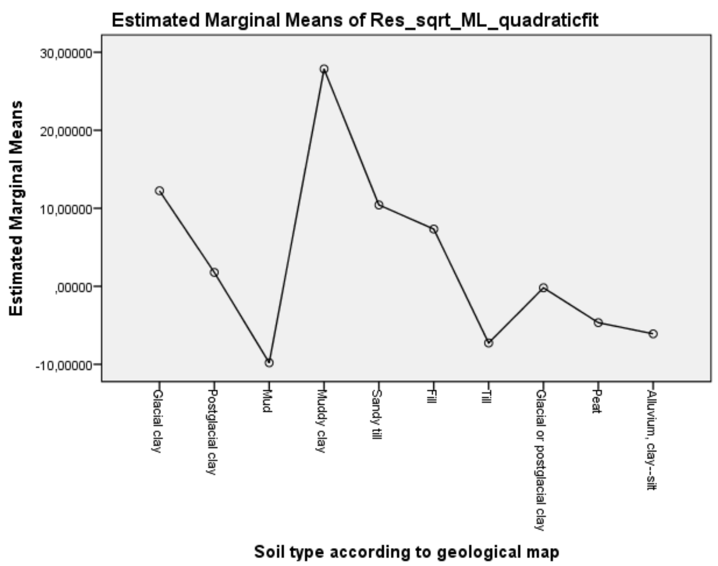


Figure 110: The main effect of Soil_type_map on the compression modulus M_L in the data set All obs. 3-8 m.

The plot in Figure 110 indicates no clear grouping of the residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth over the soil type according to the geological map.

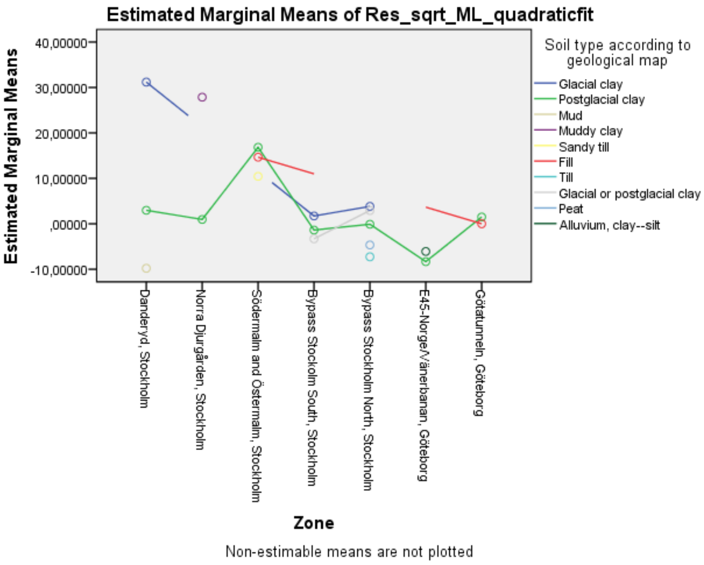


Figure 111: The interaction of Zone and Soil_type_map on the compression modulus M_L in the data set All obs. 3-8 m.

The plot in Figure 111 indicates that the residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth are generally very low in the zone E45-Norge/Vänerbanan, low in Bypass Stockholm-South, Bypass Stockholm-North and Götatunneln while they are high in Norra Djurgården and Södermalm and Östermalm and moderate in Danderyd. At the same time, the plot indicates no clear grouping of values over the soil type according to the geological map and hence, this result indicates that the effect on M_L of the interaction between the zone and the soil type according to the geological map is diffuse. The full-factorial ANOVA has an R^2 of 0.310, giving a low grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 56 and 57.

Table 56: Group statistics, City, M_L, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-5,3283833	5,40017559	,74886961
Stockholm	172	1,6109066	11,89155830	,90672282

Table 57: Independent Groups T-test, City, M_L, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	11,604	,001	-4,078	222	,000	-6,93928989	1,70168640	-10,29281586	-3,58576392
Equal variances not assumed			-5,901	188,997	,000	-6,93928989	1,17598978	-9,25904178	-4,61953800

The independent groups T-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{M_L}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's p-value (0.001) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 112.

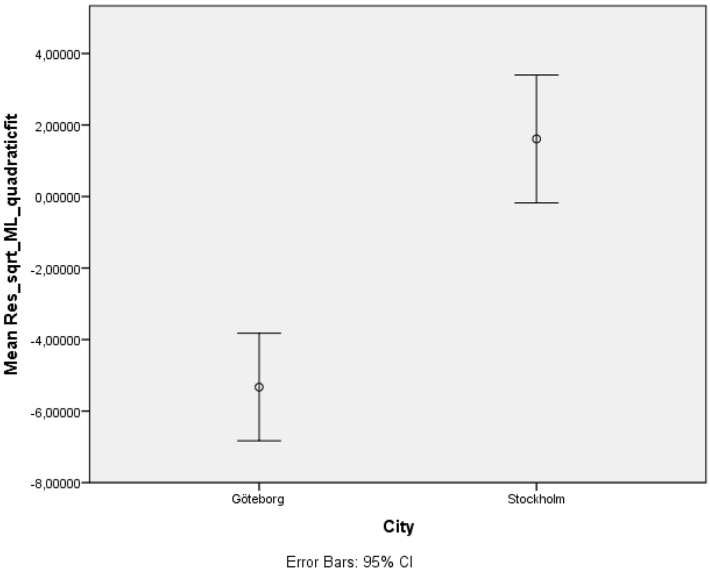


Figure 112: The effect of City on the compression modulus M_L in the data set All obs. 3-8 m.

This indicates that there is a relationship between the compression modulus M_L and the two cities that were investigated, where values of M_L tend to be lower in Göteborg than in Stockholm.

6.5 The compression modulus M'

In this chapter, the results from the analysis of the compression modulus M' are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.5.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 58. For the complete output from this one-way ANOVA, see Appendix B. page 42.

Table 58: One-way ANOVA, M', Göteborg.

Source	F
Corrected Model	2,038
Intercept	,776
Depth_INT	1,277
Urbanization	6,635
Soil_type_map	,386
Overlaying_layer__INT	,744
Time_overlying_layer	1,795

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Soil_type_map and Overlaying_layer_INT, since each of them show an *F*-factor higher than 1, see Table 59 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 43.

Table 59: Full-factorial ANOVA, M', Göteborg.

Source	F	Sig.
Corrected Model	1,173	,235
Intercept	1,841	,179
Depth_INT	,953	,538
Urbanization	6,097	,004
Time_overlying_layer	1,188	,324

The corrected model is not significant and therefore, none of the main factors are significant.

***T*-test**

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 60 and 61.

Table 60: Group statistics, Zone, M', Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0225929	,39738812	,03788947
Götatunneln, Göteborg	79	-,0314584	,26108066	,02937387

Table 61: Independent Groups T-test output, Zone, M', Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	11,613	,001	1,056	187	,292	,05405131	,05118916	-,04693113	,15503376
Equal variances not assumed			1,127	185,671	,261	,05405131	,04794201	-,04052978	,14863241

The independent group's *T*-test shows that there is no significant difference in the mean values of the residuals of $\sqrt{M'}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area.

6.5.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 62. For the complete output from this one-way ANOVA, see Appendix B. page 44.

Table 62: One-way ANOVA, M', Stockholm.

Source	F
Corrected Model	,655
Intercept	3,137
Depth_INT	,439
Zone	,652
Soil_type_map	,608
Overlaying_layer__INT	,591

Source	F
Time_overlying_layer	,199
Urbanization	1,580

Since there is only one single variable showing an *F*-factor higher than 1, Soil_type_map, it is of no use to perform a full-factorial ANOVA. Instead, all other variables are removed and a second one-way ANOVA is performed, see Table 63 for result. For the complete output from this second one-way ANOVA, see Appendix B. page 45.

Table 63: Full-factor ANOVA, M', Stockholm.

Source	F	Sig.
Corrected Model	2,356	,097
Intercept	1,162	,282
Urbanization	2,356	,097

The corrected model is not significant and therefore, the main factor is insignificant.

6.5.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 64. For the complete output from this one-way ANOVA, see Appendix B. page 45.

Table 64: One-way ANOVA, M', All obs. 3-8 m.

Source	F
Corrected Model	5,240
Intercept	2,526
Zone	4,577
Soil_type_map	2,516
Depth_INT	2,295
Urbanization	,443
Overlaying_layer__INT	,417
Time_overlying_layer	1,198

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Urbanization and Overlaying_layer_INT, since each of them show an *F*-factor higher than 1, see Table 65 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 46.

Table 65: Full-factorial ANOVA, M', All obs. 3-8 m.

Source	F	Sig.
Corrected Model	2,278	,000
Intercept	4,609	,034
Zone	6,860	,000
Soil_type_map	,884	,521
Depth_INT	,966	,442
Time_overlying_layer	2,024	,115
Zone * Depth_INT	1,064	,397
Zone * Time_overlying_layer	1,806	,150
Soil_type_map * Time_overlying_layer	6,023	,003

The plots from all observations with significant main effects or interactions are presented below.

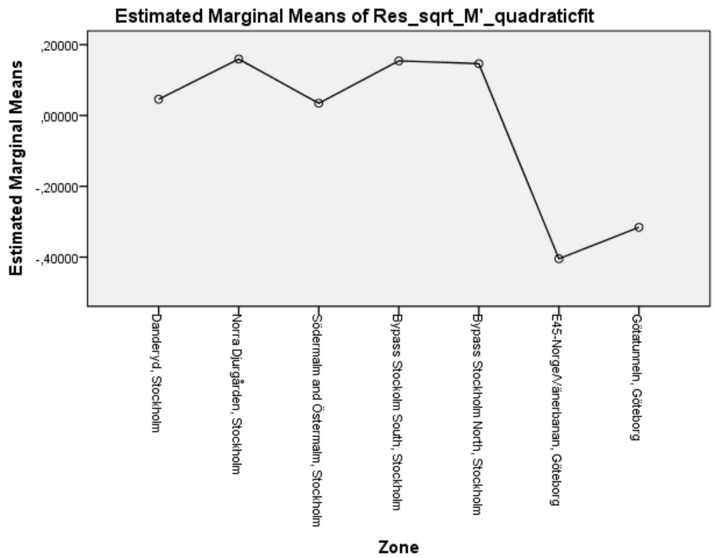


Figure 113: The main effect of Zone on the compression modulus M' in the data set All obs. 3-8 m.

The plot in Figure 113 indicates that the residuals of $\sqrt{M'}$ from a quadratic fit against the sampling depth are generally low in the zones located in Göteborg compared to the zones located in Stockholm. The overall behavior differs from the one for σ'_0, σ'_C, σ'_L and M_L, where for example the highest value is always found in the zone Södermalm and Östermalm. Since it is reasonable to believe that at least M_L is dependent on the local clay structure in the different zones rather than any of the investigated external factors, this result could be interpreted as an indication that M' is also dependent on the local clay structure but within a wider range, that is, within the two cities. One notable thing is also that the raw data of M', unlike σ'_0, σ'_C, σ'_L and M_L, was almost completely normally distributed prior to the transformation and normalization of variables.

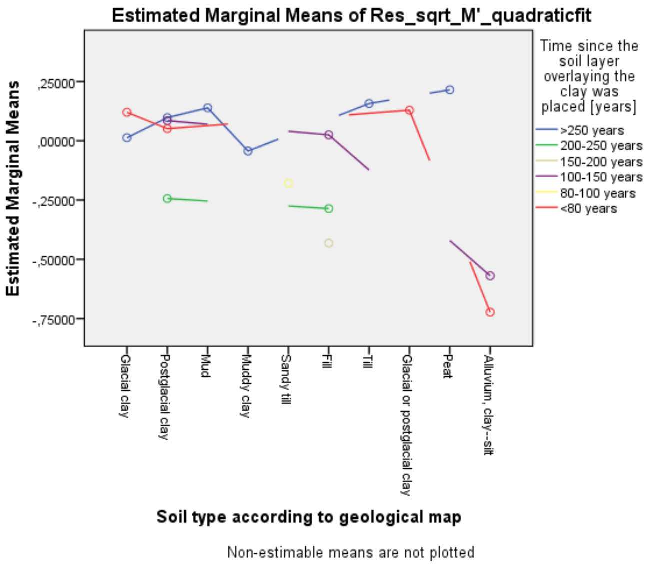


Figure 114: The interaction of Soil_type_map and Time_overlaying_layer on the compression modulus M' in the data set All obs. 3-8 meters.

The plot in Figure 114 indicates that the residuals of $\sqrt{M'}$ from a quadratic fit against the sampling depth generally are low for observations from areas where the geological map shows Alluvium, clay--silt compared to the rest of the soil types. The plot also suggests that there is no clear grouping of values over the time since the soil layer overlaying the clay was placed. The result indicates that the interaction between the soil type according to the geological map and the time since the soil layer overlaying the clay was placed is diffuse. The full-factorial ANOVA has an R^2 of 0.704, giving a relatively high grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 66 and 67.

Table 66: Group statistics, City, M', All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-,4219656	,42082205	,05835752
Stockholm	172	,1275710	,31931207	,02434732

Table 67: Independent Groups T-test output, City, M', All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	5,753	,017	-10,057	222	,000	-,54953656	,05464277	-,65722148	-,44185165
Equal variances not assumed			-8,691	69,670	,000	-,54953656	,06323284	-,67566098	-,42341215

The independent groups T-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{M'}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's p-value (0.017) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 115.

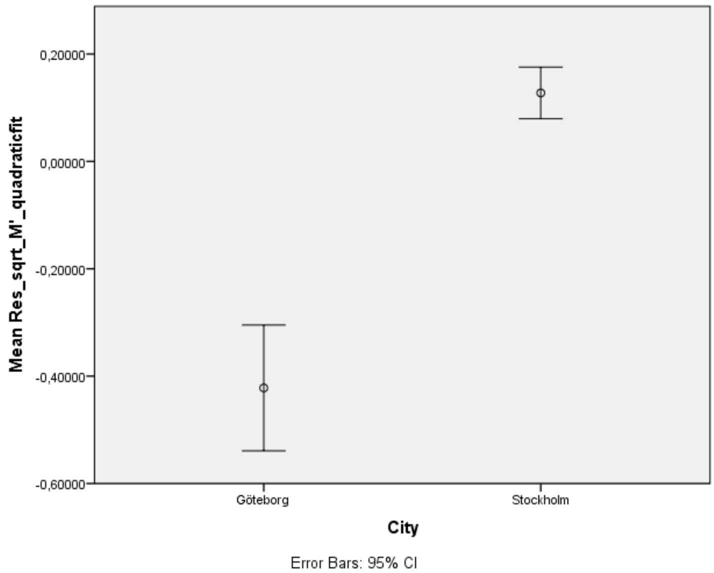


Figure 115: The effect of City on the compression modulus M' in the data set All obs. 3-8 m.

This indicates that there is a relationship between the compression modulus M' and the two cities that were investigated, where values of M' tend to be lower in Göteborg than in Stockholm. This result confirms the grouping of values that can be seen in the ANOVA for the zones, see Figure X.

6.6 OCR

In this chapter, the results from the analysis of OCR are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.6.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 68. For the complete output from this one-way ANOVA, see Appendix B. page 48.

Table 68: One-way ANOVA, OCR,Göteborg.

Source	F
Corrected Model	2,183
Intercept	1,033
Depth_INT	,671
Urbanization	1,766
Soil_type_map	,123
Overlaying_layer__INT	6,015
Time_overlying_layer	1,067

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Depth_INT and Soil_type_map, since each of them show an *F*-factor higher than 1, see Table 69 for result. For the complete output from this one-way ANOVA, see Appendix B. page 49.

Table 69: Full-factorial ANOVA, OCR,Göteborg.

Source	F	Sig.
Corrected Model	5,911	,000
Intercept	,073	,787
Urbanization	9,937	,000
Overlaying_layer__INT	7,493	,000
Time_overlying_layer	2,865	,025

The plots from all observations with significant main effects or interactions are presented below.

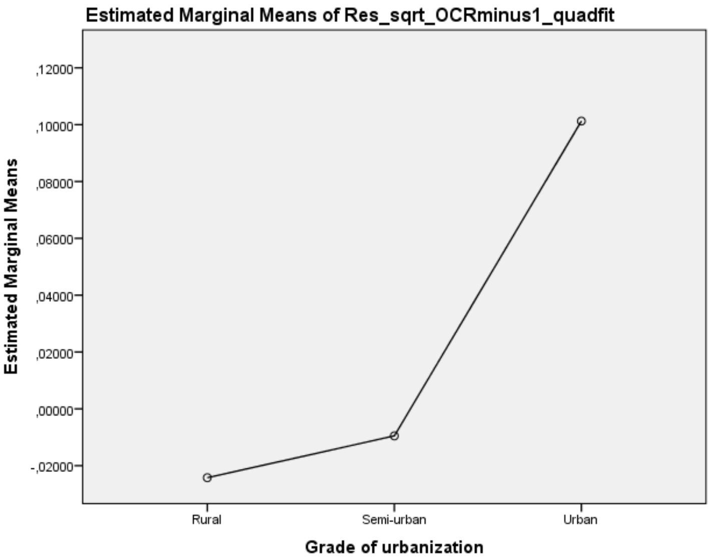


Figure 116: The main effect of Urbanization on OCR in the data set Göteborg.

The residuals of $\sqrt{OCR - 1}$ from a quadratic fit against the sampling depth seem to follow a clear grouping of low values in rural and semi-urban areas compared to urban areas, as can be seen in Figure 116. This indicates that the difference between σ'_C and σ'_0 generally is larger in urban areas. The result could be interpreted as an indication of that the aging process has generally advanced further in urban areas compared to semi-urban and rural areas, giving comparatively higher values of σ'_C.

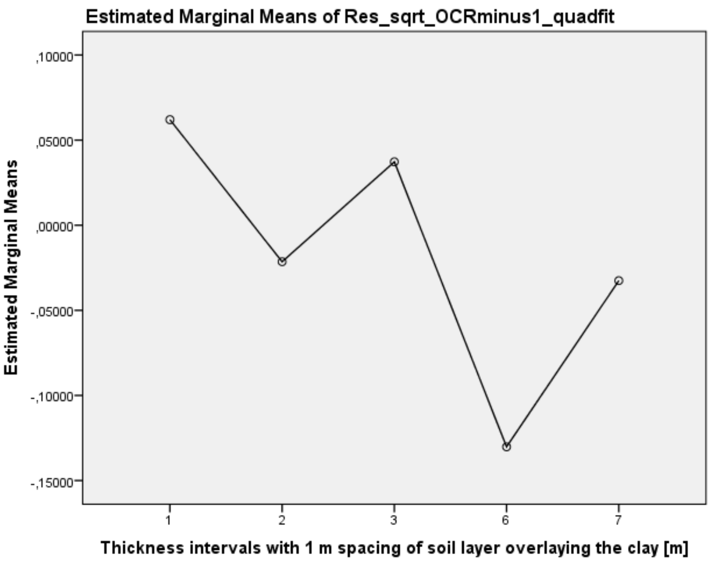


Figure 117: The main effect of Overlaying_layer_INT on OCR in the data set Göteborg.

The value jumps up and down with a slight indication of a negative trend in the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth toward thicker layers of soil overlaying the clay, as can be seen in Figure 117. The weak trend could be explained by the fact that thicker layers would mean higher effective stresses and thus, lower OCR-values. However, the volatility of the value in this result still means that the relationship is very weak.

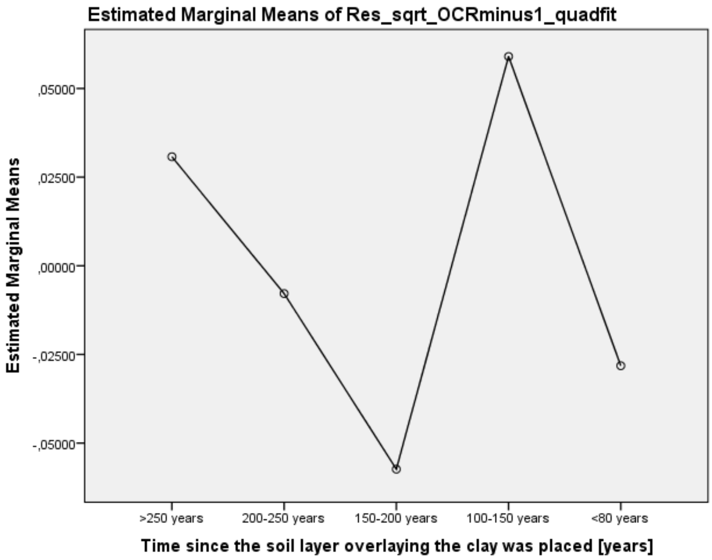


Figure 118: The main effect of Time_overlaying_layer on OCR in the data set Göteborg.

The plot in Figure 118 indicates that there is no clear trend of the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth over the time since the soil layer overlaying the clay was placed. The full-factorial ANOVA has an R^2 of 0.339, giving a low grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 70 and 71.

Table 70: Groups statistics, Zone, OCR, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0695302	,71888421	,06854292
Götatunneln, Göteborg	79	-,0968142	,75213663	,08462198

Table 71: Independent Groups T-test output, Zone, OCR, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,050	,823	1,539	187	,126	,16634444	,10809063	-,04688929	,37957818
Equal variances not assumed			1,528	163,547	,129	,16634444	,10889909	-,04868500	,38137389

The independent group's *T-test* shows that there is no significant difference in the mean values of the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area.

6.6.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 72. For the complete output from this one-way ANOVA, see Appendix B. page 50.

Table 72: One-way ANOVA, OCR, Stockholm.

Source	F
Corrected Model	1,489
Intercept	,054
Depth_INT	,737
Soil_type_map	4,174
Zone	3,344
Urbanization	2,626
Overlaying_layer__INT	,241
Time_overlying_layer	,840

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along the variables Soil_type_map, Zone and Urbanization, since each of them show an F-factor higher than 1, see Table 73 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 51.

Table 73: Full-factorial ANOVA, OCR, Stockholm.

Source	F	Sig.
Corrected Model	2,907	,000
Intercept	1,063	,304
Soil_type_map	2,411	,017
Zone	3,634	,007
Urbanization	3,997	,020

The plots from all observations with significant main effects or interactions are presented below.

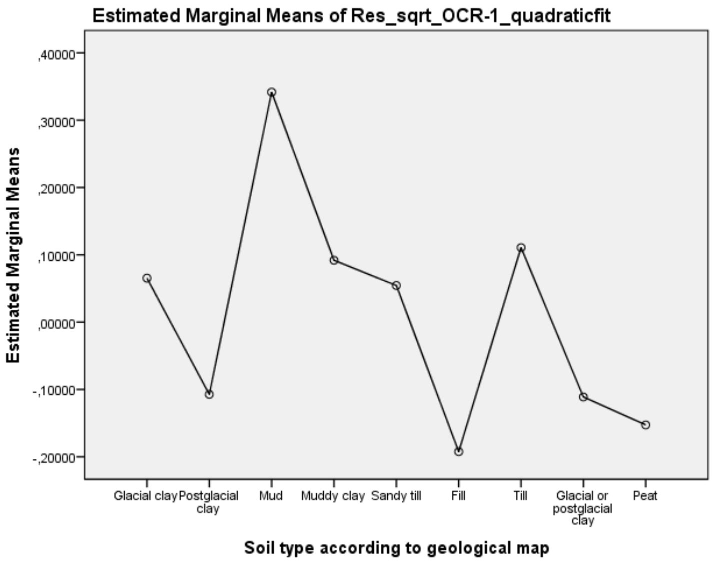


Figure 119: The main effect of Soil_type_map on OCR in the data set Stockholm.

The plot in Figure 119 indicates no clear grouping of the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth over the soil type according to the geological map.

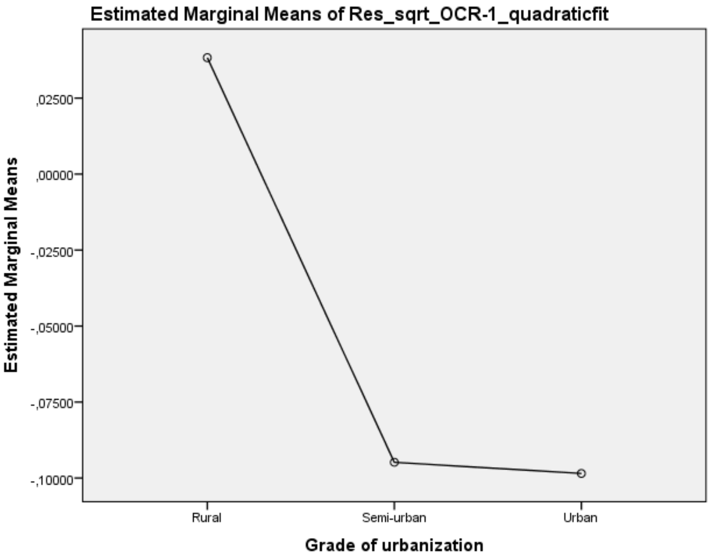


Figure 120: The main effect of Urbanization on OCR in the data set Stockholm.

The residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth seem to follow a clear grouping of low values in semi-urban and urban areas compared to rural areas, as can be seen in Figure 120. This indicates that the difference between σ'_C and σ'_0 generally is larger in rural areas. The behavior in this result for the data set Stockholm is the opposite of the one observed for the data set Göteborg. It is hard to say what is causing this difference in behavior between the two data sets. This is further evaluated in the discussion chapter.

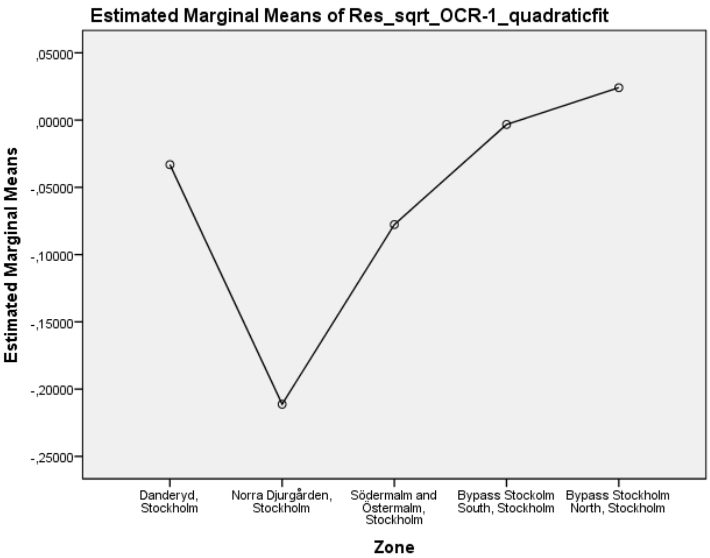


Figure 121: The main effect of Zone on OCR in the data set Stockholm.

