Concrete technology – porosity is decisive

By RALEJS TEPFERS

Porosity is the number of pores in a material for instance pores in certain concrete. Porosity is usually expelled in volume percent. The porosity of concrete has influence on the properties in many aspects. Composition of concrete, casting in practice, maturing and hardening, cement reactions and risks at freezing, all are influenced by porosity. The possibilities to influence the type of porosity are important.

Composition of concrete

Concrete technology deals in very great extent about the porosity of concrete. Concrete consists of gravel, sand and cement, all particles, and water plus air and eventual additives. The firm substances give the concrete strength. Aggregates are cheap and therefore should fill up the space as much as possible. Therefore the particle size grading should be such that this is possible. The fine cement particles find room in spaces between the aggregate particles. More cement means that the spaces between aggregates are better filled. Consequently, more cement added, stronger concrete. Water fills the rest of the spaces.

Casting, hardening hydration

Water is added in such amount that the concrete becomes possible to cast using vibrations. It usually means that more water is added than the chemical reactions require. The excessive water evaporates from cement glue and leaves pores behind, which weaken the concrete. More excess water, it means higher water/cement ratio, results in weaker concrete. Porous concrete is also more exposed to the environmental influence, because the surface exposed for environmental attack increases.
During hardening the concrete should be watered, because the exothermic cement hydration increase the temperature of the concrete, so water evaporates in such an extent that there is not enough water left for the reactions. A wet concrete surface prevents the evaporation.

At Water/Cement ratio 0.3 to 0.4 all water is used up in hydration of cement. Concrete with so low Water/Cement ration has a consistency as moist sand and cannot be cast and compacted. Adding plasticizing additive the concrete can be made possible to cast.

Cement reactions, plasticizing additives

Cement is an ionic material. It means the cement particles have electrical charges. Cement is manufactured by grinding, which result in particles with edges where the positive and negative electrical charges are concentrated, figure 1. The charges have only short distance influence. When cement particles come into water particle corners with opposite charges orientate against each other and the particles flocculate, which results in stiff voluminous structure obstructing flow. Increased amount of water can break up flocks, but the Water/Cement ratio is increased. The alternative is to use plasticizing additive – super plasticizer. When the super plasticizer is added to concrete having a consistency as moist sand and the mixing goes on, the concrete mix suddenly starts to flow and splash in the mixer.

The plasticizer chain molecules wind around the cement particles and screen the cement particles electrical charges. In cooperation with water they create particles with equal electrical charge repelling each other. In spite of the repulsion the particles comes closer to each other in comparison with the situation when they were flocculated. More over, the repulsive forces make that the particles can easy slide along each other.

Another effect can be obtained by chain molecules fixing themselves on cement particles with their molecule tails protruding from the surface of the particles and obstruct them to come close to each other, however closer than what the flocculation allow for. The result is that the cement particles leave less space between them, which are better field with hydration products. The space can also partly be filled with micro silica particles. Result is that the concrete has fewer pores and we get a stronger and environmentally more resistant concrete.

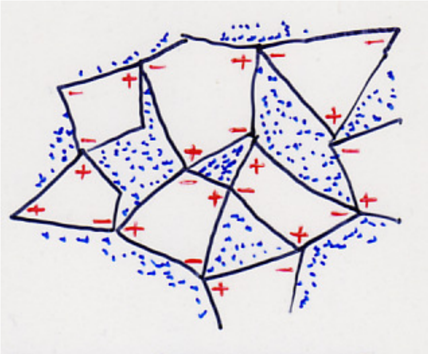

Figure 1 Flocculated cement particles.

The flow of the fresh concrete is obstructed by aggregates creating arches of stones. The forming of arches can be hindered by increased amount of cement glue. It is not possible to only increase the amount of cement, because this glue will get shrinkage cracks due to contraction shrinkage. In concrete the aggregate hinders the formed micro cracks to become visible cracks. In stead the amount of cement glue can be completed with lime stone filler, also granite filler has been used. The self-compacting concrete has so much cement glues that creation of aggregate arches is prevented and the concrete can flow freely.

Freezing, frost resistance

The water in the pores of concrete may freeze and then it expands 9%. The freezing happens successively. From a developing ice crystal the solved salts leave for rest of the water, which gets lower freezing temperature due to increased concentration of solved salts. The increased volume of the ice crystal creates water pressure. The water pressure can be released by water pressing into empty pores and freezing will not damage concrete. Air entraining agent creates small dense positioned pores in cement glue, where the water can be pressed and the pressure released by this. Water molecules have electrical poles and are hold together by hydrogen binds, figure 2. If an atomic structure has electrical charges water molecules are attracted to it – the surface is wetted, is hydrophilic. The air pores have no electrical charges on its surface. If the surface has no electrical charges, the water molecules are kept together by hydrogen binding to water drops and the water avoids the surface – the surface is water repellent, hydrophobic. Water does not by itself go into these pores, but is pressed in by active pressure from volume increase of freezing water. When the pressure is released at thaw, the water does not like to stay in these air pores and returns to the porosity where it was before. Therefore the air entraining created porosity functions also at repeated freezing.