The plot in Figure 121 indicates that the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth are generally low in the zone Norra Djurgården compared to the other specified zones. This indicates that the difference between σ'_C and σ'_0 generally is lower in the zone Norra

Djurgården compared to the other zones. It is hard to say what is causing this deviation. The full-factorial ANOVA has an R^2 of 0.237, giving a low grade of explanation for these results.

6.6.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 74. For the complete output from this one-way ANOVA, see Appendix B. page 52.

Table 74: One-way ANOVA, OCR, All obs. 3-8 m.

Source	F
Corrected Model	1,487
Intercept	,165
Zone	3,216
Depth_INT	,220
Urbanization	1,845
Soil_type_map	3,401
Overlaying_layer__INT	,759
Time_overlying_layer	,482

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along the variables Zone, Urbanization and Soil_type_map, since each of them show an *F*-factor higher than 1, see Table 74 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 52.

Table 75: Full-factorial ANOVA, OCR, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	2,641	,000
Intercept	,446	,505
Zone	5,208	,000
Urbanization	4,796	,009
Soil_type_map	2,152	,027

The plots from all observations with significant main effects or interactions are presented below.

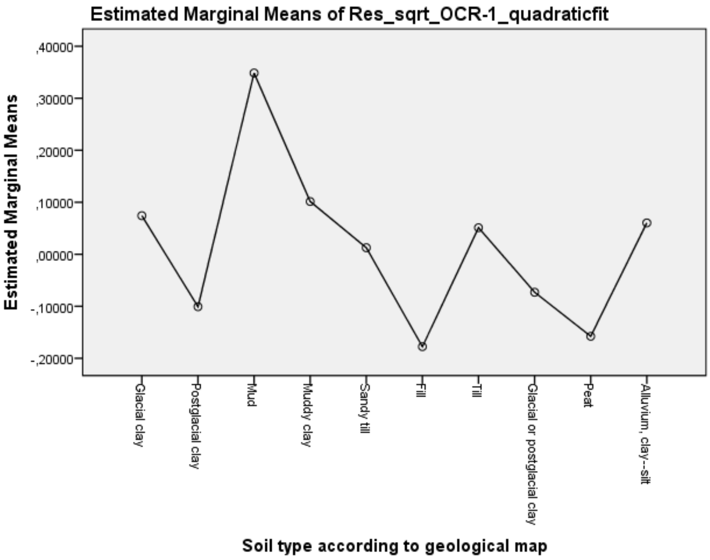


Figure 122: The main effect of Soil_type_map on OCR in the data set All obs. 3-8 m.

The plot in Figure 122 indicates no clear grouping of the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth over the soil type according to the geological map.

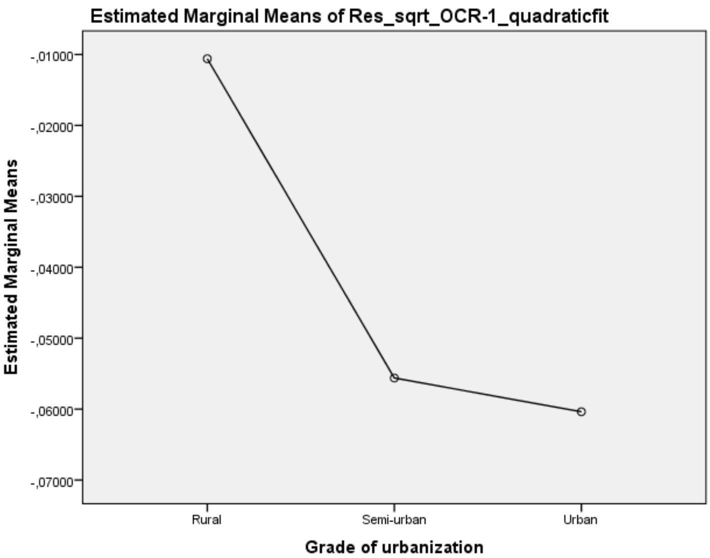


Figure 123: The main effect of Urbanization on OCR in the data set All obs. 3-8 m.

The residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth seem to follow a clear grouping of low values in semi-urban and urban areas compared to rural areas, as can be seen in Figure 123. This indicates that the difference between σ_C' and σ_0' generally is larger in rural areas. The behavior in this result for the data set All observations from 3-8 meters is very similar to the one observed for the data set Stockholm and they are both the opposite of the one observed for the data set Göteborg. It is hard to say what is causing this difference in behavior between the data sets. This is further evaluated in the discussion chapter.

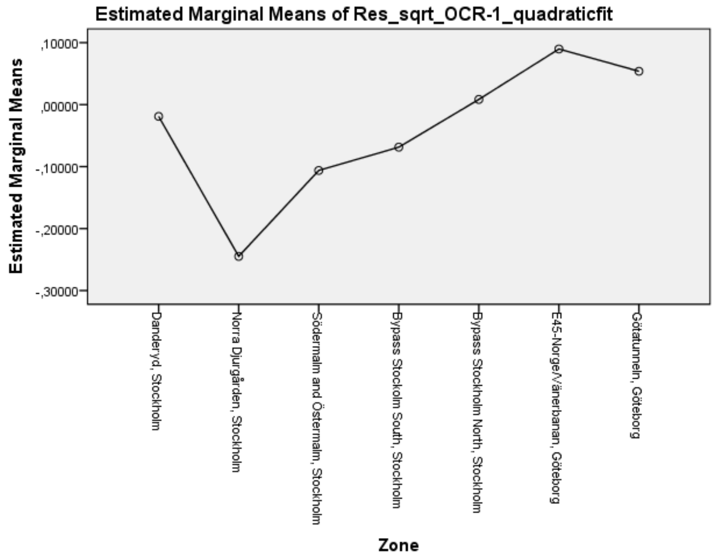


Figure 124: The main effect of Zone on OCR in the data set All obs. 3-8 m.

The plot in Figure 124 indicates that the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth are generally well spread over all zones. The difference between zones is hard to explain. The full-factorial ANOVA has an R^2 of 0.275, giving a low grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 76 and 77.

Table 76: Group statistics, City, OCR, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	,0447868	,20540595	,02848468
Stockholm	172	-,0135402	,29378736	,02240108

Table 77: Independent Groups T-test output, City, OCR, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	4,696	,031	1,335	222	,183	,05832700	,04367830	-,02775015	,14440414
Equal variances not assumed			1,610	119,912	,110	,05832700	,03623790	-,01342206	,13007605

The independent groups *T-test* shows that there is no significant difference in the mean values of the residuals of $\sqrt{OCR-1}$ from a quadratic fit against the sampling depth between the two cities.

6.7 CLR

In this chapter, the results from the analysis of CLR are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.7.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 78. For the complete output from this one-way ANOVA, see Appendix B. page 54.

Table 78: One-way ANOVA, CLR, Göteborg.

Source	F
Corrected Model	,856
Intercept	,951
Depth_INT	,859
Urbanization	,015
Soil_type_map	1,006
Overlaying_layer__INT	,629
Time_overlying_layer	,703

Since there is only one single variable showing an F-factor higher than 1, Soil_type_map, it is of no use to perform a full-factorial ANOVA. Instead, all other variables are removed and a second one-way ANOVA is performed, see Table 79 for result. For the complete output from this second one-way ANOVA, see Appendix B. page 54.

Table 79: Full-factorial ANOVA, CLR, Göteborg.

Source	F	Sig.
Corrected Model	2,354	,098
Intercept	,032	,858
Soil_type_map	2,354	,098

The corrected model is not significant and therefore, the main effect is not significant.

***T*-test**

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 80 and 81.

Table 80: Group statistics, Zone, CLR, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0068232	,12113030	,01154932
Götatunneln, Göteborg	79	-,0095006	,10127163	,01139395

Table 81: Independent Group T-test output, Zone, CLR, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	3,215	,075	,977	187	,330	,01632375	,01670475	-,01663022	,04927773
Equal variances not assumed			1,006	182,648	,316	,01632375	,01622371	-,01568624	,04833374

The independent groups *T*-test shows that there is no significant difference in the mean values of the residuals of $\sqrt{CLR-1}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area.

6.7.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 82. For the complete output from this one-way ANOVA, see Appendix B. page 55.

Table 82: One-way ANOVA, CLR, Stockholm.

Source	F
Corrected Model	1,009
Intercept	1,376
Soil_type_map	,373
Zone	2,138
Urbanization	1,818
Depth_INT	,697

Source	F
Overlaying_layer__INT	1,317
Time_overlying_layer	,324

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along the variables Zone, Urbanization and Overlaying_layer_INT, since each of them show an *F*-factor higher than 1, see Table 83 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 56.

Table 83: Full-factorial ANOVA, CLR, Stockholm.

Source	F	Sig.
Corrected Model	1,268	,186
Intercept	3,199	,075
Zone	,905	,440
Urbanization	,620	,539
Overlaying_layer__INT	1,405	,225
Zone * Urbanization	,634	,594
Zone * Overlaying_layer__INT	1,237	,297
Urbanization * Overlaying_layer__INT	,338	,798
Zone * Urbanization * Overlaying_layer__INT	2,220	,112

The corrected model is not significant and therefore, none of the main effects or interactions is significant.

6.7.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 84. For the complete output from this one-way ANOVA, see Appendix B. page 57.

Table 84: One-way ANOVA, CLR, All obs. 3-8 m.

Source	F
Corrected Model	1,259
Intercept	4,136
Zone	2,689
Urbanization	,835
Soil_type_map	,510
Depth_INT	1,088
Overlaying_layer__INT	1,760
Time_overlying_layer	,438

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Urbanization and Soil_type_map, since each of them show an *F*-factor higher than 1, see Table 85 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 58.

Table 85: Full-factorial ANOVA, CLR, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	,864	,764
Intercept	2,476	,118
Zone	1,893	,086
Overlaying_layer__INT	1,832	,097
Depth_INT	,992	,425

The corrected model is not significant and therefore, none of the main effects is significant.

T-test

Results from the independent groups T-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 86 and 87.

Table 86: Group statistics, City, CLR, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	,0502256	,14520747	,02013665
Stockholm	172	-,0151845	,18090087	,01379356

Table 87: Independent Groups T-test output, City, CLR, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	3,278	,072	2,384	222	,018	,06541004	,02743394	,01134577	,11947432
Equal variances not assumed			2,680	103,306	,009	,06541004	,02440793	,01700437	,11381572

The independent groups T-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{CLR-1}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's p-value (0.072) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 125.

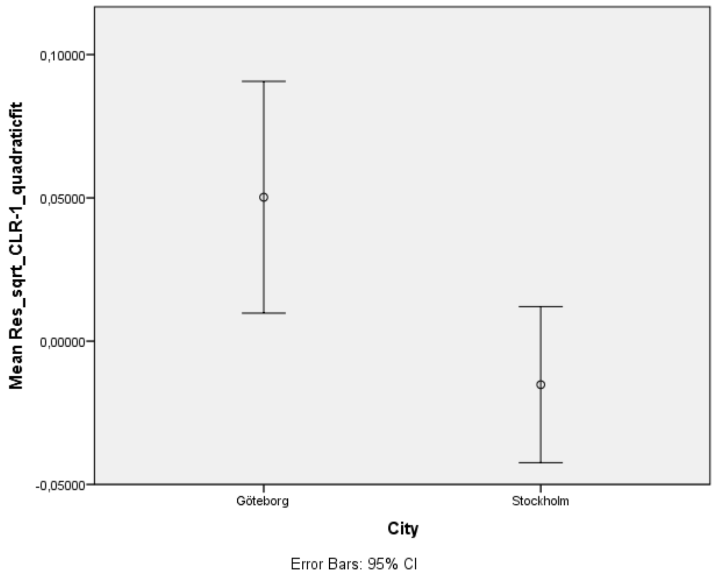


Figure 125: The effect of City on CLR in the data set All obs. 3-8 m.

This indicates that there is a relationship between CLR and the two cities that were investigated, where values tend to be higher in Göteborg than in Stockholm. This means that there is generally a bigger difference between σ_C' and σ_L' in Göteborg than in Stockholm.

6.8 Density

In this chapter, the results from the analysis of the density are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.8.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 88. For the complete output from this one-way ANOVA, see Appendix B. page 59.

Table 88: One-way ANOVA, density, Göteborg.

Source	F
Corrected Model	3,520
Intercept	,835
Depth_INT	1,407
Urbanization	2,040
Soil_type_map	1,110
Overlaying_layer__INT	3,090
Time_overlying_layer	5,788

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 89 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 60.

Table 89: Full-factorial ANOVA, density, Göteborg.

Source	F	Sig.
Corrected Model	1,435	,115
Intercept	2,943	,096
Depth_INT	1,346	,210
Urbanization	,970	,332
Soil_type_map	.	.
Overlaying_layer__INT	2,299	,080

Source	F	Sig.
Time_overlying_layer	4,157	,014

The corrected model is not significant and therefore, none of the main effects are significant.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 90 and 91.

Table 90: Group statistics, Zone, density, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,0061557	,01662178	,00158482
Götatunneln, Göteborg	79	,0085712	,02120124	,00238533

Table 91: Independent Groups T-test output, Zone, density, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	6,398	,012	-5,349	187	,000	-,01472696	,00275323	-,02015834	-,00929559
Equal variances not assumed			-5,142	142,230	,000	-,01472696	,00286382	-,02038811	-,00906582

The independent group's *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{\rho}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area. Since the Levene's *p*-value (0.012) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 126.

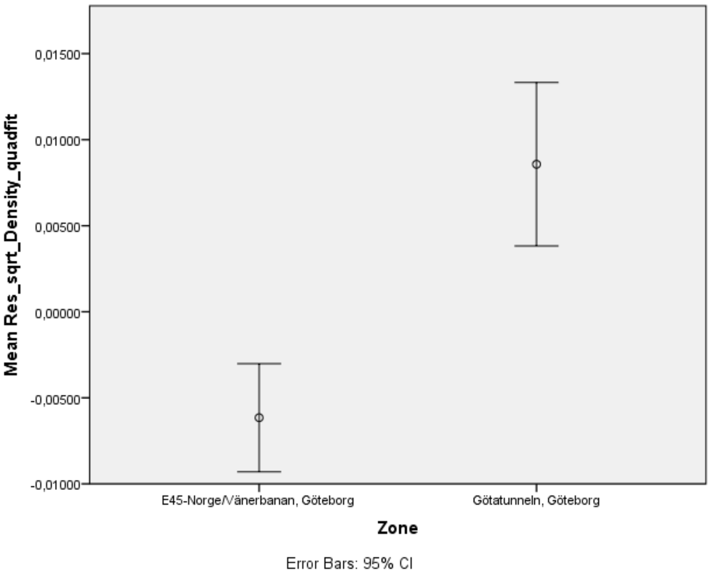


Figure 126: The effect of Zone on the density in the data set Göteborg.

This indicates that there is a relationship between the density and the zones that were investigated, where values of ρ tend to be lower at E45-Norge/Vänerbanan than at Götatunneln. This is connected to the same relationship for σ_0', since higher values of σ_0' are connected to higher density. One explanation is that it is just two different clay masses with significantly different density due to varying composition and sedimentation processes. According to laboratory protocols, it should be postglacial clay at both sites but within this category, density varies.

6.8.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 92. For the complete output from this one-way ANOVA, see Appendix B. page 63.

Table 92: One-way ANOVA, density, Stockholm.

Source	F
Corrected Model	2,923
Intercept	,367
Urbanization	2,574
Depth_INT	1,882
Zone	3,550
Soil_type_map	2,079
Overlaying_layer__INT	3,130
Time_overlying_layer	2,911

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 93 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 63.

Table 93: Full-factorial ANOVA, density, Stockholm.

Source	F	Sig.
Corrected Model	1,023	,481
Intercept	2,680	,109
Urbanization	1,220	,305
Depth_INT	1,177	,329
Zone	,822	,489
Soil_type_map	1,074	,387
Overlaying_layer__INT	,570	,723
Time_overlying_layer	1,250	,270

The corrected model is not significant and therefore, none of the main effects are significant.

6.8.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 94. For the complete output from this one-way ANOVA, see Appendix B. page 67.

Table 94: One-way ANOVA, density, All obs. 3-8 m.

Source	F
Corrected Model	9,957
Intercept	,188
Zone	23,201
Soil_type_map	2,405
Depth_INT	,938
Time_overlying_layer	1,714
Urbanization	3,803
Overlaying_layer__INT	2,603

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 95 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 68.

Table 95: Full-factorial ANOVA, density, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	6,619	,000
Intercept	5,609	,019
Zone	21,349	,000
Soil_type_map	1,105	,360
Time_overlying_layer	1,250	,289
Urbanization	2,531	,083
Overlaying_layer__INT	1,063	,387

The plots from all observations with significant main effects or interactions are presented below.

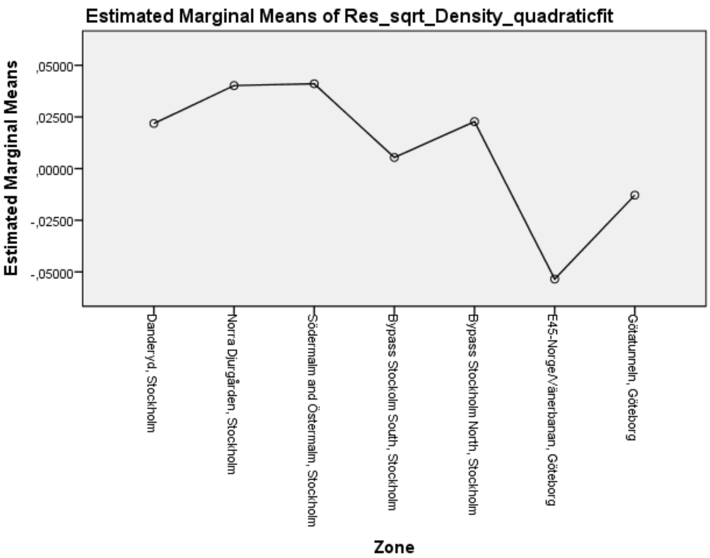


Figure 127: The main effect of Zone on the density in the data set All obs. 3-8 m.

The plot in Figure 127 indicates that the residuals of $\sqrt{\rho}$ from a quadratic fit against the sampling depth are generally higher in the zones located in Stockholm than in the zones located in Göteborg. This behavior is similar to the one in the result of the analysis of the compression modulus M', see Figure X. Both of these clay parameters are most likely dependent on the local clay structure rather than any of the investigated external factors. The full-factorial ANOVA has an R^2 of 0.709, giving a moderate grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 96 and 97.

Table 96: Group statistics, City, density, All obs. 3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-,0460105	,02578823	,00357618
Stockholm	172	,0139101	,03273140	,00249575

Table 97: Independent Groups T-test output, City, density, All obs. 3-8 m.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	3,161	,077	-12,107	222	,000	-,05992060	,00494912	-,06967387	-,05016732
Equal variances not assumed			-13,740	105,324	,000	-,05992060	,00436094	-,06856723	-,05127396

The independent groups *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{\rho}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's *p*-value (0.077) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 128.

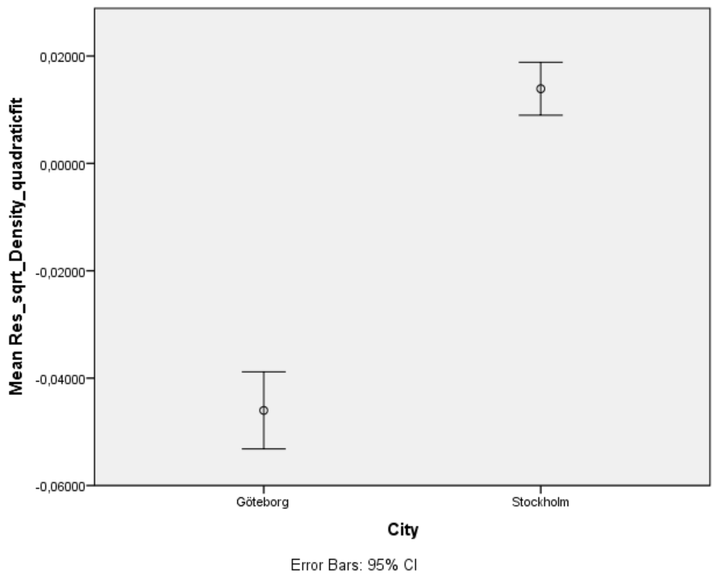


Figure 128: The effect of City on the density in the data set All obs. 3-8 m.

This indicates that there is a relationship between the density and the two cities that were investigated, where values of ρ tend to be lower in Göteborg than in Stockholm. This result confirms the grouping of values in the result from the ANOVA of the same clay parameter against the specified zones, see Figure X.

6.9 Water content (w)

In this chapter, the results from the analysis of the water content are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.9.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 98. For the complete output from this one-way ANOVA, see Appendix B. page 71.

Table 98: One-way ANOVA, water content, Göteborg.

Source	F
Corrected Model	3,679
Intercept	,115
Depth_INT	1,260
Urbanization	5,166
Soil_type_map	3,554
Overlaying_layer__INT	1,733
Time_overlying_layer	5,758

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 99 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 72.

Table 99: Full-factorial ANOVA, water content, Göteborg.

Source	F	Sig.
Corrected Model	1,303	,191
Intercept	3,317	,078
Depth_INT	1,022	,472
Urbanization	1,878	,180
Soil_type_map	.	.
Overlaying_layer__INT	1,834	,147

Source	F	Sig.
Time_overlying_layer	2,364	,090

The corrected model is not significant and therefore, none of the main effects are significant.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 100 and 101.

Table 100: Group statistics, Zone, water content, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,1781623	,43807797	,04176910
Götatunneln, Göteborg	79	-,2480741	,55162857	,06206306

Table 101: Independent Groups T-test output, Zone, water content, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	5,133	,025	5,915	187	,000	,42623645	,07206550	,28407061	,56840229
Equal variances not assumed			5,698	143,582	,000	,42623645	,07480963	,27836595	,57410695

The independent group's *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{w}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area. Since the Levene's *p*-value (0.025) is smaller than 0.05, equal variances cannot be assumed. An error bar graph showing the same values is also presented in Figure 129.

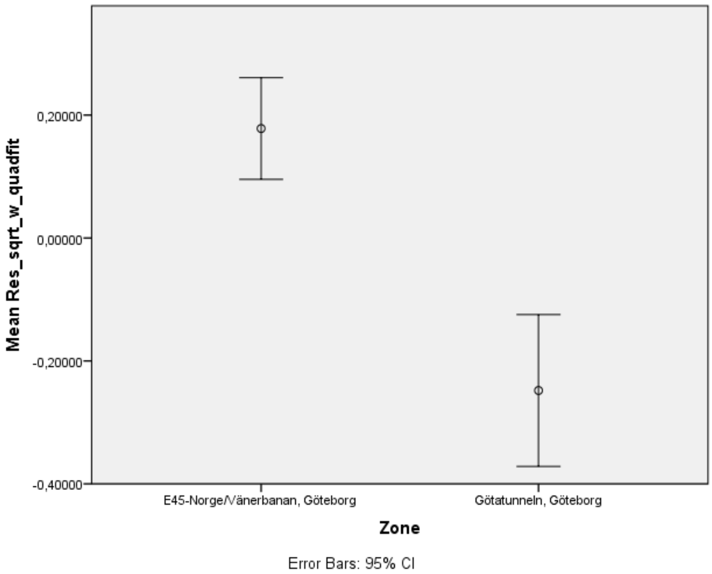


Figure 129: The effect of Zone on the water content in the data set Göteborg.

This indicates that there is a relationship between the water content and the zones that were investigated, where values of *w* tend to be higher at E45-Norge/Vänerbanan than at Götatunneln. It is hard to say what could be causing this difference. One observation is that there seems to be a clear correlation between high effective stress, high density and low water content.

6.9.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 102. For the complete output from this one-way ANOVA, see Appendix B. page 75.

Table 102: One-way ANOVA, water content, Stockholm.

Source	F
Corrected Model	3,187
Intercept	,807
Urbanization	,977
Depth_INT	2,185
Zone	3,988
Soil_type_map	2,666
Overlaying_layer__INT	3,174
Time_overlying_layer	,701

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 103 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 75.

Table 103: Full-factorial ANOVA, water content, Stockholm.

Source	F	Sig.
Corrected Model	1,672	,007
Intercept	,322	,572
Depth_INT	1,969	,043
Zone	2,981	,036
Soil_type_map	3,797	,002
Overlaying_layer__INT	1,939	,097

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 104 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 76.

Table 104: Second full-factorial ANOVA, water content, Stockholm.

Source	F	Sig.
Corrected Model	2,022	,000
Intercept	,500	,481
Depth_INT	1,849	,053
Zone	5,253	,001
Soil_type_map	4,419	,000
Depth_INT * Zone	,711	,815
Depth_INT * Soil_type_map	1,554	,052
Zone * Soil_type_map	2,943	,036
Depth_INT * Zone * Soil_type_map	1,269	,282

The plots from all observations with significant main effects or interactions are presented below.

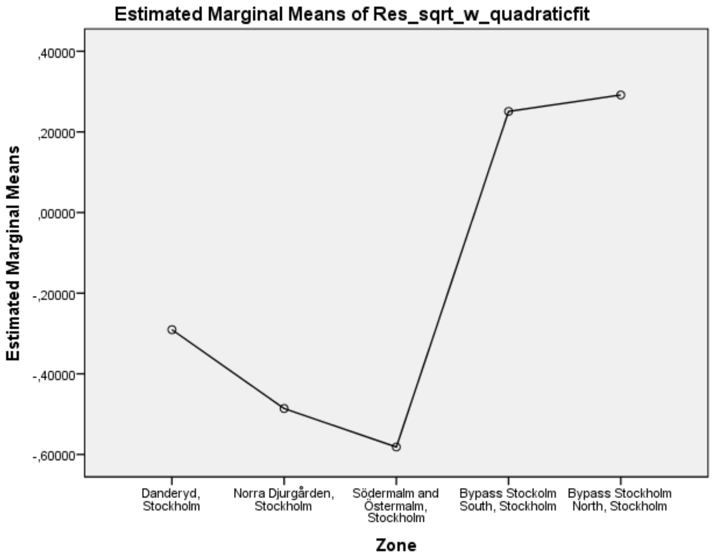


Figure 130: The main effect of Zone on the water content in the data set Stockholm.

The plot in Figure 130 indicates that the residuals of $\sqrt{w}$ from a quadratic fit against the sampling depth are generally low in the zones Danderyd, Norra Djurgården and Södermalm and Östermalm compared to the zones Bypass Stockholm-South and Bypass Stockholm-North. This behavior seems to be opposite to the one over the same zones in the result of the analysis of the density for the data set with all observations from 3-8 meters, see Figure X. Hence, there seems to be a relationship between high values of ρ and low values of w and vice versa. Both of these clay parameters are most likely dependent on the local clay structure rather than any of the investigated external factors.

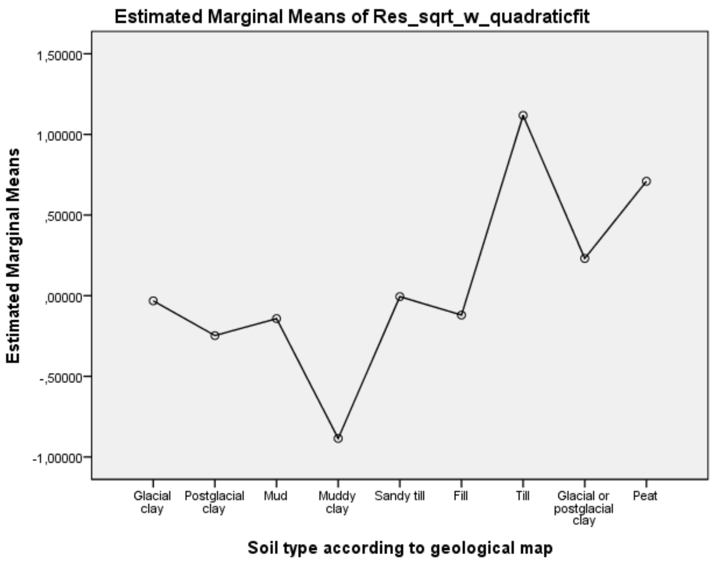


Figure 131: The main effect of Soil_type_map on the water content in the data set Stockholm.

The plot in Figure 131 indicates no clear grouping of the residuals of $\sqrt{w}$ from a quadratic fit against the sampling depth over the soil type according to the geological map.

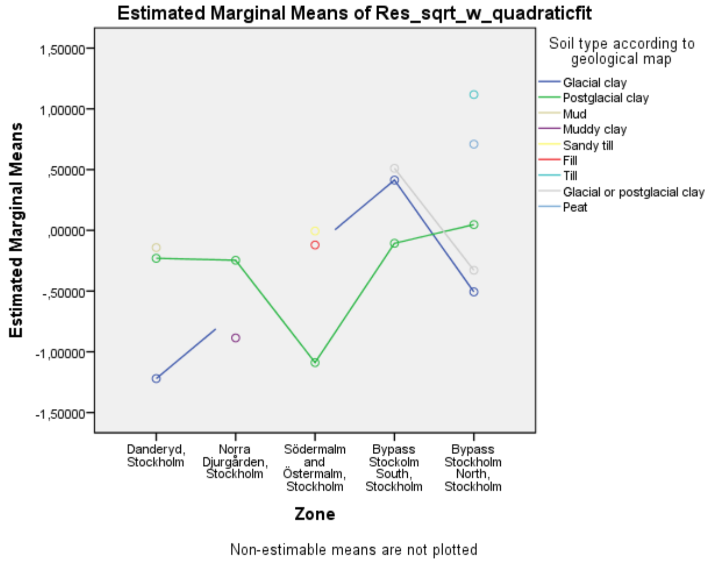


Figure 132: The interaction of Zone and Soil_type_map on the water content in the data set Stockholm.

The plot in Figure 132 indicates that the residuals of $\sqrt{w}$ from a quadratic fit against the sampling depth are generally low in the zones Danderyd, Norra Djurgården and Södermalm and Östermalm compared to the zones Bypass Stockholm-South and Bypass Stockholm-North. At the same time, there seems to be no clear grouping of the residuals over the soil type according to the geological map and hence, this result indicates that the interaction between the zone and the soil type according to the geological map is diffuse. The full-factorial ANOVA has an R^2 of 0.587, giving a moderate grade of explanation for these results

6.9.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 105. For the complete output from this one-way ANOVA, see Appendix B. page 77.

Table 105: One-way ANOVA, water content, All obs. 3-8m.

Source	F
Corrected Model	11,470
Intercept	,500
Zone	24,343
Soil_type_map	2,947
Time_overlying_layer	1,383
Urbanization	2,363

Source	F
Overlaying_layer__INT	2,398
Depth_INT	1,157

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables, since each of them show an *F*-factor higher than 1, see Table 106 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 77.

Table 106: Full-factorial ANOVA, water content, All obs. 3-8m.

Source	F	Sig.
Corrected Model	1,793	,010
Intercept	1,485	,229
Zone	10,577	,000
Soil_type_map	1,085	,381
Depth_INT	1,423	,233
Urbanization	,992	,379
Overlaying_layer__INT	,705	,647
Time_overlying_layer	1,342	,271

The plots from all observations with significant main effects or interactions are presented below.

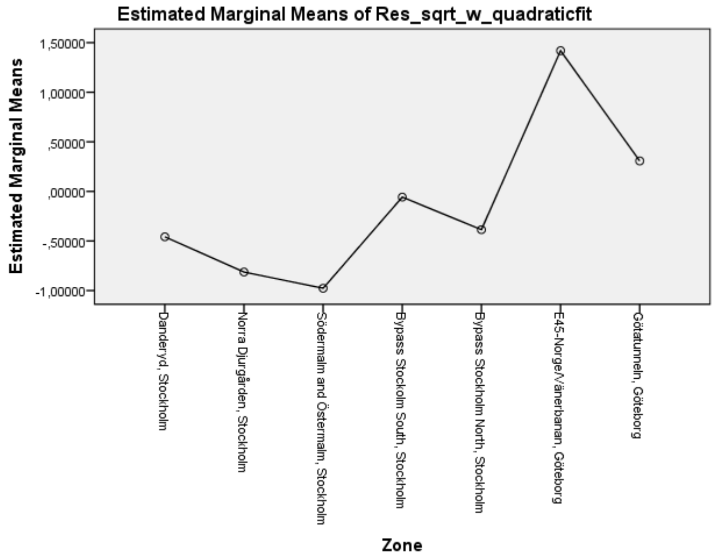


Figure 133: The main effect of Zone on the water content in the data set All obs. 3-8m.

The plot in Figure 133 indicates that the residuals of $\sqrt{w}$ from a quadratic fit against the sampling depth are generally higher in the zones located in Göteborg than in the zones located in Stockholm. This behavior seems to be opposite to the one in the result of the analysis of the density for the data set with all observations from 3-8 meters, see Figure X. Hence, there seems to be a relationship between high values of ρ and low values of w and vice versa. Both of these clay parameters are most likely dependent on the local clay structure rather than any of the investigated external factors. The full-factorial ANOVA has an R^2 of 0.870, giving a good grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 107 and 108.

Table 107: Group statistics, City, water content, All obs.3-8 m.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	1,1843419	,70803131	,09818628
Stockholm	172	-,3580569	,76749233	,05852074

Table 108: Independent Groups T-test output, City, water content, All obs.3-8 m.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,120	,730	12,922	222	,000	1,54239876	,11936358	1,30716807	1,77762945
Equal variances not assumed			13,494	90,272	,000	1,54239876	,11430320	1,31532483	1,76947269

The independent groups *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{w}$ from a quadratic fit against the sampling depth between the two cities. Since the

Levene's *p*-value (0.730) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 134.

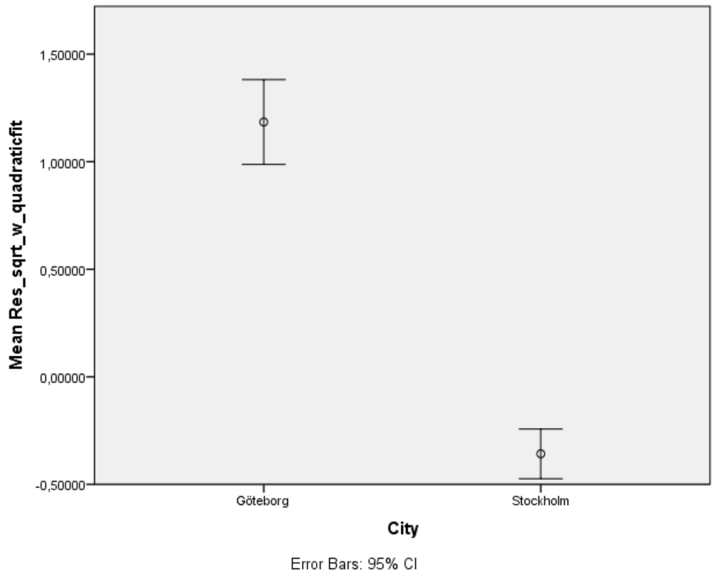


Figure 134: The effect of City on the water content in the data set All obs.3-8 m.

This indicates that there is a relationship between the water content and the two cities that were investigated, where values of *w* tend to be higher in Göteborg than in Stockholm. It is hard to say what could be causing this difference. One observation is that there seems to be a clear correlation between high effective stress, high density and low water content.

6.10 Liquid limit (w_L)

In this chapter, the results from the analysis of the liquid limit are presented for the three data sets. First the result from the data set Göteborg is presented followed by the one for Stockholm and finally for All observations from 3-8 meters.

6.10.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 109. For the complete output from this one-way ANOVA, see Appendix B. page 83.

Table 109: One-way ANOVA, liquid limit, Göteborg.

Source	F
Corrected Model	1,890
Intercept	,010
Depth_INT	,819

Source	F
Urbanization	,845
Soil_type_map	,333
Overlaying_layer__INT	2,299
Time_overlying_layer	2,319

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along the variables Overlaying_layer_INT and Time_overlaying_layer, since both of them show an *F*-factor higher than 1, see Table 110 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 84.

Table 110: Full-factorial ANOVA, liquid limit, Göteborg.

Source	F	Sig.
Corrected Model	4,859	,000
Intercept	,068	,795
Overlaying_layer__INT	4,389	,002
Time_overlying_layer	5,623	,000
Overlaying_layer__INT * Time_overlying_layer	5,485	,001

The plots from all observations with significant main effects or interactions are presented below.

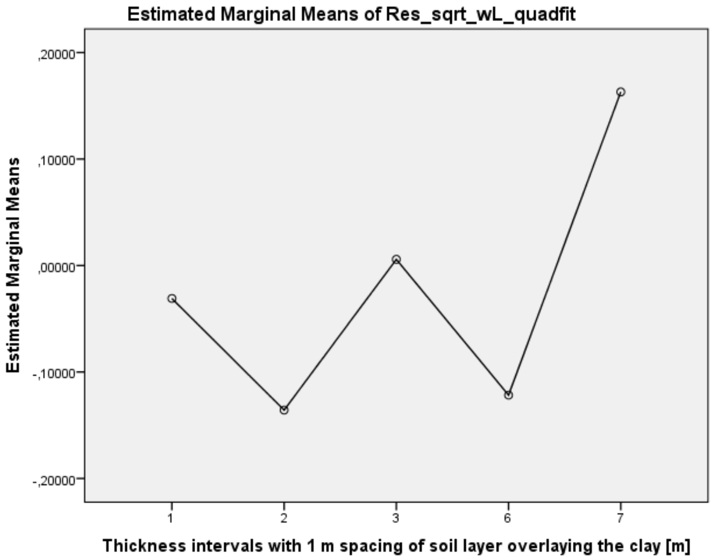


Figure 135: The main effect of Overlaying_layer_INT on the liquid limit in the data set Göteborg.

The value jumps up and down without any clear trend or grouping in Figure 135, which indicates that there is no relationship between the residuals of $\sqrt{w_L}$ from a quadratic fit against sampling depth and the thickness of the soil layer overlaying the clay, as can be seen.

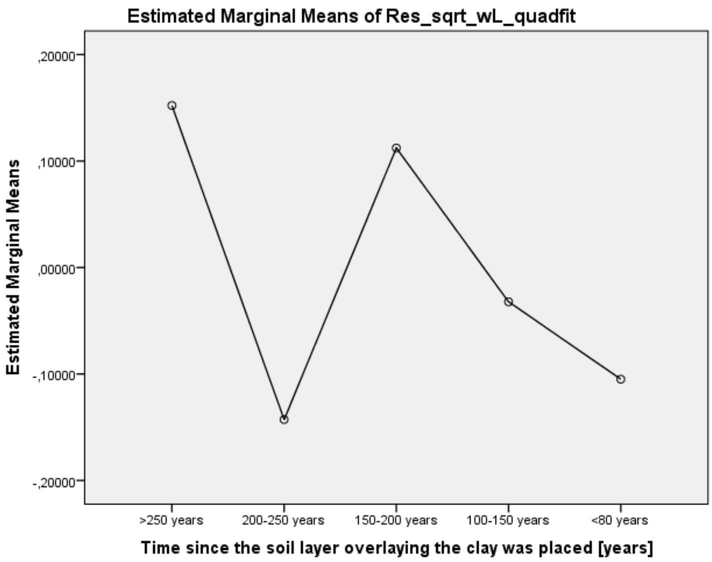


Figure 136: The main effect of Time_overlaying_layer on the liquid limit in the data set Göteborg.

The value jumps up and down without any clear trend which indicates that there is no relationship between the residuals of $\sqrt{w_L}$ from a quadratic fit against sampling depth and the time since the soil layer overlaying the clay was placed, as can be seen in Figure 136.

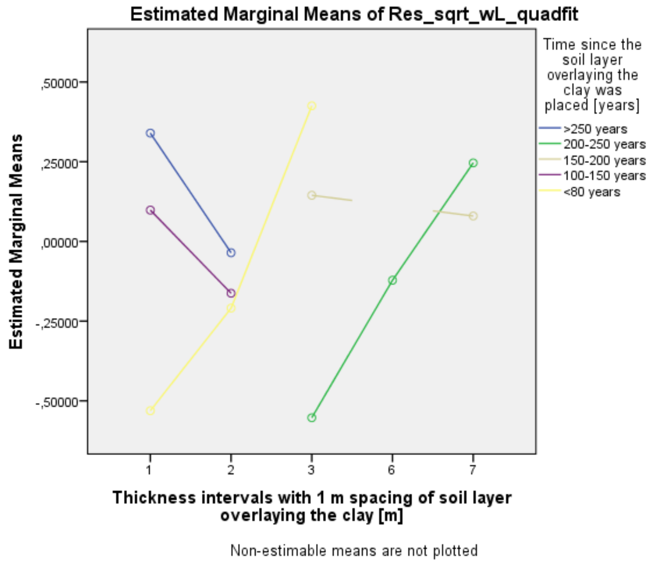


Figure 137: The interaction of Overlaying_layer_INT and Time_overlaying_layer on the liquid limit in the data set Göteborg.

The value jumps up and down without any clear trend or grouping of values over any of the independent variables which indicates that there is no relationship between the residuals of $\sqrt{w_L}$ from a quadratic fit against sampling depth and the thickness of the soil layer overlaying the clay or the time since the soil layer overlaying the clay was placed, as can be seen in Figure 137. The interaction between the independent variables is diffuse. This clay parameter is most likely dependent on the local clay structure rather than any of the investigated external factors. The full-factorial ANOVA has an R^2 of 0.232, giving a poor grade of explanation for these results.

T-test

Results from the independent groups *T*-test of the variable Zone in Göteborg are presented in Tables 111 and 112.

Table 111: Group statistics, Zone, liquid limit, Göteborg.

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0146965	,61883961	,05900404
Götatunneln, Göteborg	79	-,0204634	,53164538	,05981478

Table 112: Independent Groups Test output s, Zone, liquid limit, Göteborg.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,358	,551	,408	187	,684	,03515987	,08613394	-,13475923	,20507897
Equal variances not assumed			,418	181,008	,676	,03515987	,08401955	-,13062384	,20094358

The independent group's *T*-test shows that there is no significant difference in the mean values of the residuals of $\sqrt{w_L}$ from a quadratic fit against the sampling depth between the specified zones within the Göteborg area.

6.10.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 113. For the complete output from this one-way ANOVA, see Appendix B. page 85.

Table 113: One-way ANOVA, liquid limit, Stockholm.

Source	F
Corrected Model	2,187
Intercept	,308
Depth_INT	2,369
Zone	3,043
Soil_type_map	2,227
Urbanization	1,373
Overlaying_layer__INT	,261
Time_overlying_layer	,753

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Overlaying_layer_INT and Time_overlaying_layer, since each of them show an *F*-factor higher than 1, see Table 114 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 86.

Table 114: Full-factorial ANOVA, liquid limit, Stockholm.

Source	F	Sig.
Corrected Model	1,772	,002
Intercept	,301	,585
Depth_INT	2,861	,003
Zone	,186	,945
Soil_type_map	2,867	,007
Urbanization	1,832	,166

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 115 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 87.

Table 115: Second full-factorial ANOVA, liquid limit, Stockholm.

Source	F	Sig.
Corrected Model	2,095	,000
Intercept	1,538	,217
Depth_INT	2,634	,004
Soil_type_map	3,317	,002
Depth_INT * Soil_type_map	1,589	,036

The plots from all observations with significant main effects or interactions are presented below.

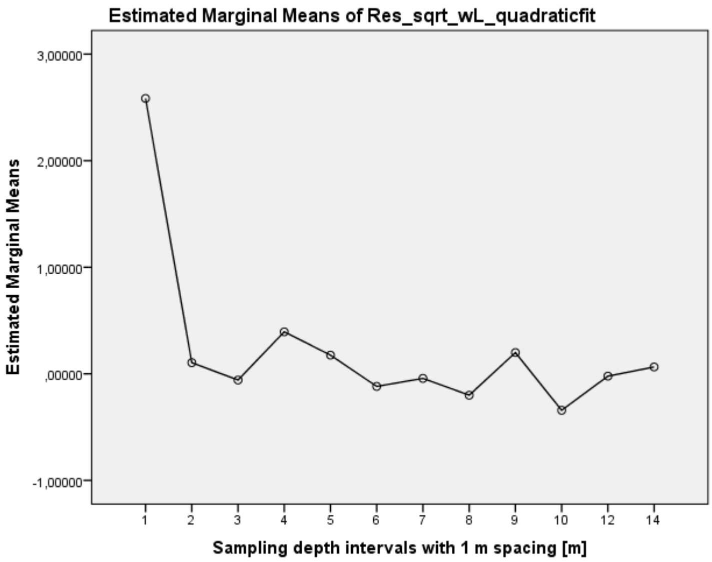


Figure 138: The main effect of Depth_INT on the liquid limit in the data set Stockholm.

The plot in Figure 138 indicates a clear grouping of the residuals of $\sqrt{w_L}$ from a quadratic fit against sampling depth and the sampling depth. At depths up to one meter, w_L is supposed to be much higher than at all other depths. However, the grouping in this result stems from one single observation that should probably have been removed as an outlier. The rest of the plot shows no trend or grouping of values which indicates that the normalization against depth successfully eliminated any intrinsic relationship to the sampling depth. Even though the observation that deviates should probably have been removed, it is interesting to discuss the surrounding conditions. It is the only observation in the data set Stockholm that was collected from a depth up to one meter from the ground surface and it is also the only observation where the material has been described as muddy clay in the geotechnical report. This has probably something to do with the much higher value of w_L.

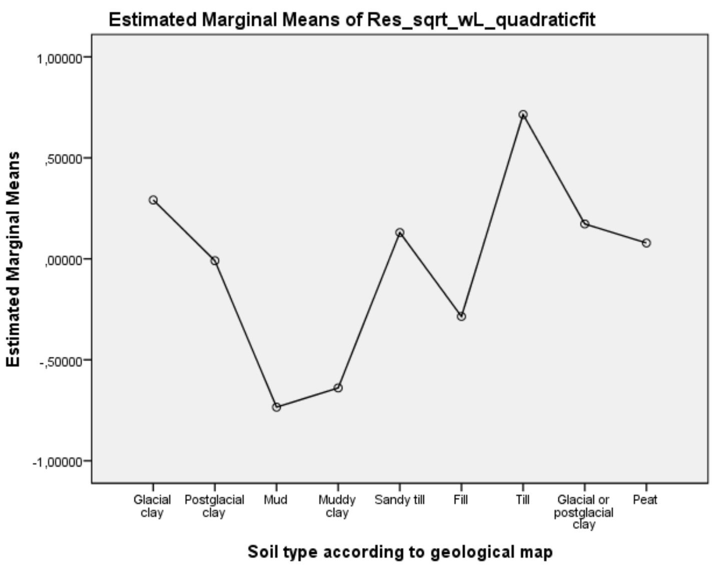


Figure 139: The main effect of Soil_type_map on the liquid limit in the data set Stockholm.

The plot in Figure 139 indicates no clear grouping of the residuals of $\sqrt{w_L}$ from a quadratic fit against the sampling depth over the soil type according to the geological map.

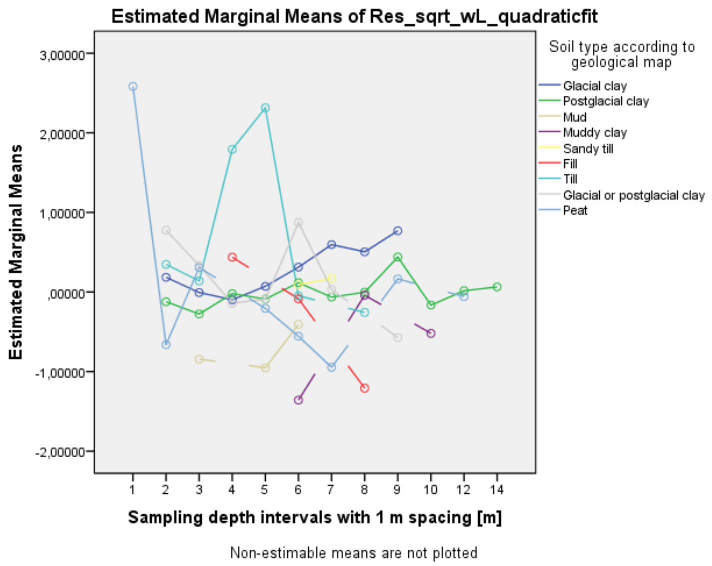


Figure 140: The interaction of Depth_INT and Soil_type_map on the liquid limit in the data set Stockholm.

The plot in Figure 140 indicates no clear grouping of the residuals of $\sqrt{w_L}$ from a quadratic fit against the sampling depth over the soil type according to the geological map other than the outlier, mentioned earlier, and for observations from between 4 and 5 meters where the geological map indicates till. The outlier is discussed earlier in the evaluation of the result of the ANOVA for the residuals against the sampling depth. The other deviation stems from six observations at two different locations. However, two of these observations deviate much from the others and they both come from the same sampling point. These should probably also have been removed as outliers. It is hard to say what causes them to deviate in such a way from the other observations. The full-factorial ANOVA has an R^2 of 0.410, giving a moderate grade of explanation for these results.

6.10.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA including all the independent variables are presented in Table 116. For the complete output from this one-way ANOVA, see Appendix B. page 87.

Table 116: One-way ANOVA, liquid limit, All obs. 3-8 m.

Source	F
Corrected Model	12,401
Intercept	,162
Zone	31,672
Soil_type_map	1,904
Depth_INT	2,901
Urbanization	1,096
Overlaying_layer__INT	,300
Time_overlying_layer	1,207

Full-factorial ANOVA

The full-factorial ANOVA is made carrying along all variables except Overlaying_layer_INT, since each of them show an *F*-factor higher than 1, see Table 117 for result. For the complete output from this full-factorial ANOVA, see Appendix B. page 88.

Table 117: Full-factorial ANOVA, liquid limit, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	2,913	,000
Intercept	1,258	,266
Zone	10,925	,000
Soil_type_map	1,722	,117
Depth_INT	3,854	,004
Urbanization	,291	,748
Overlaying_layer__INT	,618	,715

A second full-factorial ANOVA is made carrying along only significant main factors from the first one, see Table 118 for result. For the complete output from this second full-factorial ANOVA, see Appendix B. page 90.

Table 118: Second full-factorial ANOVA, liquid limit, All obs. 3-8 m.

Source	F	Sig.
Corrected Model	11,366	,000
Intercept	1,444	,231
Zone	47,745	,000
Depth_INT	3,495	,005
Zone * Depth_INT	1,200	,246

The plots from all observations with significant main effects or interactions are presented below.

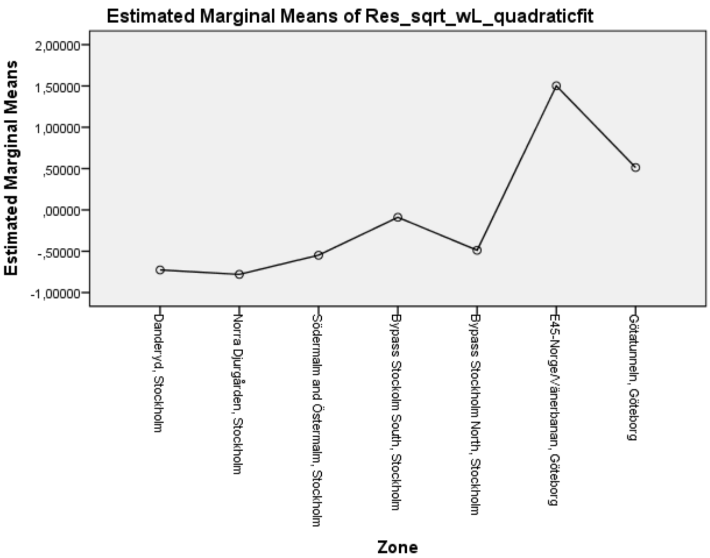


Figure 141: The main effect of Zone on the liquid limit in the data set All obs. 3-8 m.