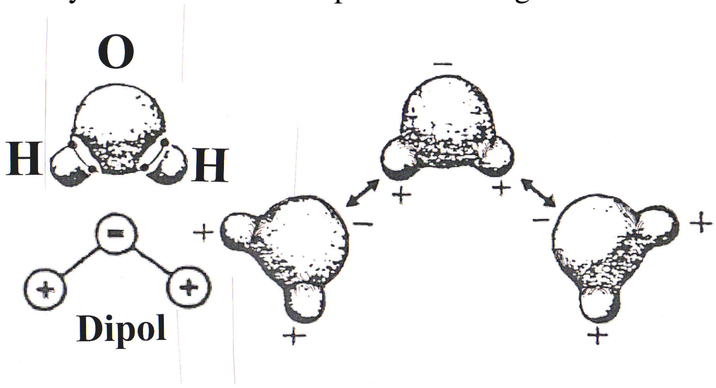

Figure 2 Water molecules with electrical charges – hydrogen binding.

Different types of pores in concrete

In figure 3 different types of pores characterized by their diameter are shown along a scaling of length. The scaling goes from right hand side to left and covers diameters from 10mm to 1Å.

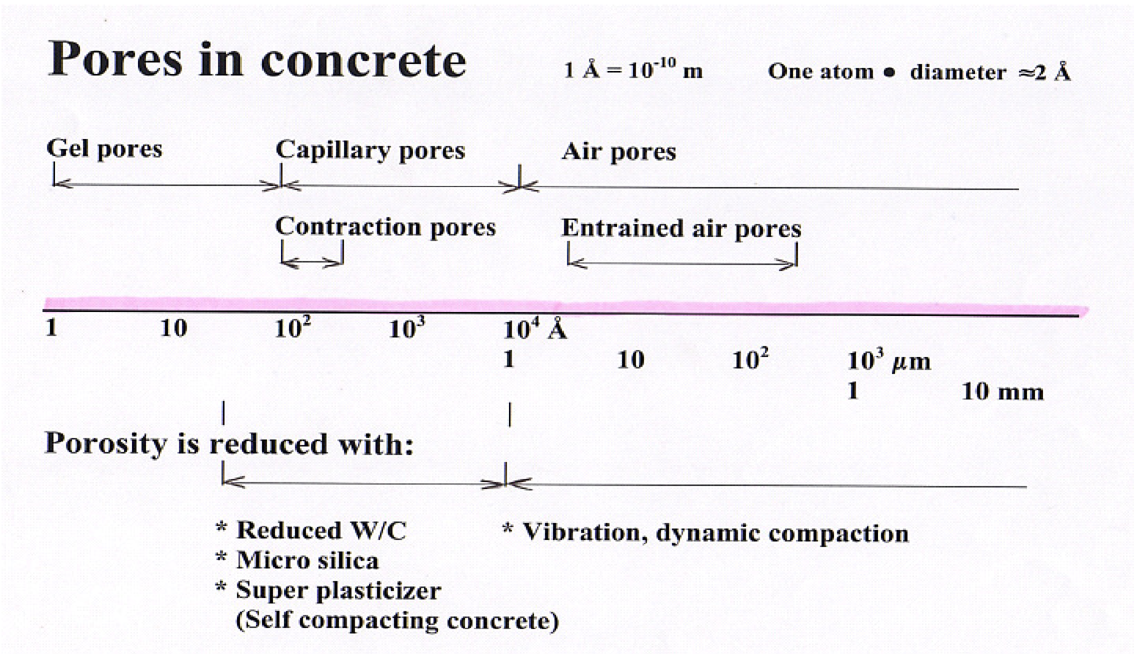

Figure 3 Pores in concrete.

Air pores are closed by vibration. Cement glue gets local pressure increase from the vibrating device. The pressure parts the aggregate particles so the friction is reduced and they can slide along each other.

The capillary porosity is reduced using lower Water/Cement relation and plasticizing additives plus micro silica.
Gel pores are in principle atom vacancies and the space between atoms is for time being difficult to do something about.

Contraction pores appear during hydration, because the volume of the hydration products is less than that of the constituents cement plus water and this is very difficult to do something about.

The pores created by the air entraining agent are deliberately created pores to prevent the concrete suffer from freezing. This concrete should not be vibrated too much.

The concrete can be made stronger

To day it is possible in production to reach concrete compressive strength up to 150 MPa. In laboratory Aalborg Cement AS, Denmark they have reached 300 MPa and French researchers have reached 800 MPa. In that case they have hardened the concrete at 200^{o}C and under pressure. It can be supposed that they have succeeded to reduce the gel and contraction porosity by pressing atoms with thermo vibrations into the micro pores of the structure. Basically they have applied nanotechnology for achieving this.

Summing up, the concrete technology is about to reduce the porosity of the concrete. In this way the concrete becomes both stronger and more environment resistant.

The relation problem of civil engineers

Many people have mixed sand, stone, cement with water, cast it and the mix became hard concrete, so now they know concrete technology. This fact leads to the relation problem of civil engineers, which the civil engineer Andrejs Muzikants has commented in a laconic way:

Everybody ***« knows everything »*** *about this* ***« simple »*** *branch and if there are problems, for sure,* ***« there is lacking competence »*** *- finally* ***« construction engineering is an old and well tested branch ».***

What should the civil engineers tell people?

In civil engineering the built and final object is the first prototype, therefore no wonder there will be problems. In car industry certainly there will be fifty prototypes before the car model is commercialized.

We civil engineers have to be aware, the way other people understand construction industry and therefore we have to tell them that construction industry is different from other branches and always repeatedly underline that ***construction industry is high tech comprising also nanotechnology,*** as in concrete technology moving molecules.

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