The plot in Figure 141 indicates that the residuals of $\sqrt{w_L}$ from a quadratic fit against the sampling depth are generally higher in the zones located in Göteborg than in the zones located in Stockholm. This behavior seems to be opposite to the one in the result of the analysis of the density for the data set All observations from 3-8 meters, see Figure X. Hence, there seems to be a relationship between high values of ρ and low values of w_L and vice versa. Both of these clay parameters are most likely dependent on the local clay structure rather than any of the investigated external factors.

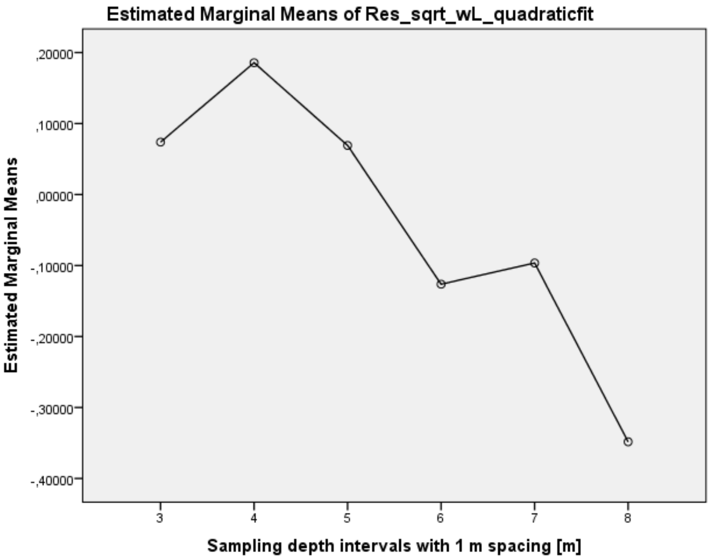


Figure 142: The main effect of Depth_INT on the liquid limit in the data set All obs. 3-8 m.

The plot in Figure 142 indicates a trend of generally lower values of the residuals of $\sqrt{w_L}$ from a quadratic fit against sampling depth towards deeper sampling points. This indicates that there is a relationship between w_L and the sampling depth which is a behavior that cannot be explained with geotechnical theory. This will be thoroughly discussed in the discussion. The full-factorial ANOVA has an R^2 of 0.679, giving a moderate grade of explanation for these results.

***T*-test**

Results from the independent groups *T*-test of the variable City for the data set All observations from 3-8 meters are presented in Tables 119 and 120.

Table 119: Group statistics, City, liquid limit, All obs. 3-8 meter.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	1,2366364	,66536134	,09226902
Stockholm	172	-,3738668	,64001374	,04880059

Table 120: Independent Groups Test output City, liquid limit, All obs. 3-8 meter.

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,043	,837	15,755	222	,000	1,61050327	,10222100	1,40905560	1,81195094
Equal variances not assumed			15,429	81,618	,000	1,61050327	,10437945	1,40284476	1,81816178

The independent groups *T*-test shows that there is a significant difference in the mean values of the residuals of $\sqrt{w_L}$ from a quadratic fit against the sampling depth between the two cities. Since the Levene's *p*-value (0.837) is greater than 0.05, equal variances can be assumed. An error bar graph showing the same values is also presented in Figure 143.

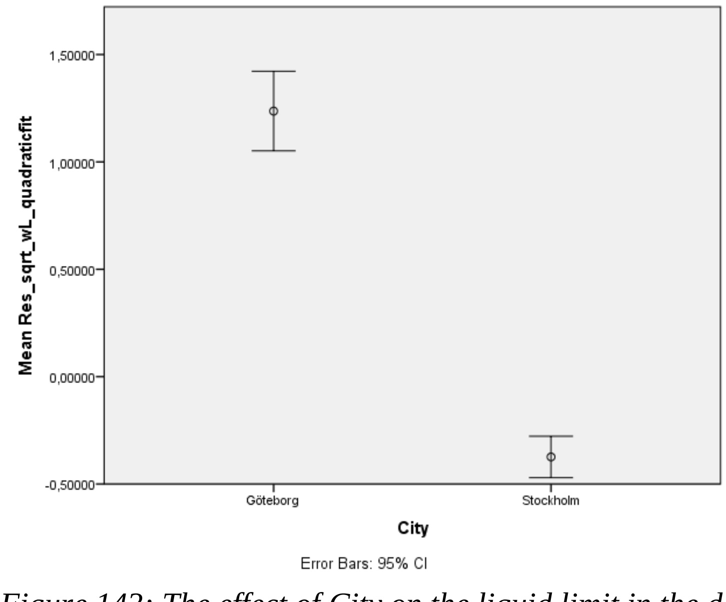


Figure 143: The effect of City on the liquid limit in the data set All obs. 3-8 m.

This indicates that there is a relationship between the liquid limit and the two cities that were investigated, where values of w_L tend to be higher in Göteborg than in Stockholm. It is hard to say what could be causing this difference. One observation is that there seems to be a clear correlation between high effective stress, high density and low liquid limit.

6.11 Summary of results

In Tables 121, 122 and 123 below, the significance level of each main effect from the ANOVA and each *T*-test result is shown for the three data sets Göteborg, Stockholm and All observations from 3-8 meters. For practical reasons, the interactions from the ANOVA are not included in these tables but are instead shown in Tables 121, 122 and 123. Values marked with "T" stem from independent groups *T*-tests.

Table 121: The significance level of each main effect from the ANOVA and each T-test result, Göteborg.

Göteborg	Depth	Grade of urbanization	Type of soil according to geological map	Thickness of soil layer overlaying the clay	Time since the soil layer overlaying the clay was placed	Zone
σ'_0	0.001	-	-	0.000	0.037	0.000 (T)
σ'_C	-	-	-	0.000	0.000	0.000 (T)
σ'_L	0.047	-	-	0.000	0.004	0.000 (T)
M_L	0.000	-	-	0.000	-	0.000 (T)
M'	0.538	0.004	-	-	0.324	0.261 (T)
OCR	-	0.000	-	0.000	0.025	0.126 (T)
CLR	-	-	0.098	-	-	0.330 (T)
ρ	0.210	0.332	-	0.080	0.014	0.000 (T)
w	0.472	0.180	-	0.147	0.090	0.000 (T)
w_L	-	-	-	0.002	0.000	0.684 (T)

Table 122: The significance level of each main effect from the ANOVA and each T-test result, Stockholm.

Stockholm	Depth	Grade of urbanization	Type of soil according to geological map	Thickness of soil layer overlaying the clay	Time since the soil layer overlaying the clay was placed	Zone
σ'_0	0.001	-	0.000	0.000	-	0.000
σ'_C	0.684	0.117	0.723	0.792	-	0.069
σ'_L	0.997	-	0.091	0.074	-	0.773
M_L	0.990	-	0.396	0.291	-	0.197
M'	-	-	-	-	-	-
OCR	-	0.020	0.017	-	-	0.007
CLR	-	0.539	-	0.225	-	0.440
ρ	0.329	0.305	0.387	0.723	0.270	0.489
w	0.053	-	0.000	-	-	0.001
w_L	0.004	-	0.002	-	-	-

Table 123: The significance level of each main effect from the ANOVA and each T-test result, All obs. 3-8 meters.

All obs. 3-8 m	Depth	Grade of urbanization	Type of soil according to geological map	Thickness of soil layer overlaying the clay	Time since the soil layer overlaying the clay was placed	Zone	City
σ'_0	0.001	0.003	0.000	0.000	-	0.000	0.000 (T)
σ'_C	-	0.907	-	-	-	0.000	0.000 (T)
σ'_L	-	0.007	0.987	0.086	0.029	0.000	0.000 (T)
M_L	-	-	0.000	-	-	0.000	0.000 (T)
M'	0.442	-	0.521	-	0.115	0.000	0.000 (T)

All obs. 3-8 m	Depth	Grade of urbanization	Type of soil according to geological map	Thickness of soil layer overlaying the clay	Time since the soil layer overlaying the clay was placed	Zone	City
OCR	-	0.009	0.027	-	-	0.000	0.058 (T)
CLR	0.425	-	-	0.097	-	0.086	0.018 (T)
ρ	-	0.083	0.360	0.387	0.289	0.000	0.000 (T)
w	0.233	0.379	0.381	0.647	0.271	0.000	0.000 (T)
w_L	0.005	-	-	-	-	0.000	0.000 (T)

In Table 124, the number of significant cases of either main effects from the ANOVA or *T*-test results is shown for each external factor in each data set. They are also summarized for the whole investigation at the bottom of the table. As can be seen, the external factor that gives rise to the greatest number of significant results is the zone.

Table 124: The number of significant cases of either main effects from the ANOVA or T-test results.

Data set	Depth	Grade of urbanization	Type of soil according to geological map	Thickness of soil layer overlaying the clay	Time since the soil layer overlaying the clay was placed	Zone	City
Göteborg	3	2	0	6	6	6	-
Stockholm	2	1	4	1	0	3	-
All obs. 3-8 m	2	3	3	1	1	9	9
TOT	7	6	7	8	7	18	9

In Figure 143 below, some of the result plots from the ANOVA of the data set All observations from 3-8 meters are shown. All of them show significant main effects of the external factor Zone on various clay parameters. As can be seen, the variation over the different zones is similar for many of the parameters and some plots are almost the reflection of each other. Not only is the difference between zones mostly significant, the values also generally follow the same pattern over them. This indicates that there is a strong correlation between the investigated clay parameters.

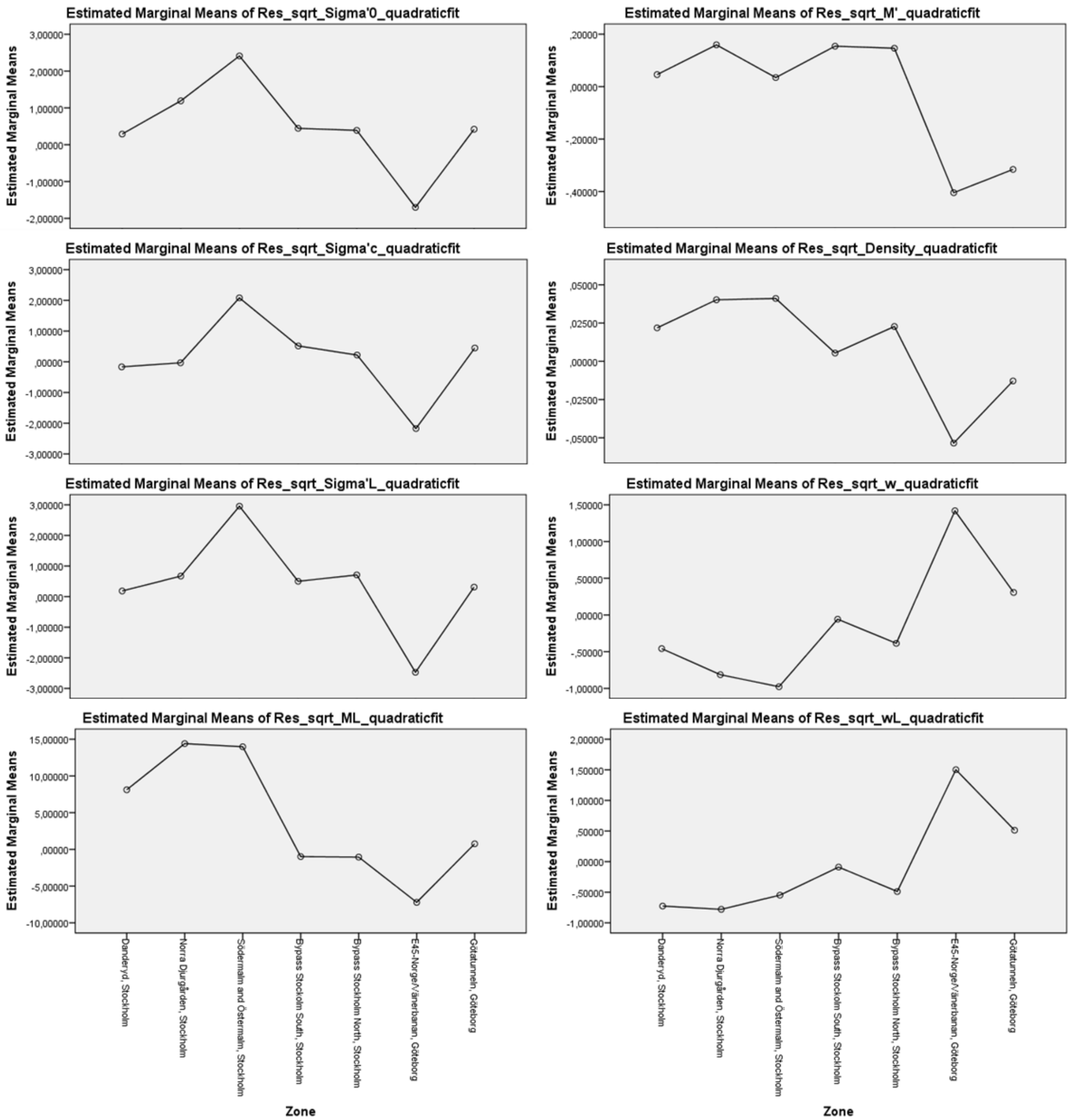


Figure 144: The main effect of Zone on some of the independent variables in the data set All obs. 3-8 m.

In Tables 125, 126 and 127 below, the significance level of each interaction from the ANOVA is shown for the three data sets Göteborg, Stockholm and All observations from 3-8 meters. The number of significant cases are not shown and summarized in any table. However, it is clear that also here the zone seems to be involved in many cases. Another observation is that the interaction between the thickness of the soil layer overlaying the clay and the time since this layer was placed shows to have a significant effect on several clay parameters.

Table 125: The significance level of interactions from the ANOVA, Göteborg.

Göteborg	Thickness of soil layer overlaying the clay * Time since the soil layer overlaying the clay was placed	Depth * Thickness of soil layer overlaying the clay
σ'_0	0.000	-
σ'_C	0.000	-
σ'_L	0.018	-
M_L	-	0.006
M'	-	-
OCR	-	-
CLR	-	-
ρ	-	-
w	-	-
w_L	0.001	-

Table 126: The significance level of interactions from the ANOVA, Stockholm.

Stockholm	Zone * Type of soil according to geological map	Depth * Type of soil according to geological map
σ'_0	-	-
σ'_C	-	-
σ'_L	-	-
M_L	-	-
M'	-	-
OCR	-	-
CLR	-	-

Stockholm	Zone * Type of soil according to geological map	Depth * Type of soil according to geological map
ρ	-	-
w	0.036	-
w_L	-	0.036

Table 127: The significance level of interactions from the ANOVA, All obs. 3-8 m.

All obs. 3-8 m	Zone * Grade of urbanization	Type of soil according to geological map * Time since the soil layer overlaying the clay was placed
σ'_0	0.000	-
σ'_C	0.000	-
σ'_L	0.046	-
M_L	-	-
M'	-	0.003
OCR	-	-
CLR	-	-
ρ	-	-
w	-	-
w_L	-	-

6.12 Sensitivity analysis

The result from the sensitivity analysis of the effective stress in one sampling point from Götatunneln is presented in Table 128. The sampling point is located five meters from the house wall and the house constitutes a load of 180 kPa. The first calculation is made with no piles and the increase in percentage of effective stress is presented in the second column. The result from the calculation with 12 meters long piles is found in the third column. The calculations are found in Appendix C. If the house is founded directly on the surface, it seems there is no effect on the effective stress down to a depth of nine meters. However, if there is any effect at all, it is quite large. The same result is given if the house is founded on cohesion piles, but then the effect starts at a depth of 17 meters instead.

Table 128: Differences of effective stress at different depth for two scenarios.

Depth [m]	percentage increase of effective stress, house without piles	percentage increase of effective stress, house with 12m piles
7	0	0
9	0	0
11	48	0
13	60	0
15	48	0
17	39	0
19	32	49
21	27	40
23	22	33
25	19	27

7 Discussion

In this chapter, the method and the results of this master's thesis are discussed. First, the division of data is discussed followed by a discussion of the transformations and normalizations, uncertainties in both external factors and clay parameters, methodology, the results from the statistical analyses, the sensitivity analysis, suggestions on further investigations and finally, difficulties.

7.1 The division of data

The division of data into three data sets; Göteborg, Stockholm and All observations from between 3-8 meters, was made to avoid an intrinsic bias in the data. This bias is constituted by the dominance of observations from shallow depths and could have affected the results from the statistical analyses. However, since the data was later normalized against the sampling depth, this may have been unnecessary and if the analyses instead had been performed on all of the data at once, higher degrees of freedom may have been achieved and more significant relationships may have been found.

A reason for the often much higher value of R^2 for transformations of variables in Göteborg compared to the other two data sets may be that these data are collected from fewer individual boreholes but a greater depth span. It seems like there is a stronger correlation between observations from different depths within the same borehole than between observations from the same depth but different boreholes. This indicates that the assumption that the observations are independent from each other even though they come from the same borehole is not entirely correct. Since the data from Stockholm are collected from a large area while the data from Göteborg comes from two smaller areas, the two data sets are very different from each other.

The R^2 of the results from the ANOVA is also generally higher in Göteborg compared to the other two data sets. This may be another effect of the same condition as described earlier. Because many observations in Göteborg come from the same borehole, they have all been noted for the same external factors and since it is likely that clay parameters within the same borehole have similar values, this gives rise to higher correlations between these external factors and clay parameters. To reduce this effect, it seems suitable to collect data from a greater number of boreholes in Göteborg and hence also capture a wider range of different external factors.

7.2 The transformation and normalization of variables

All dependent variables were transformed to residuals from a quadratic regression function of the square root of the original value against sampling depth. The argument for using the same transformation and curve fit for all clay parameters is that it was assumed that there should be one transformation and curve fit that is representative for all clay parameters. In this reasoning, the small differences between this adjustment and the assessed best transformation and curve fit for each individual variable should stem from the error variance rather than any other potential relationship. In retrospect, it has come to attention that OCR should follow a logarithmic function against depth instead of a quadratic function as was used in the transformation. However, this mistake probably has a small effect on the analysis since the differences in R^2 and significance level between the selected transformation and the best one according to the original assessment are very small.

For the three clay parameters density, water content and liquid limit the transformation either gave no substantial effect or lead to data being further from normally distributed than the raw data. It would probably have been better not to transform these data. However, there is then a risk that illogical values could arise from back-calculation.

7.3 Uncertainties in external factors

The independent variables were derived from a number of external factors that were chosen because they might have an effect on the observed clay parameters. These factors are the sampling depth, the grade of urbanization, the soil type according to the geological map, the thickness of the soil layer overlaying the clay, the time since the soil layer overlaying the clay was placed, a number of smaller specified zones (Danderyd, Norra Djurgården, Södermalm and Östermalm, Bypass Stockholm North and South, E45-Norge/Vänerbanan and Götatunneln) and the two cities (Göteborg and Stockholm).

In Chapter 3, describing the statistical analysis methods, it is mentioned that independent variables should be measured with no or at least negligible error. Some of the independent variables that are used in this master's thesis are, however, subjectively assumed and evaluated from definitions that are rather broad. This approach likely leads to high intrinsic uncertainties in the statistical analyses.

The variable representing the sampling depth has some categories that only include one observation, resulting in zero degrees of freedom. This could be the reason why many analyses give insignificant results.

The variable representing the grade of urbanization has few categories with very broad definitions. With more time and better investigations, this variable could probably be refined to enhance its explanatory value. A greater number of categories with slimmer definitions is recommended, where each category should be represented by many observations.

The variable representing the soil type according to the geological map has a very skewed distribution of observations between its categories and should be revised. One proposal is to sort the soil types after particle size, making it an ordinal variable. The categories of this factor, i.e. the different soil types, could have been made wider so that more observations would fall within each level. For example; Mud, Muddy clay and Peat could be made into one category instead of three. This would prevent that it is in fact the different sampling points that are investigated instead of the different soil types.

The variable representing the thickness of the soil layer overlaying the clay has been measured from geotechnical drawings. Hence, the errors in this should be small. The thickness of the soil layer overlaying the clay is set to have an ordinal measure in the statistical analyses. However, the definition states that it should actually have a scale measure. As an ordinal measure, its values are ranked in the right order but SPSS assumes that there is no information in the distance between values. How this is affecting the analysis is hard to say (hopefully not at all), without carrying out the analysis once again. The analysis would probably be more affected if the measured errors were large.

The variable representing the time since the soil layer overlaying the clay was placed was evaluated as accurately as possible within the limited time for this master's thesis. With more time, a better evaluation could have been done. Areas where the geological soil map indicates fill were thoroughly investigated through a literature study of old maps and documents. In these areas, errors are likely quite small. However, such documentation was not always available and where not, evaluation was performed through ocular inspection using the Internet tool Google Maps, see Chapter 4.4.5. In these areas, errors are likely larger due to the rather coarse approach. The occurrence of fill material is strongly correlated with the grade of urbanization and in order to reduce uncertainties and enhance the explanatory value of both this variable and the one representing the grade of urbanization, a rigorous investigation of the construction history in interesting areas should be performed. The decision to only investigate areas where the geological soil map indicates fill for this variable may have led to that some areas that actually have been filled were missed. How this can have affected the results is hard to say. The variable representing the time since the soil layer overlaying the clay was placed has six categories representing different time spans. All time spans are, however, not equally long but since an ordinal measure is used, this should not affect the results. On the other hand, one thing that may have an effect on the results is that some categories only contain a few observations while others contain many. Several categories are, furthermore, only represented by observations from one single project or even one single zone in some cases. This makes it very hard to distinguish if there is a relationship between a certain clay parameter and either the time since the soil layer overlaying the clay was placed or the zone from where the samples were collected. For Göteborg it is clear that the categories are connected to certain areas since each category is only noted for observations within the same zone. However, there are only two zones specified and if there were more, better reliability in the results may be obtained.

The variable representing the specified zones has been derived using a rather crude approach. Observations were simply grouped together by looking at a map and selecting a number of areas without any further investigation of the geological history or the occurrence of natural geological rooms. The zones are very different in size and contain differing numbers of observations. A more rigorous investigation of zones that should have similar conditions regarding clay parameters should be performed to enhance the explanatory value of this variable.

The variable representing the city was constructed to investigate if there were any significant differences between the clay in Göteborg and Stockholm. The category Göteborg includes all observations from the projects Götatunneln and E45-Norge/Vänerbanan while the category Stockholm includes all observations from the projects CityLink and Bypass Stockholm. However, these observations only represent a fraction of the cities and therefore, no certain conclusions about the actual difference between the cities should be drawn.

7.4 Uncertainties in clay parameters

The dependent variables are derived from the following clay parameters: σ_0', σ_C', σ_L', M_L, M', OCR, CLR, ρ, w and w_L.

The values of most of these parameters are obtained through manual assessment by a professional in a laboratory, resulting in some minor uncertainty due to operational inaccuracy. These values have mostly been collected from laboratory protocols while those from CRS curves from the project E45-Norge/Vänerbanan were assessed by the authors themselves. The uncertainty in these values is also assumed to be quite small since the procedure of evaluation is rather simple. However, each laboratory and each person will likely evaluate a CRS curve a little differently and the optimal approach would be to let one person evaluate all the CRS curves. This would obviously take a lot of time and was not considered feasible for this master's thesis.

The values of σ_0', OCR and CLR are, on the other hand, calculated. The newly invented parameter CLR is just the ration between σ_L' and σ_C', which means it inherits the small uncertainty within these two individual parameters. The values of σ_0' and thus also those of OCR incorporates a lot of uncertainties for several reasons and are therefore discussed more thoroughly in the section below, 7.4.1 Effective stress.

If the soil samples that are denoted as undisturbed have been treated badly or been exposed to vibrations during transportation, there could be uncertainties in values due to sampling errors. This master's thesis has not considered this kind of errors but they are assumed to be small.

Some observations have been screened away because the value of OCR was lower than one. However, since the values of σ_0' was probably underrated for many observations because loads from buildings and roads were neglected, more observations would probably have been screened away if these loads were accounted for.

The transformation that was used made extreme values appear less prominent. However, there are still some extreme values in the data that probably should have been rejected as outliers.

7.4.1 Effective stress

The values of σ_0' incorporates a lot of uncertainties for several reasons and is considered the most uncertain of all investigated clay parameters. It has been calculated using the density of the soil, the pore water pressure distribution and the sampling depth. External loads from buildings and roads have been neglected because it was considered too time consuming to make the proper investigations needed to include these.

The thickness of the soil layer overlaying the clay was, as mentioned earlier, measured from geotechnical drawings and the errors in these measurements are assumed to be small. However, the density of the material in the overlaying soil layers was not always stated in the laboratory reports. In these cases, a density of 1.7 t/m³, corresponding to that of macadam ballast, was assumed with reference to empirical guideline values. This has been used as a standard value everywhere without any consideration of whether it is the most likely density for the actual material or not, which adds to the uncertainty in the resulting values of σ_0'.

The pore water pressure distribution has been evaluated manually and is based on different types of information. The optimal condition would be to have both piezometers and groundwater pipes that measure the pressure in both the upper and lower magazine. This is, however, not the case for any of the observed sampling points. For some sampling points, there are piezometer test results, for some there are data from groundwater pipes and for some, there is no information about the pore water pressure at all. The largest uncertainties concerning the pore water pressure distribution are, obviously, allocated to those sampling points where no information about the pore water pressure was reported. For these points, the pore water pressure distribution was estimated based on data from the nearest groundwater pipe, which could be located between 19 to 100 meters away. In Göteborg, there were five such points while there were none in Stockholm.

The external loads from buildings and roads were, as mentioned earlier, neglected in the calculations of σ_0'. This have likely resulted in underrated values of σ_0' in densely urbanized areas. A sensitivity analysis, using the 2:1 method, was performed to investigate approximate differences in σ_0' if these loads would have been included. This is discussed in the section about the sensitivity analysis, 7.6, further ahead.

7.5 Results

In this section, the results from the statistical analyses are discussed for one external factor at the time. There has been an ambition to discuss all possible relationships between the external factors and clay parameters with reference to the results received from the statistical analyses.

Notable for all external factors, except for the soil type according to the geological map, is that they are all either involved in the calculation of σ_0' (depth and thickness of the soil layer overlaying the clay) or completely irrelevant for the values of this parameter (grade of urbanization, since the external loads from buildings are neglected, and the time since the soil layer overlaying the clay was placed). There were, furthermore, no relevant results from the analysis of the relationship to the soil type according to the geological map for this parameter. Therefore, the investigational value of the results from the analyses of σ_0' itself is low. These results are, however, included to be compared to the results of other clay parameters.

7.5.1 Sampling depth

All results from the statistical analyses of the sampling depth should show that there is no grouping or trend of values since all dependent variables were normalized against depth. All results also showed no relationship with the sampling depth except for one, the one of the variable representing the liquid limit in the data set All observations from 3-8 meters. It is hard to say what causes this trend. One hypothesis is that the data, after transformation and normalization, has two separate normal distributions, one for Göteborg and one for Stockholm, which may be the result of operational differences between laboratories in the two cities (Alén, 2014). However, it may be that the data from the data set All observations from 3-8 meters were not normally distributed from the beginning and not after the transformation and normalization either. Yet, the scatter plot of the residuals against depth indicates that the dependency of the sampling depth should be gone.

7.5.2 Grade of urbanization

The grade of urbanization was significant for all three data sets when it comes to the clay parameter OCR. The data set Göteborg showed an opposite grouping compared to the other two data sets. The grouping in Göteborg was that of higher values of OCR in urban areas compared to semi-urban and rural areas while the trend in Stockholm and for All observations from 3-8 meters was that of higher values of OCR in rural areas compared to semi-urban and urban areas. No clear reason for this difference has been found. One hypothesis about the grouping in Göteborg is the following: *Due to the aging process, σ_C' increases while σ_0' remains the same. It increases faster in urban areas due to the higher external loads from buildings and roads. These higher loads are, however, not included in the calculation of σ_0', resulting in a bigger difference between σ_C' and σ_0' in urban areas compared to semi-urban and rural areas.* Why this does not apply in Stockholm and for All observations from 3-8 meters may have something to do with the difference in depth span. It has been implied by an expert that there may be a shift in the behavior of OCR against depth (Alén, 2014). Close to the surface, there seems to be some kind of quadratic or logarithmic function that best describes the data while it straightens out at greater depths. Maybe, the data sets Stockholm and All observations from 3-8 meters are dominated by the trend that exists before the function curves and straightens out while the data set Göteborg is dominated by the trend of the straight function at greater depths. One way to test this hypothesis could be to divide the data set Göteborg into two sets, one with observations with samplings depths from 0-15 meters and the other with depths from

15 meters and beyond. The two new data sets for Göteborg could then be analyzed separately to see if there are two different trends.

7.5.3 Soil type according to the geological map

There were some significant results from the statistical analyses of the soil type according to the geological map. However, these did not show any clear grouping. Many of the categories within this variable were only represented by a few observations while others were well represented. If this independent variable had been constructed in another way, as mentioned earlier, it may have been possible to recognize a trend if there were any.

7.5.4 Thickness of the soil layer overlaying the clay

The analysis of the thickness of the soil layer overlaying the clay gave some significant results. Most of these come from the data set Göteborg, where the analyses of σ'_0, σ'_C, σ'_L, M_L, OCR and w_L gave significant results while for the other two data sets, only the results of the analysis of σ'_0 were significant. As mentioned earlier, the thickness of the soil layer overlaying the clay is included in the calculation of σ'_0 and it is therefore not surprising that there were many significant results for this external factor. This makes the results from the analysis of this particular external factor regarding this particular clay parameter rather meaningless. The results from the analyses of σ'_C, σ'_L and M_L all show a grouping of generally higher values for thicker layers of soil overlaying the clay. At least for σ'_C and σ'_L, this seems reasonable and could be explained by the aging process, which is speeded up by higher loads due to thicker overlaying soil layers. How M_L, on the other hand, could be connected to this external factor is hard to say. Notable is that the mean thickness of the soil layer overlaying the clay is 0.92 meters in the zone E45-Norge/Vänerbanan and 5.05 meters in the zone Götatunneln. Hence, the grouping may instead be dependent on the zone rather than the external factor itself. The zone would thus act as a lurking variable in the interpretation of these results. Notable is also that there are no observations of thicknesses between 3 and 6 meters. In the result plot from the analysis of OCR, a weak trend of lower values against thicker layers appears. The trend could be explained by the fact that thicker layers would mean higher values of σ'_0 and thus, lower OCR. However, the volatility of the value in this result still means that the relationship is very weak. The result plot from the analysis of w_L indicates that there is really no relationship between this clay parameter and the thickness of the soil layer overlaying the clay.

7.5.5 Time since the soil layer overlaying the clay was placed

The analysis of the time since the soil layer overlaying the clay was placed just showed that the soil overlaying the clay was placed at different times in different zones and therefore, nothing can really be said about the relationship between this factor and the clay parameters based on these results. There were also some significant interactions between the time and the thickness of the overlaying soil for the clay parameters σ'_0, σ'_c, σ'_L and $w_L$but this could also be related to the lurking variable zone. However, it is reasonable that this interaction actually could have some relationship to some of the clay parameters and it should therefore not be discarded as insignificant with reference to the results in this master's thesis.

7.5.6 Zone

The zone from which the samples were collected is the external factor giving the highest number of significant results. It should be mentioned that the zone is not really an external factor in the sense that it potentially could be used for predictions of clay parameters elsewhere, it is simply a variable used to investigate differences between locations.

For the data set Göteborg, there are only two specified zones and the differences between these were analyzed with independent groups T-tests. There were six significant results from these tests and they showed that the values of σ_0', σ_C', σ_L', M_L and ρ are generally significantly higher in the zone Götatunneln than in the zone E45-Norge/Vänerbanan. The opposite applies for the values of w. Notable here is that the thickness of the soil layer overlaying the clay and the grade of urbanization generally also is higher in the zone Götatunneln than in the zone E45-Norge/Vänerbanan. That high values of σ_0' matches with thick layers of soil overlaying the clay is not surprising since the thickness, or more accurately the depth, is included in the calculation of this parameter. The higher values of σ_C' and σ_L' in areas with thicker layers of soil overlaying the clay and higher external loads from denser urbanization may be explained by the aging process that is speeded up by higher loads. Maybe, the difference between the clay parameters in the two zones is simply caused by a somewhat different formation history rather than the result of the investigated external factors.

For the data set Stockholm, there are five specified zones and the differences between these were tested using ANOVA. There were three significant results from these analyses and they showed, firstly, that the values of σ_0' are generally low in the zones Danderyd, Bypass Stockholm South and Bypass Stockholm North while they are moderate in the zone Norra Djurgården and high in the zone Södermalm and Östermalm, secondly that the values of OCR are generally low in the zone Norra Djurgården compared to the other zones and thirdly, that the values of w are generally high in the zones Bypass Stockholm South and Bypass Stockholm North compared to the other zones. For this data set, it is not as easy to say something about the possible relationships between the clay parameters and the external factors. There are not many significant results and there is really no clear correlation with either the thickness of the soil layer overlaying the clay or the grade of urbanization as was the case in Göteborg. This could be an indication that the difference between the zones is again caused by differences in formation history.

For the data set All observations from 3-8 meters, the results from all statistical analyses of the zone were significant except for one, the one concerning the clay parameter CLR. The variation of values representing σ_0', σ_C', σ_L' and to some extent M_L generally follows a similar pattern over the zones. These parameters seem to have similar values in most zones with two exceptions; they are generally high in the zone Södermalm and Östermalm and low in the zone E45-Norge/Vänerbanan compared to the other zones. Notable is that these two zones differ a lot in terms of both the thickness of the soil layer overlaying the clay and the grade of urbanization, where values are generally much higher in the zone Södermalm and Östermalm compared to the zone E45-Norge/Vänerbanan. Since the other zones show similar values, it may be the big difference between the two extreme zones causing all analyses of this external factor, except for CLR, to be significant. Another pattern is identified for the variation of values representing w and w_L, which also looks like the reflection of the pattern of the variation of values representing ρ. The variations of values representing M' are clearly grouped into high values in the zones located in Stockholm compared to the zones located in Göteborg. How w, w_L, ρ and M' could be connected to the thickness of the soil layer overlaying the clay or the grade of urbanization is, on the other hand, hard to explain. The result plot for the clay parameter OCR shows that the values of this basically differ between all zones. Maybe, the difference between the clay parameters in the different zones is simply caused by a somewhat different formation history rather than the result of the investigated external factors. The fact that many clay parameters show similar patterns indicate that there are correlations between the clay parameters.

7.5.7 City

The city from which the samples were collected is an external factor that could only be investigated with the data set All observations from 3-8 meters, as it is the only one containing data from both cities. Since there are only two categories, Göteborg and Stockholm, the differences between these were analyzed with independent groups T-tests. There were nine significant results from these tests and they showed that the values of σ_0', σ_C', σ_L', M_L, M' and ρ are generally significantly higher in Stockholm than in Göteborg. The opposite applies for the values of CLR, w and w_L. It is possible that it is the big difference between the two extreme zones, Södermalm and Östermalm in Stockholm and E45-Norge/Vänerbanan in Göteborg, which causes most of these results to be significant rather than any general difference between the two cities. One interesting thing though is that the only significant result for the clay parameter CLR is found when the two cities are compared. It indicates that the difference between σ_L' and σ_C' is significantly larger in Göteborg compared to Stockholm and could maybe have something to do with the contradicting trends between the two cities concerning OCR, as discussed earlier, since both ratios contain the clay parameter σ_C'.

7.6 Sensitivity analysis

A sensitivity analysis, using the 2:1 method, was performed to investigate the difference in σ_0' if the external loads from buildings and roads would have been included. The 2:1 method implies that the addition in normal stress from an external load decreases with depth and spreads out with an inclination of 2:1. In Göteborg, where the clay generally reaches great depths, many buildings have foundations consisting of cohesion piles. These transfer the addition in normal stress from the ground surface down to about two thirds of the pile length from where the load starts spreading out. The loads from these buildings hence start to affect the soil at a depth of about 7-10 meters, depending on the pile length. For a sampling point at a distance of 5 meters from such a building, the depth where the external load from the building starts to affect the soil is then about 16-20 meters. Since most observations stem from sampling depths of less than 20 meters and most sampling points are also located at a greater distance than 5 meters from a building, the overall effect of underrating the values of σ_0' by excluding the external loads from buildings is in Göteborg assumed to be quite small.

In Stockholm, the clay thickness is generally not greater than 8-10 meters and it is therefore assumed that many buildings have foundations consisting of end bearing piles. For the external load to have any effect on the observation, the building has to be constructed directly on the ground without any deep foundation, the clay has to be about 10 meters thick and the sampling point has to be located less than 5 meters from the building all at once. It is reasonable to assume that this does not apply for that many observations. The amount of observations that were noted as urban in Stockholm was 21 out of 202, which is about 11 %. Hence, the exclusion of the external loads from buildings in Stockholm is also assumed to have had a rather small effect on the values of σ_0'.

7.7 Geotechnics today

A geotechnical engineer estimates the values of clay parameters in areas in between sampling points. The approach that is used today suggests that an area of investigation is divided into blocks around each available sampling point and the values of clay parameters within an entire block are then assumed to be similar to those evaluated from the sampling point.

The fundamental principle for a geotechnical engineer is that everything is uncertain except for the values in the specific point from where the soil sample is collected. Even if they have lots of experience and local knowledge, they still often encounter conditions that were not anticipated. Therefore, the geotechnical engineers of today are cautious in speaking too confidently about the conditions in between sampling points and many of them have expressed skepticism towards the more refined kind of method that is investigated in this master's thesis.

According to Alén[14], the load history of cities is really hard to determine since it covers so many events, such as altering of the groundwater level and changes in loads from buildings and roads. In both Göteborg and Stockholm, there is a long history of urbanization, which includes numerous construction projects where the groundwater level has been lowered and areas have been filled out and built on. In order to make good estimations of the effects of these events, all of them have to be investigated.

7.8 Further investigations

The first thing that is recommended for further investigations on this subject is to make more rigorous examinations of external factors so that the initial requirement of the ANOVA can be adequately satisfied, namely that the independent variables should be measured with no or at least negligible error. How this is supposed to be done exactly is hard to say but maybe some kind of detailed framework for evaluation could be developed in cooperation with experienced geotechnicians and statisticians. This would probably reduce the error variance due to operational dissimilarities between different evaluators and thus reduce the uncertainties in the independent variables. It would also likely prevent the inclusion of irrelevant variables, which otherwise disturb the results of the ANOVA, giving lower F-factors, significance levels and R^2s. For example, the inclusion of the independent variable representing the sampling depth was basically unnecessary since the data were normalized against depth prior to the statistical analysis. In this master's thesis, it was used as a control variable to see how well the normalization had worked but for further investigations, it is recommended to exclude this variable.

One example of another external factor that probably should be investigated for inclusion in the ANOVA is how the groundwater level has changed over a long time. This would require extensive investigations and likely take a lot of time in order to reach adequate accuracy. In some areas, it would probably be very difficult since there is a limited amount of groundwater level measurements, especially which go far back in time. One such area is central Göteborg. Another external factor that also is recommended to use in further investigations is a factor that considers the formation history of the clay.

In order to safely separate potential relationships between external factors and clay parameters from natural differences between zones due to e.g. varying formation history, which otherwise acts as a

[14] Claes Alén, assistent professor, Chalmers University of Technology, conversation May 22, 2014.

lurking variable, many more sampling points covering much larger areas should be included. This would also help capture more variations of the investigated external factors.

The results from a well performed ANOVA could be used to identify suitable variables to include in a multiple regression analysis. If such an analysis turns out well, it could maybe be used to develop some kind of statistical prognosis tool that may be utilized in the early stages of a geotechnical investigation. This could, in turn, be guiding in the assessment of how an area will respond to stress changes due to e.g. a lowering of the groundwater level following an underground construction.

7.9 Difficulties

There were many difficulties along the way in the execution of the investigation that constitutes the core of this master's thesis. The overall methodology was adopted by an expert and was very hard to grasp. The statistical analysis methods were somewhat complicated and most importantly, the results were very hard to interpret. The procedure of transforming and normalizing the data in order to avoid illogical values from back-calculation and to eliminate any intrinsic relationship to the sampling depth made it hard to understand how the results actually associates to reality. Attempts were made, after best effort, to interpret the results and relate them to geotechnical theory as understood by the authors. Looking at one result at the time, it is fairly easy to draw some hypothetical conclusions about the potential relationship between a certain external factor and a certain clay parameter. However, in the wider perspective, very little can be said about the existence of any such relationships based on the results from this investigation.

8 Conclusions

In this chapter, the conclusions from the entire investigation that constitutes this master's thesis are presented in bullet points.

- The methodology has been hard to understand and the results are also hard to interpret.
- The single external factor that gives rise to the greatest number of significant results is the zone.
- The variation of values representing σ'_0, σ'_C, σ'_L and to some extent M_L generally follows a similar pattern over the zones. Another pattern is identified for the variation of values representing w and w_L, which also looks like the reflection of the pattern of the variation of values representing ρ. The variations of values representing M' are clearly grouped into high values in Stockholm compared to Göteborg.
- Because the results are often contradicting and hard to interpret, the conclusion is that it is not possible to say if there exist any significant relationships between the external factors and the clay parameters.

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Appendix A, classification of zones

In Figure 1, the five specified zones in the Stockholm area are marked. The zones are numbered as follows:

(1) Danderyd
(2) Norra Djurgården
(3) Södermalm and Östermalm
(4) Bypass Stockholm South
(5) Bypass Stockholm North

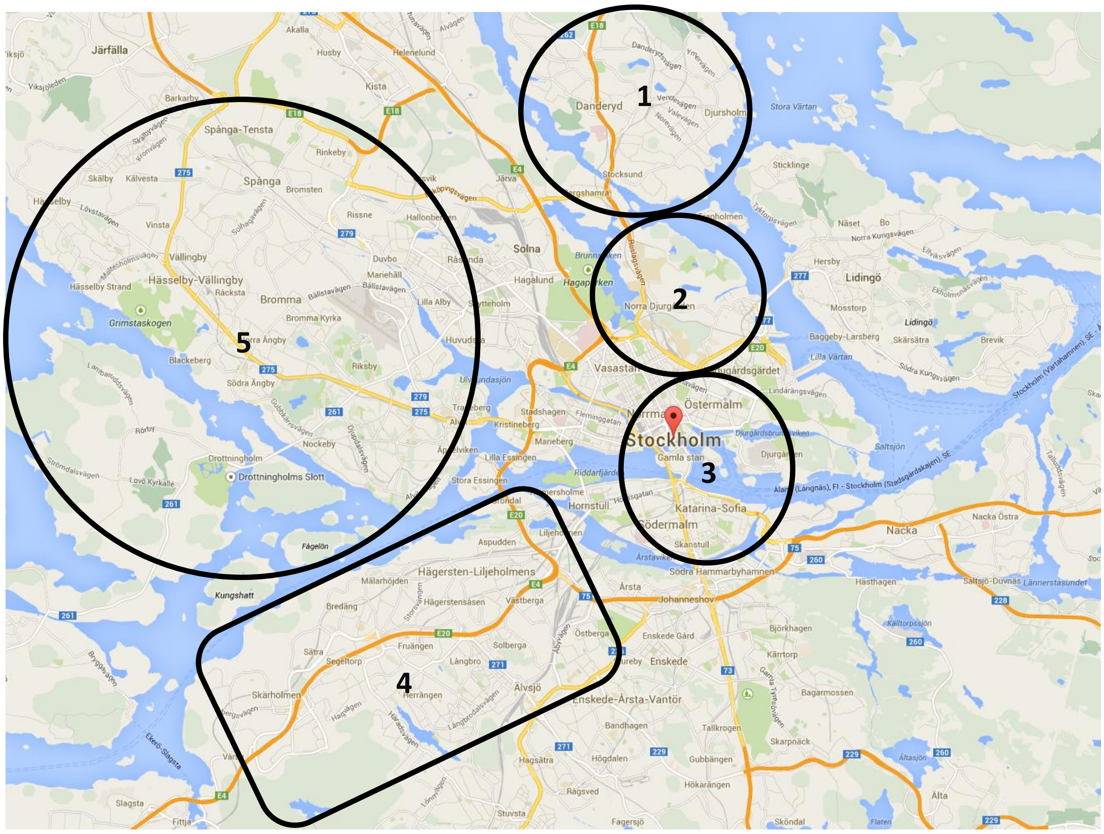

Figure 1: The five specified zones in the Stockholm area (www.maps.google.com).

In Figure 2, the two specified zones in the Göteborg area are marked. The zones are numbered as follows:

(6) Göta älv (Project E45-Norge/Vänerbanan)

(7) Göteborg Centre (Project Götatunneln)

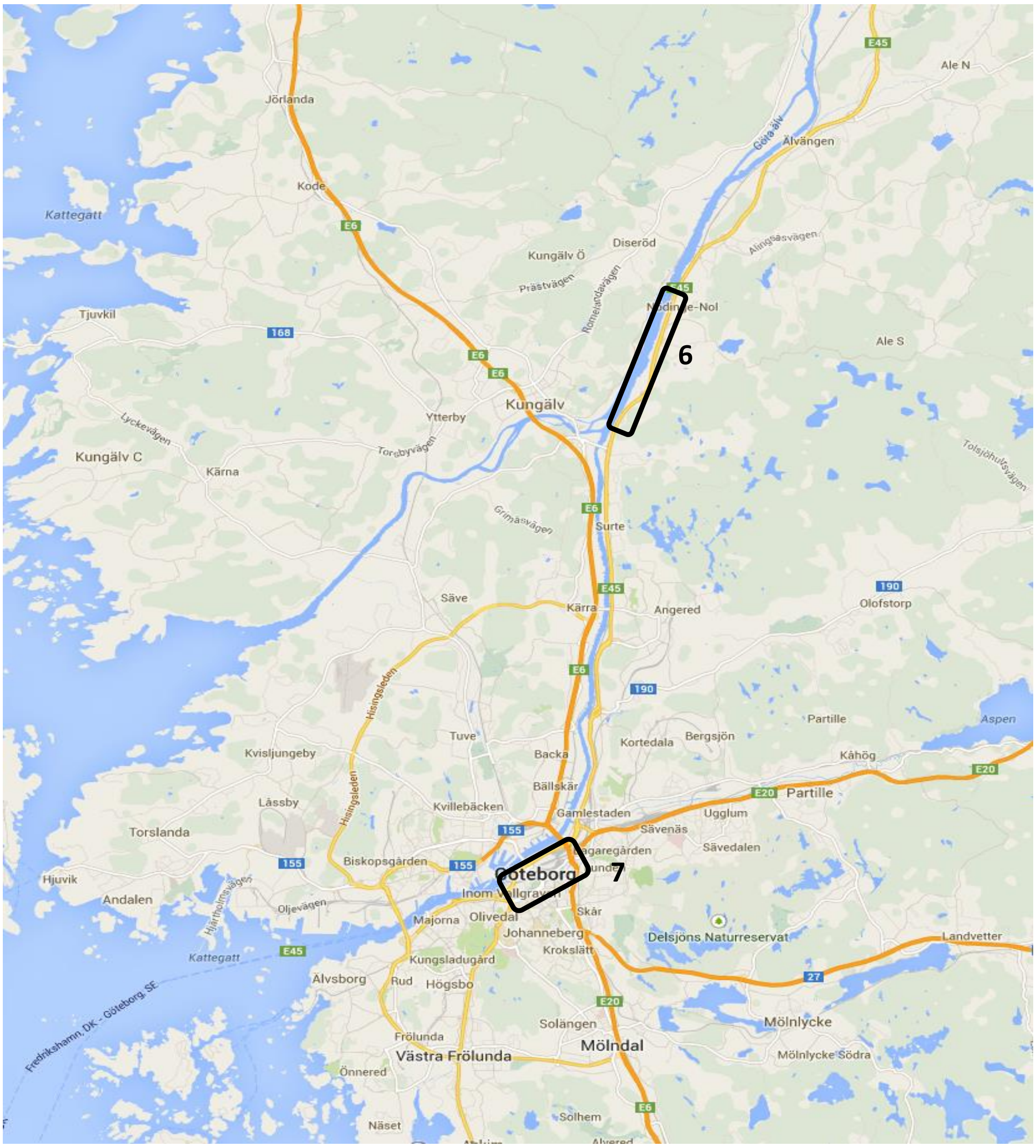

Figure 2: The two specified zones in the Göteborg area (www.maps.google.com).

Appendix B, outputs from SPSS

B.1 Effective stress

B.1.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 1. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma10_quadfit, Göteborg.

Table 1 Effective stress, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	183.818[a]	37	4.968	22.638	,000	,847
Intercept	6,718	1	6,718	30,613	,000	,169
Depth_INT	14,262	26	,549	2,500	,000	,301
Urbanization	,000	1	,000	,001	,979	,000
Soil_type_map	,806	1	,806	3,672	,057	,024
Overlaying_layer__INT	26,261	4	6,565	29,916	,000	,442
Time_overlying_layer	7,743	3	2,581	11,761	,000	,189
Error	33,137	151	,219			
Total	216,955	189				
Corrected Total	216,955	188				

a. R Squared = ,847 (Adjusted R Squared = ,810)

Full-factorial ANOVA

The full-factorial has been made with all variables since each of them show an *F*-factor higher than 1, see Table 2 for results. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma10_quadfit, Göteborg.

Table 2 Effective stress, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	210,357[a]	156	1,348	6,540	,000	,970
Intercept	3,890	1	3,890	18,868	,000	,371
Depth_INT	11,999	26	,462	2,238	,016	,645
Urbanization	,146	1	,146	,706	,407	,022
Soil_type_map	,000	0	.	.	.	,000
Overlaying_layer__INT	11,045	4	2,761	13,393	,000	,626
Time_overlying_layer	8,362	3	2,787	13,518	,000	,559
Depth_INT * Urbanization	1,058	6	,176	,855	,538	,138
Depth_INT * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT	2,053	26	,079	,383	,993	,237
Depth_INT * Time_overlying_layer	4,390	22	,200	,968	,523	,400
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	2,049	1	2,049	9,939	,004	,237
Depth_INT * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,972	4	,243	1,178	,339	,128
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	6,598	32	,206			
Total	216,955	189				

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Total	216,955	188				

a. R Squared = ,970 (Adjusted R Squared = ,821)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 3 for results of the second full-factorial.

Table 3 Effective stress, second Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	207,001[a]	133	1,556	8,599	,000	,954
Intercept	3,872	1	3,872	21,396	,000	,280
Depth_INT	13,327	26	,513	2,832	,001	,572
Overlaying_layer__INT	11,787	4	2,947	16,281	,000	,542
Time_overlying_layer	1,990	4	,498	2,749	,037	,167
Depth_INT * Overlaying_layer__INT	4,148	32	,130	,716	,844	,294
Depth_INT * Time_overlying_layer	9,729	39	,249	1,378	,135	,494
Overlaying_layer__INT * Time_overlying_layer	6,139	3	2,046	11,307	,000	,381
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	1,186	9	,132	,728	,681	,106
Error	9,954	55	,181			
Total	216,955	189				
Corrected Total	216,955	188				

a. R Squared = ,954 (Adjusted R Squared = ,843)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 4 and 5.

Table 4 Effetive stress, T_test of Zone Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,7246840	,64590921	,06158503
Götatunneln, Göteborg	79	1,0090536	,65315097	,07348523

Table 5 Effective stress, T-test of Zone Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1,517	,220	-18,116	187	,000	-1,73373761	,09570295	-1,92253380	-1,54494143
Equal variances not assumed			-18,083	167,068	,000	-1,73373761	,09587906	-1,92302829	-1,54444694

B.1.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 6. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma10_quadfit Stockholm.

Table 6 Effective stress, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	117,054[a]	31	3,776	25,433	,000	,823
Intercept	4,023	1	4,023	27,095	,000	,137
Depth_INT	12,364	11	1,124	7,570	,000	,329
Zone	12,985	4	3,246	21,864	,000	,340
Urbanization	1,714	2	,857	5,774	,004	,064
Soil_type_map	6,814	6	1,136	7,649	,000	,213
Overlaying_layer__INT	25,788	5	5,158	34,739	,000	,505
Time_overlying_layer	,071	1	,071	,477	,491	,003
Error	25,240	170	,148			

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	142,294	202				
Corrected Total	142,294	201				

a. R Squared = ,823 (Adjusted R Squared = ,790)

Full-factorial ANOVA

The full-factorial has been made with all variables except time since the soil overlaying the clay was place, since each of them show an *F*-factor higher than 1, see Table 7 for results. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma10_quadfit, Stockholm.

Table 7 Effective stress, Full-factorial Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	131,658[a]	139	,947	5,522	,000	,925
Intercept	8,104	1	8,104	47,243	,000	,432
Depth_INT	7,670	11	,697	4,065	,000	,419
Zone	4,981	3	1,660	9,679	,000	,319
Urbanization	,622	2	,311	1,813	,172	,055
Soil_type_map	3,447	6	,574	3,349	,006	,245
Overlaying_layer__INT	4,554	5	,911	5,309	,000	,300
Depth_INT * Zone	,414	12	,034	,201	,998	,037
Depth_INT * Urbanization	,177	11	,016	,094	1,000	,016
Depth_INT * Soil_type_map	,905	16	,057	,330	,992	,078
Depth_INT * Overlaying_layer__INT	,184	10	,018	,107	1,000	,017
Zone * Urbanization	,006	1	,006	,035	,851	,001
Zone * Soil_type_map	,035	1	,035	,207	,651	,003
Zone * Overlaying_layer__INT	,093	3	,031	,181	,909	,009
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,223	1	,223	1,302	,258	,021
Soil_type_map * Overlaying_layer__INT	,000	1	,000	,002	,961	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Zone * Urbanization	,011	1	,011	,062	,805	,001
Depth_INT * Zone * Soil_type_map	1,757E-5	1	1,757E-5	,000	,992	,000
Depth_INT * Zone * Overlaying_layer__INT	,048	3	,016	,093	,964	,004
Depth_INT * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	,043	1	,043	,252	,618	,004
Zone * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Error	10,636	62	,172			
Total	142,294	202				

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Total	142,294	201				

a. R Squared = ,925 (Adjusted R Squared = ,758)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 8 for results of the second full-factorial.

Table 8 Effective stress, second Full-factorial Stockhom

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	129,919[a]	121	1,074	6,941	,000	,913
Intercept	7,601	1	7,601	49,140	,000	,381
Depth_INT	5,700	11	,518	3,350	,001	,315
Zone	7,497	3	2,499	16,154	,000	,377
Soil_type_map	9,329	6	1,555	10,051	,000	,430
Overlaying_layer__INT	15,377	5	3,075	19,881	,000	,554
Depth_INT * Zone	2,646	17	,156	1,006	,461	,176
Depth_INT * Soil_type_map	2,887	22	,131	,848	,658	,189
Depth_INT * Overlaying_layer__INT	1,353	12	,113	,729	,719	,099
Zone * Soil_type_map	,138	3	,046	,298	,827	,011
Zone * Overlaying_layer__INT	,824	4	,206	1,332	,265	,062
Soil_type_map * Overlaying_layer__INT	,158	3	,053	,341	,796	,013
Depth_INT * Zone * Soil_type_map	,004	3	,001	,008	,999	,000
Depth_INT * Zone * Overlaying_layer__INT	1,256	4	,314	2,030	,098	,092
Depth_INT * Soil_type_map * Overlaying_layer__INT	,264	4	,066	,426	,789	,021
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Error	12,375	80	,155			
Total	142,294	202				
Corrected Total	142,294	201				

a. R Squared = ,913 (Adjusted R Squared = ,781)

B.1.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 9. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma10_quadfit, All observation from 3-8 meters.

Table 9 Effective stress, One-way ANOVA All obs. 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	275,314[a]	31	8,881	49,097	,000	,888
Intercept	4,021	1	4,021	22,229	,000	,104
Depth_INT	,861	5	,172	,952	,449	,024
Zone	56,272	5	11,254	62,217	,000	,618
Urbanization	,908	2	,454	2,511	,084	,025
Soil_type_map	10,443	8	1,305	7,216	,000	,231
Overlaying_layer__INT	31,367	6	5,228	28,901	,000	,475
Time_overlying_layer	2,998	3	,999	5,524	,001	,079
Error	34,731	192	,181			
Total	310,045	224				
Corrected Total	310,045	223				

a. R Squared = ,888 (Adjusted R Squared = ,870)

Full-factorial ANOVA

The full-factorial has been made with all variables except sampling depth, since each of them show an *F*-factor higher than 1, see Table 10 for results. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma10_quadfit, All observation from 3-8 meters.

Table 10 Effective stress, Full-factorial ANOVA All obs. 3-8 meter

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	290,830[a]	60	4,847	41,119	,000	,938
Intercept	17,100	1	17,100	145,064	,000	,471
Zone	34,715	4	8,679	73,623	,000	,644
Urbanization	,291	2	,145	1,234	,294	,015
Soil_type_map	6,016	5	1,203	10,207	,000	,238
Overlaying_layer__INT	12,410	6	2,068	17,546	,000	,392
Time_overlying_layer	,093	2	,046	,393	,676	,005
Zone * Urbanization	,088	1	,088	,747	,389	,005
Zone * Soil_type_map	,040	1	,040	,342	,559	,002
Zone * Overlaying_layer__INT	,875	4	,219	1,855	,121	,044
Zone * Time_overlying_layer	,491	3	,164	1,388	,248	,025
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,162	1	,162	1,371	,243	,008
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,001	1	,001	,005	,946	,000
Soil_type_map * Time_overlying_layer	,671	1	,671	5,690	,018	,034
Overlaying_layer__INT * Time_overlying_layer	1,487	3	,496	4,205	,007	,072
Zone * Urbanization * Soil_type_map	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	19,215	163	,118			
Total	310,045	224				
Corrected Total	310,045	223				

a. R Squared = ,938 (Adjusted R Squared = ,915)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 11 for results of the second full-factorial.

Table 11 Effective stress, second Full-factorial All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	285,545[a]	48	5,949	42,492	,000	,921
Intercept	17,018	1	17,018	121,555	,000	,410
Zone	54,587	6	9,098	64,985	,000	,690
Urbanization	1,731	2	,866	6,182	,003	,066
Soil_type_map	6,175	8	,772	5,514	,000	,201
Overlaying_layer__INT	13,364	6	2,227	15,909	,000	,353
Zone * Urbanization	4,907	3	1,636	11,683	,000	,167
Zone * Soil_type_map	,102	1	,102	,729	,395	,004
Zone * Overlaying_layer__INT	,727	4	,182	1,299	,272	,029

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,331	1	,331	2,361	,126	,013
Soil_type_map * Overlaying_layer__INT	1,338E-5	1	1,338E-5	,000	,992	,000
Zone * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,172	1	,172	1,228	,269	,007
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Error	24,500	175	,140			
Total	310,045	224				
Corrected Total	310,045	223				

a. R Squared = ,921 (Adjusted R Squared = ,899)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable city in All observations from 3-8 meters is presented in Tables 12 and 13.

Table 12 Effective stress, T-test All obs. from 3-8 meters.

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-1,3393280	1,04534844	,14496375
Stockholm	172	,4049131	,88137494	,06720421

Table 13 Effective stress, T-test All obs. from 3-8 meters.

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	3,837	,051	-11,959	222	,000	-1,74424114	,14585268	-2,03167409	-1,45680818
Equal variances not assumed			-10,916	74,254	,000	-1,74424114	,15978390	-2,06259937	-1,42588290

B.2 Preconsolidation stress (σ'_C)

B.2.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 14. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1C_quadfit, Göteborg.

Table 14 Preconsolidation stress, One-Way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	224,834[a]	37	6,077	13,267	,000	,765
Intercept	4,907	1	4,907	10,713	,001	,066
Depth_INT	22,257	26	,856	1,869	,011	,243
Urbanization	,664	1	,664	1,450	,230	,010
Soil_type_map	,603	1	,603	1,317	,253	,009
Overlaying_layer__INT	15,400	4	3,850	8,406	,000	,182
Time_overlying_layer	6,129	3	2,043	4,460	,005	,081
Error	69,162	151	,458			
Total	293,996	189				
Corrected Total	293,996	188				

a. R Squared = ,765 (Adjusted R Squared = ,707)

Full-factorial ANOVA

The full-factorial has been made with all variables since each of them show an *F*-factor higher than 1, see Table 10 for results. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1C_quadfit, Göteborg. See Table 15 for result.

Table 15 Preconsolidation stress, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	275,316[a]	156	1,765	3,023	,000	,936
Intercept	3,843	1	3,843	6,584	,015	,171
Depth_INT	21,768	26	,837	1,434	,165	,538
Urbanization	,384	1	,384	,658	,423	,020
Soil_type_map	,000	0	.	.	.	,000
Overlaying_layer__INT	11,515	4	2,879	4,932	,003	,381
Time_overlying_layer	5,102	3	1,701	2,914	,049	,215
Depth_INT * Urbanization	5,057	6	,843	1,444	,229	,213
Depth_INT * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT	12,141	26	,467	,800	,718	,394
Depth_INT * Time_overlying_layer	7,416	22	,337	,577	,909	,284
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	1,433	1	1,433	2,455	,127	,071
Depth_INT * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	2,207	4	,552	,945	,451	,106
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	18,680	32	,584			
Total	293,996	189				

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Total	293,996	188				

a. R Squared = ,936 (Adjusted R Squared = ,627)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 16 for results of the second full-factorial.

Table 16 Preconsolidation stress, second Full-factorial Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	187,722[a]	11	17,066	28,423	,000	,639
Intercept	1,813	1	1,813	3,020	,084	,017
Overlaying_layer__INT	14,533	4	3,633	6,051	,000	,120
Time_overlying_layer	13,880	4	3,470	5,779	,000	,116
Overlaying_layer__INT * Time_overlying_layer	23,840	3	7,947	13,235	,000	,183
Error	106,274	177	,600			
Total	293,996	189				
Corrected Total	293,996	188				

a. R Squared = ,639 (Adjusted R Squared = ,616)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 17 and 18.

Table 17 Preconsolidation stress, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,7484229	,80880748	,07711677
Götatunneln, Göteborg	79	1,0421079	,98243276	,11053232

Table 18 Preconsildation stress, T-test Göteborg

	Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	7,425	,007	-13,713	187	,000	-1,79053080	,13057184	-2,04811391	-1,53294769
Equal variances not assumed			-13,285	147,421	,000	-1,79053080	,13477533	-2,05687199	-1,52418961

B.2.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 19. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1C_quadfit, Stockholm.

Table 19 Preconsolidation stress, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	179,919[a]	31	5,804	2,757	,000	,335
Intercept	4,159	1	4,159	1,976	,162	,011
Depth_INT	24,679	11	2,244	1,066	,392	,065
Zone	12,084	4	3,021	1,435	,224	,033
Soil_type_map	35,563	6	5,927	2,816	,012	,090
Overlaying_layer__INT	41,449	5	8,290	3,939	,002	,104
Urbanization	10,851	2	5,425	2,578	,079	,029
Time_overlying_layer	1,419	1	1,419	,674	,413	,004
Error	357,813	170	2,105			
Total	537,732	202				
Corrected Total	537,732	201				

a. R Squared = ,335 (Adjusted R Squared = ,213)

Full-factorial ANOVA

The full-factorial has been made with all variables except time since the soil overlaying the clay, since each of them show an *F*-factor higher than 1, see Table 20 for results. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1C_quadfit, Stockholm.

Table 20 Preconsolidation stress, Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	413,113[a]	139	2,972	1,479	,042	,768
Intercept	2,737	1	2,737	1,362	,248	,021
Depth_INT	16,653	11	1,514	,753	,684	,118
Zone	14,994	3	4,998	2,487	,069	,107
Soil_type_map	7,333	6	1,222	,608	,723	,056
Overlaying_layer__INT	4,800	5	,960	,478	,792	,037
Urbanization	8,919	2	4,459	2,219	,117	,067
Depth_INT * Zone	31,950	12	2,662	1,325	,228	,204
Depth_INT * Soil_type_map	25,623	16	1,601	,797	,683	,171
Depth_INT * Overlaying_layer__INT	8,727	10	,873	,434	,924	,065
Depth_INT * Urbanization	12,156	11	1,105	,550	,861	,089
Zone * Soil_type_map	2,120	1	2,120	1,055	,308	,017
Zone * Overlaying_layer__INT	12,619	3	4,206	2,093	,110	,092
Zone * Urbanization	2,236	1	2,236	1,113	,296	,018
Soil_type_map * Overlaying_layer__INT	,437	1	,437	,218	,643	,003
Soil_type_map * Urbanization	,000	0	.	.	.	,000
Overlaying_layer__INT * Urbanization	2,456	1	2,456	1,222	,273	,019
Depth_INT * Zone * Soil_type_map	3,791	1	3,791	1,886	,175	,030
Depth_INT * Zone * Overlaying_layer__INT	1,729	3	,576	,287	,835	,014
Depth_INT * Zone * Urbanization	,529	1	,529	,263	,610	,004
Depth_INT * Soil_type_map * Overlaying_layer__INT	5,219E-5	1	5,219E-5	,000	,996	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Depth_INT * Zone * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT * Urbanization	,000	0	.	.	.	,000
Error	124,619	62	2,010			
Total	537,732	202				
Corrected Total	537,732	201				

a. R Squared = ,768 (Adjusted R Squared = ,249)

B.2.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 21. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1C_quadfit, All observation from 3-8 meters.

Table 21 Preconsolidation stress, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	393,985[a]	31	12,709	8,278	,000	,572
Intercept	3,920	1	3,920	2,553	,112	,013
Zone	85,160	5	17,032	11,093	,000	,224
Urbanization	12,437	2	6,218	4,050	,019	,040
Soil_type_map	31,941	8	3,993	2,600	,010	,098
Overlaying_layer__INT	36,690	6	6,115	3,983	,001	,111
Depth_INT	3,658	5	,732	,477	,794	,012
Time_overlying_layer	11,714	3	3,905	2,543	,058	,038
Error	294,781	192	1,535			
Total	688,766	224				
Corrected Total	688,766	223				

a. R Squared = ,572 (Adjusted R Squared = ,503)

Full-factorial ANOVA

The full-factorial has been made with all variables except sampling depth, since each of them show an *F*-factor higher than 1, see Table 22 for results. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1C_quadfit, All observation from 3-8 meters.

Table 22 Preconsolidation stress, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	488,765[a]	60	8,146	6,639	,000	,710
Intercept	18,963	1	18,963	15,455	,000	,087

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone	33,102	4	8,276	6,745	,000	,142
Urbanization	17,352	2	8,676	7,071	,001	,080
Soil_type_map	6,616	5	1,323	1,078	,374	,032
Overlaying_layer__INT	13,220	6	2,203	1,796	,103	,062
Time_overlying_layer	3,379	2	1,690	1,377	,255	,017
Zone * Urbanization	1,803	1	1,803	1,470	,227	,009
Zone * Soil_type_map	14,045	1	14,045	11,447	,001	,066
Zone * Overlaying_layer__INT	6,035	4	1,509	1,230	,300	,029
Zone * Time_overlying_layer	3,151	3	1,050	,856	,465	,016
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	1,178	1	1,178	,960	,329	,006
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	1,520	1	1,520	1,239	,267	,008
Soil_type_map * Time_overlying_layer	,031	1	,031	,025	,874	,000
Overlaying_layer__INT * Time_overlying_layer	10,086	3	3,362	2,740	,045	,048
Zone * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	200,000	163	1,227			
Total	688,766	224				
Corrected Total	688,766	223				

a. R Squared = ,710 (Adjusted R Squared = ,603)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 23 for results of the second full-factorial.

Table 23 Preconsolidation stress, second Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	346,668[a]	13	26,667	16,370	,000	,503
Intercept	1,074	1	1,074	,659	,418	,003
Zone	175,362	6	29,227	17,941	,000	,339
Urbanization	,317	2	,159	,097	,907	,001
Zone * Urbanization	55,335	5	11,067	6,794	,000	,139
Error	342,098	210	1,629			
Total	688,766	224				
Corrected Total	688,766	223				

a. R Squared = ,503 (Adjusted R Squared = ,473)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 24 and 25.

Table 24 Preconsolidation stress, T-test All obs. from 3-8 meter

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-1,5422987	1,34570611	,18661586
Stockholm	172	,4662764	1,59553759	,12165860

Table 25 Preconsolidation stress, T-test All obs. from 3-8 meter

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1,060	,304	-8,232	222	,000	-2,00857509	,24398685	-2,48940179	-1,52774839
Equal variances not assumed			-9,016	98,268	,000	-2,00857509	,22276960	-2,45063904	-1,56651114

B.3 Limit stress (σ'_L)

B.3.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 26. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1L_quadfit, Göteborg.

Table 26 Limit stress, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	328,530[a]	37	8,879	10,842	,000	,727
Intercept	9,397	1	9,397	11,474	,001	,071
Depth_INT	32,228	26	1,240	1,513	,065	,207
Urbanization	,778	1	,778	,950	,331	,006
Soil_type_map	,258	1	,258	,315	,575	,002
Overlaying_layer__INT	24,312	4	6,078	7,421	,000	,164
Time_overlying_layer	6,644	3	2,215	2,704	,048	,051
Error	123,669	151	,819			
Total	452,199	189				
Corrected Total	452,199	188				

a. R Squared = ,727 (Adjusted R Squared = ,660)

Full-factorial ANOVA

Results from the full-factorial ANOVA with the independent variables sampling depth, thickness of soil overlaying the clay and time since the soil overlaying was placed are presented, since each of them shows an F-factor above one see Table 27. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1L_quadfit, Göteborg.

Table 27 Limit stress, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	401,040[a]	133	3,015	3,242	,000	,887
Intercept	7,060	1	7,060	7,590	,008	,121
Depth_INT	41,522	26	1,597	1,717	,047	,448
Overlaying_layer__INT	29,449	4	7,362	7,915	,000	,365
Time_overlying_layer	16,079	4	4,020	4,321	,004	,239
Depth_INT * Overlaying_layer__INT	29,598	32	,925	,994	,496	,367
Depth_INT * Time_overlying_layer	37,050	39	,950	1,021	,465	,420
Overlaying_layer__INT * Time_overlying_layer	10,118	3	3,373	3,626	,018	,165
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	2,931	9	,326	,350	,953	,054
Error	51,160	55	,930			
Total	452,199	189				
Corrected Total	452,199	188				

a. R Squared = ,887 (Adjusted R Squared = ,613)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 28 and 29.

Table 28 Limit stress, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,8754667	1,01360359	,09664331
Götatunneln, Göteborg	79	1,2190042	1,33259576	,14992874

Table 29 Limit stress, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	9,071	,003	-12,271	187	,000	-2,09447093	,17068810	-2,43119265	-1,75774922
Equal variances not assumed			-11,742	139,100	,000	-2,09447093	,17837756	-2,44715286	-1,74178901

B.3.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 30. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1L_quadfit, Stockholm.

Table 30 Limit stress, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	315,666[a]	31	10,183	2,569	,000	,319
Intercept	12,825	1	12,825	3,236	,074	,019
Depth_INT	47,427	11	4,312	1,088	,374	,066
Zone	18,055	4	4,514	1,139	,340	,026
Soil_type_map	49,299	6	8,217	2,073	,059	,068
Overlaying_layer__INT	81,829	5	16,366	4,129	,001	,108
Urbanization	5,751	2	2,876	,726	,486	,008
Time_overlying_layer	1,151	1	1,151	,290	,591	,002
Error	673,808	170	3,964			
Total	989,474	202				

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Total	989,474	201				

a. R Squared = ,319 (Adjusted R Squared = ,195)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except time since the soil overlaying was placed are presented and grade of urbanization, since they have an F-factor above one see Table 31. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1L_quadfit, Stockholm.

Table 31 Limit stress, Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	660,793[a]	121	5,461	1,329	,086	,668
Intercept	17,918	1	17,918	4,361	,040	,052
Depth_INT	8,948	11	,813	,198	,997	,027
Zone	4,600	3	1,533	,373	,773	,014
Soil_type_map	46,756	6	7,793	1,897	,091	,125
Overlaying_layer__INT	43,088	5	8,618	2,097	,074	,116
Depth_INT * Zone	80,576	17	4,740	1,154	,321	,197
Depth_INT * Soil_type_map	73,486	22	3,340	,813	,701	,183
Depth_INT * Overlaying_layer__INT	51,414	12	4,285	1,043	,419	,135
Zone * Soil_type_map	6,830	3	2,277	,554	,647	,020
Zone * Overlaying_layer__INT	20,173	4	5,043	1,227	,306	,058
Soil_type_map * Overlaying_layer__INT	28,155	3	9,385	2,284	,085	,079
Depth_INT * Zone * Soil_type_map	8,993	3	2,998	,730	,537	,027
Depth_INT * Zone * Overlaying_layer__INT	13,007	4	3,252	,791	,534	,038
Depth_INT * Soil_type_map * Overlaying_layer__INT	10,852	4	2,713	,660	,621	,032

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Error	328,681	80	4,109			
Total	989,474	202				
Corrected Total	989,474	201				

a. R Squared = ,668 (Adjusted R Squared = ,165)

B.3.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 32. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1L_quadfit, All observations from 3-8 meters.

Table 32 Limit stress, One-way ANOVA All obs. from 3-8 meter

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	586,297[a]	31	18,913	6,279	,000	,503
Intercept	19,002	1	19,002	6,308	,013	,032
Depth_INT	4,936	5	,987	,328	,896	,008
Zone	116,945	5	23,389	7,765	,000	,168
Urbanization	12,829	2	6,414	2,129	,122	,022
Soil_type_map	48,442	8	6,055	2,010	,047	,077
Overlaying_layer__INT	80,383	6	13,397	4,448	,000	,122
Time_overlying_layer	12,369	3	4,123	1,369	,254	,021
Error	578,347	192	3,012			
Total	1164,644	224				
Corrected Total	1164,644	223				

a. R Squared = ,503 (Adjusted R Squared = ,423)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except sampling depth, since they have an F-factor above one see Table 33. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Sigma1L_quadfit, All observations from 3-8 meters.

Table 33 Limit stress, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	764,096[a]	60	12,735	5,182	,000	,656
Intercept	51,345	1	51,345	20,894	,000	,114
Zone	60,108	4	15,027	6,115	,000	,130
Urbanization	24,871	2	12,435	5,060	,007	,058
Soil_type_map	1,531	5	,306	,125	,987	,004
Overlaying_layer__INT	27,834	6	4,639	1,888	,086	,065
Time_overlying_layer	17,836	2	8,918	3,629	,029	,043
Zone * Urbanization	,419	1	,419	,170	,680	,001
Zone * Soil_type_map	23,090	1	23,090	9,396	,003	,055
Zone * Overlaying_layer__INT	8,418	4	2,104	,856	,492	,021
Zone * Time_overlying_layer	7,903	3	2,634	1,072	,363	,019
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	3,093	1	3,093	1,259	,264	,008
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	5,246	1	5,246	2,135	,146	,013
Soil_type_map * Time_overlying_layer	1,093	1	1,093	,445	,506	,003
Overlaying_layer__INT * Time_overlying_layer	40,941	3	13,647	5,553	,001	,093
Zone * Urbanization * Soil_type_map	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	400,549	163	2,457			
Total	1164,644	224				
Corrected Total	1164,644	223				

a. R Squared = ,656 (Adjusted R Squared = ,529)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 34 for results of the second full-factorial.

Table 34 Limit stress, second Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	514,332[a]	25	20,573	6,264	,000	,442
Intercept	9,534	1	9,534	2,903	,090	,014
Zone	170,111	4	42,528	12,948	,000	,207
Urbanization	1,921	2	,960	,292	,747	,003
Time_overlying_layer	2,626	4	,657	,200	,938	,004
Zone * Urbanization	26,724	3	8,908	2,712	,046	,039
Zone * Time_overlying_layer	9,284	3	3,095	,942	,421	,014
Urbanization * Time_overlying_layer	3,072	2	1,536	,468	,627	,005

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Urbanization * Time_overlying_layer	7,124	2	3,562	1,084	,340	,011
Error	650,313	198	3,284			
Total	1164,644	224				
Corrected Total	1164,644	223				

a. R Squared = ,442 (Adjusted R Squared = ,371)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 35 and 36.

Table 35 Limit stress, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-1,6806186	1,74452468	,24192205
Stockholm	172	,5080940	2,18735924	,16678458

Table 36 Limit stress, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,704	,402	-6,605	222	,000	-2,18871264	,33137534	-2,84175646	-1,53566881
Equal variances not assumed			-7,449	103,994	,000	-2,18871264	,29384243	-2,77141357	-1,60601170

B.4 The compression modulus M_L

B.4.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 37. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_ML_quadfit, Göteborg.

Table 37 Compression modulus M_L, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3319,796[a]	37	89,724	7,827	,000	,657
Intercept	105,237	1	105,237	9,180	,003	,057
Depth_INT	674,304	26	25,935	2,262	,001	,280
Urbanization	20,958	1	20,958	1,828	,178	,012
Soil_type_map	5,398	1	5,398	,471	,494	,003
Overlaying_layer__INT	226,251	4	56,563	4,934	,001	,116
Time_overlying_layer	100,238	3	33,413	2,915	,036	,055
Error	1730,988	151	11,463			
Total	5050,784	189				
Corrected Total	5050,784	188				

a. R Squared = ,657 (Adjusted R Squared = ,573)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except the soil type according to the geological soil map, since they have an F-factor above one see Table 38. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_ML_quadfit, Göteborg.

Table 38 Compression modulus M_L, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4709,221[a]	156	30,187	2,828	,000	,932
Intercept	95,258	1	95,258	8,924	,005	,218

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT	616,287	26	23,703	2,221	,016	,643
Urbanization	33,035	2	16,518	1,547	,228	,088
Overlaying_layer__INT	261,692	4	65,423	6,129	,001	,434
Time_overlying_layer	65,022	4	16,255	1,523	,219	,160
Depth_INT * Urbanization	91,438	10	9,144	,857	,581	,211
Depth_INT * Overlaying_layer__INT	308,151	26	11,852	1,110	,385	,474
Depth_INT * Time_overlying_layer	200,058	28	7,145	,669	,858	,369
Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Time_overlying_layer	1,547	1	1,547	,145	,706	,005
Overlaying_layer__INT * Time_overlying_layer	70,436	1	70,436	6,599	,015	,171
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Time_overlying_layer	103,287	5	20,657	1,935	,116	,232
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	48,698	4	12,175	1,141	,355	,125
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	341,563	32	10,674			
Total	5050,784	189				
Corrected Total	5050,784	188				

a. R Squared = ,932 (Adjusted R Squared = ,603)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 39 for results of the second full-factorial.

Table 39 Compression modulus M_L, second Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3844,622[a]	78	49,290	4,495	,000	,761
Intercept	234,728	1	234,728	21,407	,000	,163
Depth_INT	915,358	26	35,206	3,211	,000	,431
Overlaying_layer__INT	1257,451	4	314,363	28,669	,000	,510
Depth_INT * Overlaying_layer__INT	950,953	48	19,812	1,807	,006	,441
Error	1206,162	110	10,965			
Total	5050,784	189				
Corrected Total	5050,784	188				

a. R Squared = ,761 (Adjusted R Squared = ,592)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 40 and 41.

Table 40 Compression modulus M_L, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-2,7229669	3,53328426	,33688544
Götatunneln, Göteborg	79	3,7914729	4,72143398	,53120282

Table 41 Compression modulus M_L, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	8,793	,003	-10,850	187	,000	-6,51443985	,60041106	-7,69888938	-5,32999032
Equal variances not assumed			-10,356	137,450	,000	-6,51443985	,62902165	-7,75825061	-5,27062909

B.4.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 42. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_ML_quadfit, Stockholm.

Table 42 Compression modulus M_L, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9390,628[a]	31	302,923	2,847	,000	,342
Intercept	166,547	1	166,547	1,565	,213	,009
Depth_INT	1464,731	11	133,157	1,252	,257	,075
Zone	1322,685	4	330,671	3,108	,017	,068
Soil_type_map	2192,536	6	365,423	3,435	,003	,108
Overlaying_layer__INT	2394,225	5	478,845	4,501	,001	,117
Urbanization	121,987	2	60,994	,573	,565	,007
Time_overlying_layer	168,812	1	168,812	1,587	,210	,009
Error	18086,412	170	106,391			
Total	27477,040	202				
Corrected Total	27477,040	201				

a. R Squared = ,342 (Adjusted R Squared = ,222)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except the grade of urbanization, since they have an F-factor above one see Table 38. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_ML_quadfit, Stockholm. See Table 43 for result.

Table 43 Compression modulus M_L, Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18675,559[a]	140	133,397	,925	,652	,680
Intercept	783,373	1	783,373	5,429	,023	,082
Depth_INT	415,496	11	37,772	,262	,990	,045

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone	695,376	3	231,792	1,606	,197	,073
Soil_type_map	758,843	5	151,769	1,052	,396	,079
Overlaying_layer__INT	911,572	5	182,314	1,264	,291	,094
Time_overlying_layer	4,190	1	4,190	,029	,865	,000
Depth_INT * Zone	1168,434	14	83,460	,578	,871	,117
Depth_INT * Soil_type_map	894,539	18	49,697	,344	,993	,092
Depth_INT * Overlaying_layer__INT	860,834	10	86,083	,597	,810	,089
Depth_INT * Time_overlying_layer	283,025	7	40,432	,280	,959	,031
Zone * Soil_type_map	51,250	2	25,625	,178	,838	,006
Zone * Overlaying_layer__INT	143,096	3	47,699	,331	,803	,016
Zone * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	707,700	2	353,850	2,452	,095	,074
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	406,691	2	203,346	1,409	,252	,044
Depth_INT * Zone * Soil_type_map	22,025	1	22,025	,153	,697	,002
Depth_INT * Zone * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	182,079	2	91,040	,631	,536	,020
Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	8801,481	61	144,287			
Total	27477,040	202				
Corrected Total	27477,040	201				

a. R Squared = ,680 (Adjusted R Squared = -,055)

B.4.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 44. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_ML_quadfit, All observations from 3-8 meters.

Table 44 Compression modulus M_L, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10927,265[a]	31	352,492	4,061	,000	,396
Intercept	402,150	1	402,150	4,634	,033	,024
Zone	2465,595	5	493,119	5,682	,000	,129
Urbanization	34,356	2	17,178	,198	,821	,002
Time_overlying_layer	229,012	3	76,337	,880	,453	,014
Depth_INT	306,458	5	61,292	,706	,619	,018
Soil_type_map	2416,711	8	302,089	3,481	,001	,127
Overlaying_layer__INT	2437,632	6	406,272	4,681	,000	,128
Error	16663,668	192	86,790			
Total	27590,933	224				
Corrected Total	27590,933	223				

a. R Squared = ,396 (Adjusted R Squared = ,299)

Full-factorial ANOVA

Results from the full-factorial ANOVA with the independent variables Zone, Soil type according to map and Overlaying thickness above clay, since they have an F-factor above one see Table 45. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_ML_quadfit, All observation from 3-8 meters.

Table 45 Compression modulus M_L, Full-factorial ANOVA All obs. from 3-8 meters

A second full-factorial has been made with only significant main factors or interactions from the

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9521,143[a]	29	328,315	3,525	,000	,345
Intercept	652,770	1	652,770	7,008	,009	,035
Zone	3374,048	5	674,810	7,245	,000	,157
Time_overlying_layer	15,388	3	5,129	,055	,983	,001
Soil_type_map	2178,443	8	272,305	2,924	,004	,108
Zone * Time_overlying_layer	214,305	4	53,576	,575	,681	,012
Zone * Soil_type_map	566,262	3	188,754	2,026	,112	,030
Time_overlying_layer * Soil_type_map	325,164	2	162,582	1,746	,177	,018
Zone * Time_overlying_layer * Soil_type_map	73,093	1	73,093	,785	,377	,004
Error	18069,790	194	93,143			
Total	27590,933	224				
Corrected Total	27590,933	223				

a. R Squared = ,345 (Adjusted R Squared = ,247)

first full-factorial. See Table 46 for results of the second full-factorial.

Table 46 Compression modulus M_L, second Full-factorial All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8540,783[a]	19	449,515	4,814	,000	,310
Intercept	704,424	1	704,424	7,543	,007	,036
Zone	4320,379	6	720,063	7,711	,000	,185
Soil_type_map	3213,519	9	357,058	3,824	,000	,144
Zone * Soil_type_map	565,000	4	141,250	1,513	,200	,029
Error	19050,151	204	93,383			
Total	27590,933	224				
Corrected Total	27590,933	223				

a. R Squared = ,310 (Adjusted R Squared = ,245)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 47 and 48.

Table 47 Compression modulus M_L, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-5,3283833	5,40017559	,74886961
Stockholm	172	1,6109066	11,89155830	,90672282

Table 48 Compression modulus M_L, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	11,604	,001	-4,078	222	,000	-6,93928989	1,70168640	-10,29281586	-3,58576392
Equal variances not assumed			-5,901	188,997	,000	-6,93928989	1,17598978	-9,25904178	-4,61953800

B.5 The compression modulus M'

B.5.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 49. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_M1_quadfit, Göteborg.

Table 49 Compression modulus M', One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7,547[a]	37	,204	2,038	,001	,333
Intercept	,078	1	,078	,776	,380	,005
Depth_INT	3,324	26	,128	1,277	,183	,180
Urbanization	,664	1	,664	6,635	,011	,042
Soil_type_map	,039	1	,039	,386	,536	,003
Overlaying_layer__INT	,298	4	,075	,744	,563	,019
Time_overlying_layer	,539	3	,180	1,795	,150	,034

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Error	15,117	151	,100			
Total	22,664	189				
Corrected Total	22,664	188				

a. R Squared = ,333 (Adjusted R Squared = ,170)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except soil type according to the geological map and thickness of the soil layer overlaying the clay, since they have an F-factor above one see Table 50. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_M1_quadfit, Göteborg.

Table 50 Compression modulus M', Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	15,053[a]	118	,128	1,173	,235	,664
Intercept	,200	1	,200	1,841	,179	,026
Depth_INT	2,695	26	,104	,953	,538	,261
Urbanization	1,326	2	,663	6,097	,004	,148
Time_overlying_layer	,517	4	,129	1,188	,324	,064
Depth_INT * Urbanization	1,170	16	,073	,672	,811	,133
Depth_INT * Time_overlying_layer	3,847	43	,089	,823	,752	,336
Urbanization * Time_overlying_layer	,193	2	,096	,887	,416	,025
Depth_INT * Urbanization * Time_overlying_layer	1,896	13	,146	1,341	,211	,199
Error	7,611	70	,109			
Total	22,664	189				
Corrected Total	22,664	188				

a. R Squared = ,664 (Adjusted R Squared = ,098)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 51 and 52.

Table 51 Compression modulus M', T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0225929	,39738812	,03788947
Götatunneln, Göteborg	79	-,0314584	,26108066	,02937387

Table 52 Compression modulus M', T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	11,613	,001	1,056	187	,292	,05405131	,05118916	-,04693113	,15503376
Equal variances not assumed			1,127	185,671	,261	,05405131	,04794201	-,04052978	,14863241

B.5.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 53. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_M1_quadfit, Stockholm.

Table 53 Compression modulus M', One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1,962[a]	31	,063	,655	,918	,107
Intercept	,303	1	,303	3,137	,078	,018
Depth_INT	,467	11	,042	,439	,936	,028
Zone	,252	4	,063	,652	,626	,015
Soil_type_map	,353	6	,059	,608	,724	,021
Overlaying_layer__INT	,286	5	,057	,591	,707	,017
Time_overlying_layer	,019	1	,019	,199	,656	,001
Urbanization	,305	2	,153	1,580	,209	,018
Error	16,433	170	,097			

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	18,394	202				
Corrected Total	18,394	201				

a. R Squared = ,107 (Adjusted R Squared = -,056)

Since there is only one single variable showing an F-factor higher than 1, soil type according to the geological map, it is of no use to perform an Full-factorial ANOVA. Instead, all other variables are removed and another one-way ANOVA is performed. See Table 54 for results.

Table 54 Compression modulus M', second One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,425[a]	2	,213	2,356	,097	,023
Intercept	,105	1	,105	1,162	,282	,006
Urbanization	,425	2	,213	2,356	,097	,023
Error	17,969	199	,090			
Total	18,394	202				
Corrected Total	18,394	201				

a. R Squared = ,023 (Adjusted R Squared = ,013)

B.5.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 55. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_M1_quadfit, All observations from 3-8 meters.

Table 55 Compression modulus M', One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	17,656[a]	31	,570	5,240	,000	,458
Intercept	,275	1	,275	2,526	,114	,013
Zone	2,488	5	,498	4,577	,001	,107
Soil_type_map	2,188	8	,273	2,516	,013	,095

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT	1,247	5	,249	2,295	,047	,056
Urbanization	,096	2	,048	,443	,643	,005
Overlaying_layer__INT	,272	6	,045	,417	,867	,013
Time_overlying_layer	,391	3	,130	1,198	,312	,018
Error	20,869	192	,109			
Total	38,525	224				
Corrected Total	38,525	223				

a. R Squared = ,458 (Adjusted R Squared = ,371)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except Grade of urbanization and thickness of the soil overlaying the clay, since they have an F-factor above one see Table 56. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_M1_quadfit, All observations from 3-8 meters.

Table 56 Compression modulus M', Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	27,137[a]	114	,238	2,278	,000	,704
Intercept	,482	1	,482	4,609	,034	,041
Zone	3,584	5	,717	6,860	,000	,239
Soil_type_map	,647	7	,092	,884	,521	,054
Depth_INT	,505	5	,101	,966	,442	,042
Time_overlying_layer	,634	3	,211	2,024	,115	,053
Zone * Soil_type_map	,113	2	,057	,542	,583	,010
Zone * Depth_INT	2,224	20	,111	1,064	,397	,163
Zone * Time_overlying_layer	,566	3	,189	1,806	,150	,047
Soil_type_map * Depth_INT	1,751	20	,088	,838	,663	,133
Soil_type_map * Time_overlying_layer	1,259	2	,629	6,023	,003	,100

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Time_overlying_layer	,308	9	,034	,327	,964	,026
Zone * Soil_type_map * Depth_INT	,213	5	,043	,408	,843	,018
Zone * Soil_type_map * Time_overlying_layer	,109	1	,109	1,045	,309	,009
Zone * Depth_INT * Time_overlying_layer	,388	7	,055	,530	,810	,033
Soil_type_map * Depth_INT * Time_overlying_layer	,197	6	,033	,315	,928	,017
Zone * Soil_type_map * Depth_INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	11,388	109	,104			
Total	38,525	224				
Corrected Total	38,525	223				

a. R Squared = ,704 (Adjusted R Squared = ,395)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 57 and 58.

Table 57 Compression modulus M', T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-,4219656	,42082205	,05835752
Stockholm	172	,1275710	,31931207	,02434732

Table 58 Compression modulus M', T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	5,753	,017	-10,057	222	,000	-,54953656	,05464277	-,65722148	-,44185165
Equal variances not assumed			-8,691	69,670	,000	-,54953656	,06323284	-,67566098	-,42341215

B.6 OCR

B.6.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 59. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_OCRminus1_quadfit, Göteborg.

Table 59 OCR, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2,284[a]	37	,062	2,183	,001	,348
Intercept	,029	1	,029	1,033	,311	,007
Depth_INT	,493	26	,019	,671	,884	,104
Urbanization	,050	1	,050	1,766	,186	,012
Soil_type_map	,003	1	,003	,123	,726	,001
Overlaying_layer__INT	,680	4	,170	6,015	,000	,137
Time_overlying_layer	,091	3	,030	1,067	,365	,021
Error	4,271	151	,028			
Total	6,555	189				
Corrected Total	6,555	188				

a. R Squared = ,348 (Adjusted R Squared = ,189)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except soil sampling depth and soil type according to the geological soil map, since they have an F-factor above one see Table 60. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_OCRminus1_quadfit, Göteborg. See Table 60 for resu

Table 60 OCR, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2,221[a]	15	,148	5,911	,000	,339
Intercept	,002	1	,002	,073	,787	,000
Urbanization	,498	2	,249	9,937	,000	,103
Overlaying_layer__INT	,751	4	,188	7,493	,000	,148
Time_overlying_layer	,287	4	,072	2,865	,025	,062
Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Time_overlying_layer	,005	1	,005	,191	,662	,001
Overlaying_layer__INT * Time_overlying_layer	,027	1	,027	1,093	,297	,006
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	4,334	173	,025			
Total	6,555	189				
Corrected Total	6,555	188				

a. R Squared = ,339 (Adjusted R Squared = ,282)

***T*-test**

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 61 and 62.

Table 61 OCR, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0695302	,71888421	,06854292
Götatunneln, Göteborg	79	-,0968142	,75213663	,08462198

Table 62 OCR, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,050	,823	1,539	187	,126	,16634444	,10809063	-,04688929	,37957818
Equal variances not assumed			1,528	163,547	,129	,16634444	,10889909	-,04868500	,38137389

B.6.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 63. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_OCRminus1_quadfit, Stockholm.

Table 63 OCR, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4,288[a]	31	,138	1,489	,059	,214
Intercept	,005	1	,005	,054	,816	,000
Depth_INT	,753	11	,068	,737	,702	,046
Soil_type_map	2,326	6	,388	4,174	,001	,128
Zone	1,242	4	,311	3,344	,012	,073
Urbanization	,488	2	,244	2,626	,075	,030
Overlaying_layer__INT	,112	5	,022	,241	,944	,007

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time_overlying_layer	,078	1	,078	,840	,361	,005
Error	15,790	170	,093			
Total	20,078	202				
Corrected Total	20,078	201				

a. R Squared = ,214 (Adjusted R Squared = ,070)

Full-factorial ANOVA

Results from the full-factorial ANOVA with the independent variables soil type according to the geological soil map, since they have an F-factor above one see Table 64. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_OCRminus1_quadfit, Stockholm.

Table 64 OCR, Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5,483[a]	23	,238	2,907	,000	,273
Intercept	,087	1	,087	1,063	,304	,006
Soil_type_map	1,581	8	,198	2,411	,017	,098
Zone	1,192	4	,298	3,634	,007	,076
Urbanization	,655	2	,328	3,997	,020	,043
Soil_type_map * Zone	,625	3	,208	2,541	,058	,041
Soil_type_map * Urbanization	,238	2	,119	1,450	,237	,016
Zone * Urbanization	,481	3	,160	1,957	,122	,032
Soil_type_map * Zone * Urbanization	,249	1	,249	3,038	,083	,017
Error	14,595	178	,082			
Total	20,078	202				
Corrected Total	20,078	201				

a. R Squared = ,273 (Adjusted R Squared = ,179)

B.6.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 65. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_OCRminus1_quadfit, All observations from 3-8 meters.

Table 65 OCR, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3,300[a]	31	,106	1,487	,057	,194
Intercept	,012	1	,012	,165	,685	,001
Zone	1,151	5	,230	3,216	,008	,077
Depth_INT	,079	5	,016	,220	,954	,006
Urbanization	,264	2	,132	1,845	,161	,019
Soil_type_map	1,948	8	,243	3,401	,001	,124
Overlaying_layer__INT	,326	6	,054	,759	,603	,023
Time_overlying_layer	,104	3	,035	,482	,695	,007
Error	13,746	192	,072			
Total	17,047	224				
Corrected Total	17,047	223				

a. R Squared = ,194 (Adjusted R Squared = ,063)

Full-factorial ANOVA

Results from the full-factorial ANOVA with the independent variables Zone, Grade of urbanization and Soil type according to map, since they have an F-factor above one see Table 66. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_OCRminus1_quadfit, All observations from 3-8 meters. See Table 66 for result.

Table 66 OCR, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4,687[a]	28	,167	2,641	,000	,275
Intercept	,028	1	,028	,446	,505	,002
Zone	1,981	6	,330	5,208	,000	,138

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization	,608	2	,304	4,796	,009	,047
Soil_type_map	1,228	9	,136	2,152	,027	,090
Zone * Urbanization	,445	4	,111	1,753	,140	,035
Zone * Soil_type_map	,452	3	,151	2,378	,071	,035
Urbanization * Soil_type_map	,280	2	,140	2,207	,113	,022
Zone * Urbanization * Soil_type_map	,061	1	,061	,965	,327	,005
Error	12,359	195	,063			
Total	17,047	224				
Corrected Total	17,047	223				

a. R Squared = ,275 (Adjusted R Squared = ,171)

***T*-test**

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 67 and 68.

Table 67 OCR, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	,0447868	,20540595	,02848468
Stockholm	172	-,0135402	,29378736	,02240108

Table 68 OCR, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	4,696	,031	1,335	222	,183	,05832700	,04367830	-,02775015	,14440414
Equal variances not assumed			1,610	119,912	,110	,05832700	,03623790	-,01342206	,13007605

B.7 CLR

B.7.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 69. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_CLRminus1_quadfit, Göteborg.

Table 69 CLR, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,418[a]	37	,011	,856	,703	,173
Intercept	,013	1	,013	,951	,331	,006
Depth_INT	,295	26	,011	,859	,664	,129
Urbanization	,000	1	,000	,015	,903	,000
Soil_type_map	,013	1	,013	1,006	,317	,007
Overlaying_layer__INT	,033	4	,008	,629	,642	,016
Time_overlying_layer	,028	3	,009	,703	,552	,014
Error	1,993	151	,013			
Total	2,412	189				
Corrected Total	2,412	188				

a. R Squared = ,173 (Adjusted R Squared = -,029)

Since there is only one single variable showing an *F*-factor higher than 1, soil type according to the geological map, it is of no use to perform an Full-factorial ANOVA. Instead, all other variables are removed and another one-way ANOVA is performed. See Table 70 for result from the second One-way ANOVA.

Table 70 CLR, second One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,060[a]	2	,030	2,354	,098	,025
Intercept	,000	1	,000	,032	,858	,000
Soil_type_map	,060	2	,030	2,354	,098	,025
Error	2,352	186	,013			

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	2,412	189				
Corrected Total	2,412	188				

a. R Squared = ,025 (Adjusted R Squared = ,014)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 71 and 72.

Table 71 CLR, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0068232	,12113030	,01154932
Götatunneln, Göteborg	79	-,0095006	,10127163	,01139395

Table 72 CLR, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	3,215	,075	,977	187	,330	,01632375	,01670475	-,01663022	,04927773
Equal variances not assumed			1,006	182,648	,316	,01632375	,01622371	-,01568624	,04833374

B.7.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 73. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_CLRminus1_quadfit, Stockholm.

Table 73 CLR, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,955[a]	31	,031	1,009	,462	,155
Intercept	,042	1	,042	1,376	,242	,008

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Soil_type_map	,068	6	,011	,373	,895	,013
Zone	,261	4	,065	2,138	,078	,048
Urbanization	,111	2	,056	1,818	,165	,021
Depth_INT	,234	11	,021	,697	,741	,043
Overlaying_layer__INT	,201	5	,040	1,317	,259	,037
Time_overlying_layer	,010	1	,010	,324	,570	,002
Error	5,192	170	,031			
Total	6,147	202				
Corrected Total	6,147	201				

a. R Squared = ,155 (Adjusted R Squared = ,001)

Full-factorial ANOVA

Results from the full-factorial ANOVA with the independent variables overlaying soil thickness, zone and grade of urbanization, since they have an F-factor above one see Table 74. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_CLRminus1_quadfit, Stockholm.

Table 74 CLR, Full-factorial Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,975[a]	26	,037	1,268	,186	,159
Intercept	,095	1	,095	3,199	,075	,018
Zone	,080	3	,027	,905	,440	,015
Urbanization	,037	2	,018	,620	,539	,007
Overlaying_layer__INT	,208	5	,042	1,405	,225	,039
Zone * Urbanization	,056	3	,019	,634	,594	,011
Zone * Overlaying_layer__INT	,146	4	,037	1,237	,297	,027
Urbanization * Overlaying_layer__INT	,030	3	,010	,338	,798	,006
Zone * Urbanization * Overlaying_layer__INT	,131	2	,066	2,220	,112	,025

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Error	5,173	175	,030			
Total	6,147	202				
Corrected Total	6,147	201				

a. R Squared = ,159 (Adjusted R Squared = ,034)

B.7.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 75. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_CLRminus1_quadfit, All observations from 3-8 meters.

Table 75 CLR, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1,156[a]	31	,037	1,259	,177	,169
Intercept	,122	1	,122	4,136	,043	,021
Zone	,398	5	,080	2,689	,023	,065
Urbanization	,049	2	,025	,835	,436	,009
Soil_type_map	,121	8	,015	,510	,848	,021
Depth_INT	,161	5	,032	1,088	,368	,028
Overlaying_layer__INT	,313	6	,052	1,760	,109	,052
Time_overlying_layer	,039	3	,013	,438	,726	,007
Error	5,687	192	,030			
Total	6,842	224				
Corrected Total	6,842	223				

a. R Squared = ,169 (Adjusted R Squared = ,035)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except Grade of urbanization and Soil type according to geological map, since they have an F-factor above one see Table 76. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_CLRminus1_quadfit, All observations from 3-8 meters.

Table 76 CLR, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2,289[a]	82	,028	,864	,764	,335
Intercept	,080	1	,080	2,476	,118	,017
Zone	,367	6	,061	1,893	,086	,075
Overlaying_layer__INT	,355	6	,059	1,832	,097	,072
Depth_INT	,160	5	,032	,992	,425	,034
Zone * Overlaying_layer__INT	,044	8	,005	,170	,994	,010
Zone * Depth_INT	,288	22	,013	,406	,992	,060
Overlaying_layer__INT * Depth_INT	,433	15	,029	,893	,573	,087
Zone * Overlaying_layer__INT * Depth_INT	,290	16	,018	,561	,908	,060
Error	4,553	141	,032			
Total	6,842	224				
Corrected Total	6,842	223				

a. R Squared = ,335 (Adjusted R Squared = -,052)

***T*-test**

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 77 and 78.

Table 77 CLR, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	,0502256	,14520747	,02013665
Stockholm	172	-,0151845	,18090087	,01379356

Table 78 CLR, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	3,278	,072	2,384	222	,018	,06541004	,02743394	,01134577	,11947432
Equal variances not assumed			2,680	103,306	,009	,06541004	,02440793	,01700437	,11381572

B.8 Density

B.8.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 79. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Density_quadfit, Göteborg.

Table 79 Density, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,035[a]	37	,001	3,520	,000	,463
Intercept	,000	1	,000	,835	,362	,005
Depth_INT	,010	26	,000	1,407	,106	,195
Urbanization	,001	1	,001	2,040	,155	,013
Soil_type_map	,000	1	,000	1,110	,294	,007
Overlaying_layer__INT	,003	4	,001	3,090	,018	,076
Time_overlying_layer	,005	3	,002	5,788	,001	,103
Error	,040	151	,000			

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	,075	189				
Corrected Total	,075	188				

a. R Squared = ,463 (Adjusted R Squared = ,332)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables since they have an F-factor above one see Table 80. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Density_quadfit, Göteborg.

Table 80 Density, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,066[a]	156	,000	1,435	,115	,875
Intercept	,001	1	,001	2,943	,096	,084
Depth_INT	,010	26	,000	1,346	,210	,522
Urbanization	,000	1	,000	,970	,332	,029
Soil_type_map	,000	0	.	.	.	,000
Overlaying_layer__INT	,003	4	,001	2,299	,080	,223
Time_overlying_layer	,004	3	,001	4,157	,014	,280
Depth_INT * Urbanization	,001	6	,000	,675	,670	,112
Depth_INT * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT	,004	26	,000	,570	,928	,316
Depth_INT * Time_overlying_layer	,003	22	,000	,458	,970	,239
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	,000	1	,000	1,520	,227	,045
Depth_INT * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	4	5,221E-5	,178	,948	,022
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	,009	32	,000			
Total	,075	189				
Corrected Total	,075	188				

a. R Squared = ,875 (Adjusted R Squared = ,265)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 81 and 82.

Table 81 Density, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	-,0061557	,01662178	,00158482
Götatunneln, Göteborg	79	,0085712	,02120124	,00238533

Table 82 Density, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	6,398	,012	-5,349	187	,000	-,01472696	,00275323	-,02015834	-,00929559
Equal variances not assumed			-5,142	142,230	,000	-,01472696	,00286382	-,02038811	-,00906582

B.8.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 83. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Density_quadfit, Stockholm.

Table 83 Density, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,074[a]	31	,002	2,923	,000	,348
Intercept	,000	1	,000	,367	,546	,002
Urbanization	,004	2	,002	2,574	,079	,029
Depth_INT	,017	11	,002	1,882	,045	,109
Zone	,012	4	,003	3,550	,008	,077
Soil_type_map	,010	6	,002	2,079	,058	,068
Overlaying_layer__INT	,013	5	,003	3,130	,010	,084
Time_overlying_layer	,002	1	,002	2,911	,090	,017
Error	,140	170	,001			
Total	,214	202				
Corrected Total	,214	201				

a. R Squared = ,348 (Adjusted R Squared = ,229)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables since they have an F-factor above one see Table 84. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Density_quadfit, Stockholm.

Table 84 Density, Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,167[a]	156	,001	1,023	,481	,780
Intercept	,003	1	,003	2,680	,109	,056
Urbanization	,003	2	,001	1,220	,305	,051
Depth_INT	,014	11	,001	1,177	,329	,223

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone	,003	3	,001	,822	,489	,052
Soil_type_map	,006	5	,001	1,074	,387	,107
Overlaying_layer__INT	,003	5	,001	,570	,723	,060
Time_overlying_layer	,001	1	,001	1,250	,270	,027
Urbanization * Depth_INT	,002	9	,000	,263	,981	,050
Urbanization * Zone	,000	0	.	.	.	,000
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,000	1	,000	,440	,511	,010
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone	,003	10	,000	,305	,976	,064
Depth_INT * Soil_type_map	,007	15	,000	,421	,965	,123
Depth_INT * Overlaying_layer__INT	,003	9	,000	,266	,981	,051
Depth_INT * Time_overlying_layer	,003	5	,001	,626	,681	,065
Zone * Soil_type_map	,000	1	,000	,158	,693	,003
Zone * Overlaying_layer__INT	,001	3	,000	,414	,743	,027
Zone * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	1,454E-5	1	1,454E-5	,014	,907	,000
Urbanization * Depth_INT * Zone	,000	0	.	.	.	,000
Urbanization * Depth_INT * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Depth_INT * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Depth_INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization * Zone * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Zone * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Zone * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Zone * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Zone * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Depth_INT * Zone * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization * Depth_INT * Zone * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization * Depth_INT * Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	,047	45	,001			
Total	,214	202				
Corrected Total	,214	201				

a. R Squared = ,780 (Adjusted R Squared = ,017)

B.8.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 85. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Density_quadfit, All observations from 3-8 meters.

Table 85 Density, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,222[a]	31	,007	9,957	,000	,617
Intercept	,000	1	,000	,188	,665	,001
Zone	,084	5	,017	23,201	,000	,377

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Soil_type_map	,014	8	,002	2,405	,017	,091
Depth_INT	,003	5	,001	,938	,458	,024
Time_overlying_layer	,004	3	,001	1,714	,166	,026
Urbanization	,005	2	,003	3,803	,024	,038
Overlaying_layer__INT	,011	6	,002	2,603	,019	,075
Error	,138	192	,001			
Total	,360	224				
Corrected Total	,360	223				

a. R Squared = ,617 (Adjusted R Squared = ,555)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables since they have an F-factor above one see Table 86. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_Density_quadfit, All observations from 3-8 meters.

Table 86 Density, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	,256[a]	60	,004	6,619	,000	,709
Intercept	,004	1	,004	5,609	,019	,033
Zone	,055	4	,014	21,349	,000	,344
Soil_type_map	,004	5	,001	1,105	,360	,033
Time_overlying_layer	,002	2	,001	1,250	,289	,015
Urbanization	,003	2	,002	2,531	,083	,030
Overlaying_layer__INT	,004	6	,001	1,063	,387	,038
Zone * Soil_type_map	4,564E-6	1	4,564E-6	,007	,933	,000
Zone * Time_overlying_layer	,002	3	,001	1,156	,328	,021
Zone * Urbanization	,001	1	,001	,833	,363	,005
Zone * Overlaying_layer__INT	,002	4	,000	,702	,591	,017

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Soil_type_map * Time_overlying_layer	,000	1	,000	,268	,605	,002
Soil_type_map * Urbanization	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,002	1	,002	2,648	,106	,016
Time_overlying_layer * Urbanization	,000	0	.	.	.	,000
Time_overlying_layer * Overlaying_layer__INT	,004	3	,001	1,984	,118	,035
Urbanization * Overlaying_layer__INT	,000	1	,000	,456	,500	,003
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Time_overlying_layer * Urbanization	,000	0	.	.	.	,000
Zone * Time_overlying_layer * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer * Urbanization	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time_overlying_layer * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Time_overlying_layer * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Error	,105	163	,001			
Total	,360	224				
Corrected Total	,360	223				

a. R Squared = ,709 (Adjusted R Squared = ,602)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 87 and 88.

Table 87 Density, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	-,0460105	,02578823	,00357618
Stockholm	172	,0139101	,03273140	,00249575

Table 88 Density, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	3,161	,077	-12,107	222	,000	-,05992060	,00494912	-,06967387	-,05016732
Equal variances not assumed			-13,740	105,324	,000	-,05992060	,00436094	-,06856723	-,05127396

B.9 Water content

B.9.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 89. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_w_quadfit, Göteborg.

Table 89 Water content, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	25,130[a]	37	,679	3,679	,000	,474
Intercept	,021	1	,021	,115	,735	,001
Depth_INT	6,048	26	,233	1,260	,195	,178
Urbanization	,954	1	,954	5,166	,024	,033
Soil_type_map	,656	1	,656	3,554	,061	,023
Overlaying_layer__INT	1,280	4	,320	1,733	,145	,044
Time_overlying_layer	3,189	3	1,063	5,758	,001	,103
Error	27,876	151	,185			

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	53,007	189				
Corrected Total	53,007	188				

a. R Squared = ,474 (Adjusted R Squared = ,345)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables since they have an F-factor above one see Table 90. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_w_quadfit, Göteborg.

Table 90 Water content, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	45,798[a]	156	,294	1,303	,191	,864
Intercept	,747	1	,747	3,317	,078	,094
Depth_INT	5,984	26	,230	1,022	,472	,454
Urbanization	,423	1	,423	1,878	,180	,055
Soil_type_map	,000	0	.	.	.	,000
Overlaying_layer__INT	1,652	4	,413	1,834	,147	,186
Time_overlying_layer	1,597	3	,532	2,364	,090	,181
Depth_INT * Urbanization	1,297	6	,216	,960	,468	,153
Depth_INT * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT	1,939	26	,075	,331	,997	,212
Depth_INT * Time_overlying_layer	2,160	22	,098	,436	,977	,231
Urbanization * Soil_type_map	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	,627	1	,627	2,781	,105	,080
Depth_INT * Urbanization * Soil_type_map	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,030	4	,007	,033	,998	,004
Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	7,209	32	,225			
Total	53,007	189				
Corrected Total	53,007	188				

a. R Squared = ,864 (Adjusted R Squared = ,201)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 91 and 92.

Table 91 Water content, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,1781623	,43807797	,04176910
Götatunneln, Göteborg	79	-,2480741	,55162857	,06206306

Table 92 Water content, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	5,133	,025	5,915	187	,000	,42623645	,07206550	,28407061	,56840229
Equal variances not assumed			5,698	143,582	,000	,42623645	,07480963	,27836595	,57410695

B.9.2 Stockholm, ANOVA result

Results from the one-way ANOVA with all the independent variables are presented in Table 93. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_w_quadfit, Stockholm.

Table 93 Water content, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	43,154[a]	31	1,392	3,187	,000	,368
Intercept	,352	1	,352	,807	,370	,005
Urbanization	,854	2	,427	,977	,378	,011
Depth_INT	10,497	11	,954	2,185	,017	,124
Zone	6,968	4	1,742	3,988	,004	,086
Soil_type_map	6,987	6	1,165	2,666	,017	,086
Overlaying_layer__INT	6,931	5	1,386	3,174	,009	,085
Time_overlying_layer	,306	1	,306	,701	,404	,004
Error	74,248	170	,437			
Total	117,402	202				
Corrected Total	117,402	201				

a. R Squared = ,368 (Adjusted R Squared = ,252)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except grade of urbanization, since they have an F-factor above one see Table 94. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_w_quadfit, Stockholm.

Table 94 Water content, Fullfactorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	84,134[a]	121	,695	1,672	,007	,717
Intercept	,134	1	,134	,322	,572	,004
Depth_INT	9,007	11	,819	1,969	,043	,213
Zone	3,719	3	1,240	2,981	,036	,101
Soil_type_map	9,474	6	1,579	3,797	,002	,222
Overlaying_layer__INT	4,033	5	,807	1,939	,097	,108
Depth_INT * Zone	5,815	17	,342	,822	,663	,149

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Soil_type_map	9,890	22	,450	1,081	,384	,229
Depth_INT * Overlaying_layer__INT	2,105	12	,175	,422	,951	,060
Zone * Soil_type_map	2,412	3	,804	1,933	,131	,068
Zone * Overlaying_layer__INT	1,133	4	,283	,681	,607	,033
Soil_type_map * Overlaying_layer__INT	1,957	3	,652	1,568	,204	,056
Depth_INT * Zone * Soil_type_map	,595	3	,198	,477	,699	,018
Depth_INT * Zone * Overlaying_layer__INT	,696	4	,174	,419	,795	,021
Depth_INT * Soil_type_map * Overlaying_layer__INT	1,702	4	,426	1,023	,400	,049
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Error	33,268	80	,416			
Total	117,402	202				
Corrected Total	117,402	201				

a. R Squared = ,717 (Adjusted R Squared = ,288)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 95 for results of the second full-factorial.

Table 95 Water content, second Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	68,929[a]	83	,830	2,022	,000	,587
Intercept	,205	1	,205	,500	,481	,004
Depth_INT	8,353	11	,759	1,849	,053	,147
Zone	8,632	4	2,158	5,253	,001	,151
Soil_type_map	14,523	8	1,815	4,419	,000	,231

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Zone	6,132	21	,292	,711	,815	,112
Depth_INT * Soil_type_map	18,515	29	,638	1,554	,052	,276
Zone * Soil_type_map	3,627	3	1,209	2,943	,036	,070
Depth_INT * Zone * Soil_type_map	2,606	5	,521	1,269	,282	,051
Error	48,473	118	,411			
Total	117,402	202				
Corrected Total	117,402	201				

a. R Squared = ,587 (Adjusted R Squared = ,297)

B.9.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 96. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_w_quadfit, All observations from 3-8 meters.

Table 96 Water content, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	143,691[a]	31	4,635	11,470	,000	,649
Intercept	,202	1	,202	,500	,480	,003
Zone	49,189	5	9,838	24,343	,000	,388
Soil_type_map	9,529	8	1,191	2,947	,004	,109
Time_overlying_layer	1,677	3	,559	1,383	,249	,021
Urbanization	1,910	2	,955	2,363	,097	,024
Overlaying_layer__INT	5,815	6	,969	2,398	,029	,070
Depth_INT	2,338	5	,468	1,157	,332	,029
Error	77,592	192	,404			
Total	221,283	224				
Corrected Total	221,283	223				

a. R Squared = ,649 (Adjusted R Squared = ,593)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except grade of urbanization, since they have an F-factor above one see Table 97. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_w_quadfit, All observations from 3-8 meters.

Table 97 Water content, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	192,603[a]	176	1,094	1,793	,010	,870
Intercept	,906	1	,906	1,485	,229	,031
Zone	25,817	4	6,454	10,577	,000	,474
Soil_type_map	3,310	5	,662	1,085	,381	,103
Depth_INT	4,342	5	,868	1,423	,233	,131
Urbanization	1,210	2	,605	,992	,379	,040
Overlaying_layer__INT	2,582	6	,430	,705	,647	,083
Time_overlying_layer	1,638	2	,819	1,342	,271	,054
Zone * Soil_type_map	,246	1	,246	,404	,528	,009
Zone * Depth_INT	4,186	13	,322	,528	,896	,127
Zone * Urbanization	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT	,373	4	,093	,153	,961	,013
Zone * Time_overlying_layer	,017	1	,017	,027	,869	,001
Soil_type_map * Depth_INT	5,826	13	,448	,734	,721	,169
Soil_type_map * Urbanization	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization	,819	7	,117	,192	,986	,028

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Overlaying_layer__INT	,978	9	,109	,178	,995	,033
Depth_INT * Time_overlying_layer	1,439	6	,240	,393	,880	,048
Urbanization * Overlaying_layer__INT	,210	1	,210	,344	,560	,007
Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Overlaying_layer__INT * Time_overlying_layer	,426	2	,213	,349	,707	,015
Zone * Soil_type_map * Depth_INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Depth_INT * Urbanization	,000	0	.	.	.	,000
Zone * Depth_INT * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Depth_INT * Time_overlying_layer	,003	1	,003	,004	,949	,000
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Urbanization	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Soil_type_map * Depth_INT * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,024	2	,012	,020	,980	,001
Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Urbanization * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Urbanization * Overlaying_layer__INT * Time_overlying_layer	,000	0	.	.	.	,000
Error	28,681	47	,610			
Total	221,283	224				
Corrected Total	221,283	223				

a. R Squared = ,870 (Adjusted R Squared = ,385)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 98 and 99.

Table 98 Water content, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	1,1843419	,70803131	,09818628
Stockholm	172	-,3580569	,76749233	,05852074

Table 99 Water content, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,120	,730	12,922	222	,000	1,54239876	,11936358	1,30716807	1,77762945
Equal variances not assumed			13,494	90,272	,000	1,54239876	,11430320	1,31532483	1,76947269

B.10 Liquid limit (w_L)

B.10.1 Göteborg, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 100. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_wL_quadfit, Göteborg.

Table 100 Liquid limit, One-way ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	20,208[a]	37	,546	1,890	,004	,317
Intercept	,003	1	,003	,010	,921	,000
Depth_INT	6,157	26	,237	,819	,717	,124
Urbanization	,244	1	,244	,845	,360	,006
Soil_type_map	,096	1	,096	,333	,565	,002
Overlaying_layer__INT	2,658	4	,664	2,299	,061	,057
Time_overlying_layer	2,010	3	,670	2,319	,078	,044
Error	43,639	151	,289			
Total	63,846	189				
Corrected Total	63,846	188				

a. R Squared = ,317 (Adjusted R Squared = ,149)

Full-factorial ANOVA

Results from the full-factorial ANOVA with the independent variables thickness of the soil layer overlaying the clay and the time since the soil layer overlaying the clay was placed, since they have an F-factor above one see Table 101. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_wL_quadfit, Göteborg.

Table 101 Liquid limit, Full-factorial ANOVA Göteborg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	14,809[a]	11	1,346	4,859	,000	,232
Intercept	,019	1	,019	,068	,795	,000
Overlaying_layer__INT	4,864	4	1,216	4,389	,002	,090
Time_overlying_layer	6,231	4	1,558	5,623	,000	,113
Overlaying_layer__INT * Time_overlying_layer	4,559	3	1,520	5,485	,001	,085
Error	49,037	177	,277			
Total	63,846	189				
Corrected Total	63,846	188				

a. R Squared = ,232 (Adjusted R Squared = ,184)

***T*-test**

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 102 and 103.

Table 102 Liquid limit, T-test Göteborg

	N	Mean	Std. Deviation	Std. Error Mean
E45-Norge/Vänerbanan, Göteborg	110	,0146965	,61883961	,05900404
Götatunneln, Göteborg	79	-,0204634	,53164538	,05981478

Table 103 Liquid limit, T-test Göteborg

	Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	,358	,551	,408	187	,684	,03515987	,08613394	-,13475923	,20507897
Equal variances not assumed			,418	181,008	,676	,03515987	,08401955	-,13062384	,20094358

B.10.2 Stockholm, ANOVA result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 104. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_wL_quadfit, Stockholm.

Table 104 Liquid limit, One-way ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	22,335[a]	31	,720	2,187	,001	,285
Intercept	,102	1	,102	,308	,579	,002
Depth_INT	8,587	11	,781	2,369	,009	,133
Zone	4,010	4	1,003	3,043	,019	,067
Soil_type_map	4,404	6	,734	2,227	,043	,073
Urbanization	,905	2	,452	1,373	,256	,016
Overlaying_layer__INT	,429	5	,086	,261	,934	,008
Time_overlying_layer	,248	1	,248	,753	,387	,004
Error	56,014	170	,329			
Total	78,349	202				
Corrected Total	78,349	201				

a. R Squared = ,285 (Adjusted R Squared = ,155)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except for the thickness of the soil layer overlaying the clay and the time since the soil layer overlaying the clay was placed, since they have an F-factor above one see Table 105. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_wL_quadfit, Stockholm.

Table 105 Liquid limit, Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	52,033[a]	106	,491	1,772	,002	,664
Intercept	,083	1	,083	,301	,585	,003
Depth_INT	8,719	11	,793	2,861	,003	,249
Zone	,206	4	,052	,186	,945	,008
Soil_type_map	6,353	8	,794	2,867	,007	,194
Urbanization	1,015	2	,508	1,832	,166	,037
Depth_INT * Zone	6,644	19	,350	1,262	,227	,202
Depth_INT * Soil_type_map	10,537	25	,421	1,522	,077	,286
Depth_INT * Urbanization	,958	12	,080	,288	,990	,035
Zone * Soil_type_map	,503	2	,251	,907	,407	,019
Zone * Urbanization	3,848	3	1,283	4,631	,005	,128
Soil_type_map * Urbanization	,709	2	,355	1,280	,283	,026
Depth_INT * Zone * Soil_type_map	,838	5	,168	,605	,696	,031
Depth_INT * Zone * Urbanization	,240	1	,240	,868	,354	,009
Depth_INT * Soil_type_map * Urbanization	,182	1	,182	,656	,420	,007
Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Depth_INT * Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Error	26,315	95	,277			
Total	78,349	202				
Corrected Total	78,349	201				

a. R Squared = ,664 (Adjusted R Squared = ,289)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 106 for results of the second full-factorial.

Table 106 Liquid limit, second Full-factorial ANOVA Stockholm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	32,088[a]	50	,642	2,095	,000	,410
Intercept	,471	1	,471	1,538	,217	,010
Depth_INT	8,877	11	,807	2,634	,004	,161
Soil_type_map	8,130	8	1,016	3,317	,002	,149
Depth_INT * Soil_type_map	15,095	31	,487	1,589	,036	,246
Error	46,260	151	,306			
Total	78,349	202				
Corrected Total	78,349	201				

a. R Squared = ,410 (Adjusted R Squared = ,214)

B.10.3 All observations from 3-8 meters, ANOVA and *T*-test result

One-way ANOVA

Results from the one-way ANOVA with all the independent variables are presented in Table 107. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_wL_quadfit, All observations from 3-8 meters.

Table 107 Liquid limit, One-way ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	130,841[a]	31	4,221	12,401	,000	,667
Intercept	,055	1	,055	,162	,688	,001
Zone	53,897	5	10,779	31,672	,000	,452
Soil_type_map	5,185	8	,648	1,904	,061	,074
Depth_INT	4,936	5	,987	2,901	,015	,070
Urbanization	,746	2	,373	1,096	,336	,011
Overlaying_layer__INT	,612	6	,102	,300	,936	,009
Time_overlying_layer	1,233	3	,411	1,207	,308	,019
Error	65,345	192	,340			

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	196,186	224				
Corrected Total	196,186	223				

a. R Squared = ,667 (Adjusted R Squared = ,613)

Full-factorial ANOVA

Results from the full-factorial ANOVA with all the independent variables except for the thickness of the soil layer overlaying the clay, since they have an F-factor above one see Table 108. Tests of Between-Subjects Effects of the dependent variable: Res_sqrt_wL_quadfit, All obsevations from 3-8 meters.

Table 108 Liquid limit, Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	168,098[a]	150	1,121	2,913	,000	,857
Intercept	,484	1	,484	1,258	,266	,017
Zone	21,017	5	4,203	10,925	,000	,428
Soil_type_map	4,638	7	,663	1,722	,117	,142
Depth_INT	7,414	5	1,483	3,854	,004	,209
Urbanization	,224	2	,112	,291	,748	,008
Overlaying_layer__INT	1,426	6	,238	,618	,715	,048
Zone * Soil_type_map	,601	1	,601	1,561	,216	,021
Zone * Depth_INT	3,304	17	,194	,505	,942	,105
Zone * Urbanization	,507	1	,507	1,319	,255	,018
Zone * Overlaying_layer__INT	,262	4	,065	,170	,953	,009
Soil_type_map * Depth_INT	5,693	16	,356	,925	,545	,169
Soil_type_map * Urbanization	,000	0	.	.	.	,000
Soil_type_map * Overlaying_layer__INT	,692	1	,692	1,800	,184	,024

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Depth_INT * Urbanization	,474	8	,059	,154	,996	,017
Depth_INT * Overlaying_layer__INT	1,410	11	,128	,333	,976	,048
Urbanization * Overlaying_layer__INT	,147	1	,147	,381	,539	,005
Zone * Soil_type_map * Depth_INT	,278	1	,278	,723	,398	,010
Zone * Soil_type_map * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Depth_INT * Urbanization	,158	1	,158	,410	,524	,006
Zone * Depth_INT * Overlaying_layer__INT	,218	4	,055	,142	,966	,008
Zone * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Urbanization	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Overlaying_layer__INT	,008	1	,008	,020	,888	,000
Soil_type_map * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Urbanization	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Overlaying_layer__INT	,000	0	.	.	.	,000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Zone * Soil_type_map * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Soil_type_map * Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Zone * Soil_type_map * Depth_INT * Urbanization * Overlaying_layer__INT	,000	0	.	.	.	,000
Error	28,088	73	,385			
Total	196,186	224				
Corrected Total	196,186	223				

a. R Squared = ,857 (Adjusted R Squared = ,563)

A second full-factorial has been made with only significant main factors or interactions from the first full-factorial. See Table 109 for results of the second full-factorial.

Table 109 Liquid limit, second Full-factorial ANOVA All obs. from 3-8 meters

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	133,225[a]	35	3,806	11,366	,000	,679
Intercept	,483	1	,483	1,444	,231	,008
Zone	95,938	6	15,990	47,745	,000	,604
Depth_INT	5,852	5	1,170	3,495	,005	,085
Zone * Depth_INT	9,647	24	,402	1,200	,246	,133
Error	62,961	188	,335			
Total	196,186	224				
Corrected Total	196,186	223				

a. R Squared = ,679 (Adjusted R Squared = ,619)

T-test

Results in form of mean values and their corresponding standard deviations from independent groups *T*-test of the variable Zone in Göteborg is presented in Tables 110 and 111.

Table 110 Liquid limit, T-test All obs. from 3-8 meters

	N	Mean	Std. Deviation	Std. Error Mean
Göteborg	52	1,2366364	,66536134	,09226902
Stockholm	172	-,3738668	,64001374	,04880059

Table 111 Liquid limit, T-test All obs. from 3-8 meters

	Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,043	,837	15,755	222	,000	1,61050327	,10222100	1,40905560	1,81195094
Equal variances not assumed			15,429	81,618	,000	1,61050327	,10437945	1,40284476	1,81816178

Appendix C, sensitivity analysis

The normal stress is calculated for three scenarios; once without the external load from the building, once including the external load from the building assuming a foundation consisting of 12 meters long cohesion piles and once including the load from the same building assuming it is founded directly on the ground without any deep foundation. To be able to calculate the effective stress for the three different scenarios the load from the house considered to affect the sampling point JF8 in Götatunneln has to be calculated. The input data for the calculation of the house load is presented in Table 1. The result from the three calculations of additional effective stress is presented in Table 2. In Table 3, the differences in effective stress from the first scenario for the other two scenarios are shown.

Table 112: Input data.

Width, W:	11	[m]
Length, L:	51	[m]
House area, A:	561	[m²]
Height:	10	[m]
Volume:	5610	[m³]
Density:	1800	[kg/m³] Given from Sundell and Haaf, Brick and year 1850
Mass, M:	10098000	[kg]
Load, q:	180	[kPa]

The load is calculated as follows:

$$q = \frac{M \times 10}{A} \times 10^{-3}$$

In Figure 1 illustrates the load distribution of an external load q when the load starts to affect the soil at the ground surface. This represents the scenario of a house with no piles. In case of piles the load starts to affect the soil two third of the pile length beneath ground surface. The pile length in the third scenario is 12 meters, which means that the additional load from the house start to affect the soil at eight meters depth. The sampling point is located five meters from the house wall.

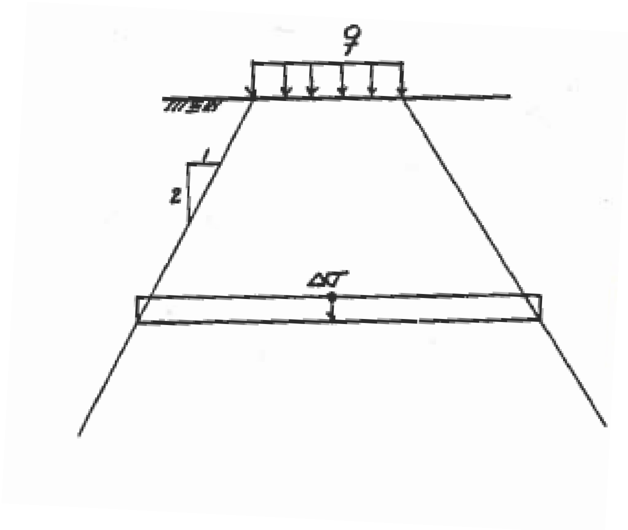

Figure 3: Load distribution (Sällfors, 2001).

$$\Delta\sigma_z = \frac{W \times L \times q}{(W + z) \times (L + z)}$$

z, is the depth counting from the ground surface.

Table 113: Result from calculations of effective stress with house loads.

Depth, z [m]	σ0 [kPa]	σ´0 [kPa]	σ0+Δσ house [kPa]	σ´0 house [kPa]	σ0+Δσ house with pile [kPa]	σ´0 house with pile [kPa]
7	116,90	72,90	116,90	116,90	116,90	116,90
9	148,90	84,90	148,90	148,90	148,90	148,90
11	181,30	97,30	228,30	228,30	181,30	181,30
13	213,70	109,70	279,70	279,70	213,70	213,70
15	246,70	122,70	305,70	305,70	246,70	246,70
17	280,70	136,70	333,70	333,70	280,70	280,70
19	315,30	151,30	363,30	363,30	389,30	389,30
21	349,90	165,90	393,90	393,90	415,90	415,90
23	384,90	180,90	424,90	424,90	443,90	443,90
25	420,50	196,50	457,50	457,50	473,50	473,50

Table 114: The increase of effective stress with house loads.

Depth, z [m]	percentage increase of effective stress, house without pile	percentage increase of effective stress, house with 12m piles
7	0	0
9	0	0
11	48	0
13	60	0
15	48	0
17	39	0
19	32	49
21	27	40
23	22	33
25	19	27