DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING & TECHNOLOGY

TRANSPORTATION ENGINEERING – I (Highway Engineering)

Topics to be covered:

- Introduction to Concrete and History of Concreting
- Properties of Concrete
- Factors affecting Properties of Concrete
- Properties of Reinforcements
- Problems related to the Topics Discussed

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FACTORS INFLUENCING CONCRETE PROPERTIES :

WATER CEMENT RATIO (W/C RATIO) : One property of concrete is the water/cement ratio. In contemporary concrete, w/c is frequently replaced with w/b (water/binder) or w/p (water/powder), since Portland cement is not the only binding material in such a concrete. The w/c or w/b ratio is one of the most important factors influencing concrete properties, such as compressive strength, permeability, and diffusivity. A lower w/c ratio will lead to a stronger and more durable concrete. The influence of w/c on the concrete compressive strength has been known since the early 1900s leading to Abrams's law: $f_c = \frac{A}{B^{1.5(w/c)}}$ where fc is the compressive strength, A is an empirical constant (usually 97 MPa or 14,000 psi), and B is a constant that depends mostly on the cement properties (usually 4). It can be seen from the formula that the higher the w/c ratio, the lower the compressive strength.

CEMENT CONTENT : When water is added a concrete mix, cement paste will be formed. Cement paste has three functions in concrete: binding, coating, and lubricating. Cement paste provides binding to individual aggregates, reinforcing bars, and fibers and glues them together to form a unique material. Cement paste also coats the surface of the aggregates and fibers during the fresh stage of concrete. The cement content influences concrete workability in the fresh stage, heat release rate in the fast hydration stage, and volume stabilities in the hardened stage. The range of the amount of cement content in mass concrete is 160–200 kg/m3, in normal strength concrete it is less than 400 kg/m3, and in high strength concrete it is 400–600 kg/m3.

AGGREGATE :

(A) MAXIMUM AGGREGATE SIZE: The maximum coarse aggregate size mainly influences the cement paste requirement in the concrete. For the same volume of aggregate, the ones with a large aggregate size will lead to a small total surface area and a lower amount of cement paste coating. Hence, if the same amount of cement is used, concrete with a larger maximum aggregate size will have more cement paste left as a lubricant and the fluidity of concrete can be enhanced, as compared to concrete with a smaller maximum aggregate size.

CONTINUED…….. FACTORS INFLUENCING CONCRETE PROPERTIES :

For normal-strength concrete, at the same w/c ratio and with the same cement content, the larger the maximum sizes, the better the workability; at the same workability, the larger the maximum sizes, the higher the strength. However, a larger aggregate size has some drawbacks. First, a larger aggregate size may make the concrete appear non-homogeneous. Second, a larger aggregate size may lead to a large interface that can influence the concrete transport properties and the mechanical properties. Generally, the maximum size of coarse aggregate should be the largest that is economically available and consistent with the dimensions of the structure. In no event should the maximum size exceed one-fifth of the narrowest dimension in the sizes of the forms, one-third of the depth of slabs, or three-quarters of the minimum clear spacing between reinforcing bars.

(B) AGGREGATE GRADING: Aggregate grading refers to the size distribution of the aggregate. The grading mainly influences the space filling or particle packing. The classical idea of particle packing is based on the Apollonian concept, in which the smaller particles fit into the interstices left by the large particles. Well-defined grading with an ideal size distribution of aggregate will decrease the voids in the concrete and hence the cement content. As the price of the aggregate is usually only one-tenth that of cement, well-defined grading not only will lead to a better compressive strength and low permeability, but also is more economical at lower cost.

(C) AGGREGATE SHAPE AND TEXTURE: The aggregate shape and texture can influence the workability, bonding, and compressive strength of concrete. At the same w/c ratio and with the same cement content, aggregates with angular shape and rough surface texture result in lower workability, but lead to a better bond and better mechanical properties. On the other hand, aggregates with spherical shape and smooth surface texture result in higher workability, but lead to a lower bond and lower mechanical properties.

(D) SAND/COARSE AGGREGATE RATIO: The fine/coarse aggregate ratio will influence the packing of concrete. It also influences the workability of concrete in the fresh stage. Increase of the sand to coarse aggregate ratio can lead to an increase of cohesiveness, but reduces the consistency.

CONTINUED……FACTORS INFLUENCING CONCRETE PROPERTIES :

Of all the measures for improving the cohesiveness of concrete, increasing the Sand / coarse aggregate ratio has been proven to be the most effective one.

(E) AGGREGATE/CEMENT RATIO: The aggregate/cement ratio has an effect on the concrete cost, workability, mechanical properties, and volume stability. Due to the price difference between the aggregate and cement, increasing the aggregate/cement ratio will decrease the cost of concrete. From a workability point of view, an increase of the aggregate to cement ratio results in a lower consistency because of less cement paste for lubrication.

As for mechanical properties, increase of the aggregate/cement ratio can lead to a high stiffness and compressive strength if proper compaction can be guaranteed. Increasing the aggregate/cement ratio will definitely improve concrete's dimension stability due to reduction of shrinkage and creep.

ADMIXTURES : Admixtures (chemical admixtures and mineral admixtures) are important and necessary components for contemporary concrete technology. The concrete properties, both in fresh and hardened states, can be modified or improved by admixtures. For instance, concrete workability can be affected by air entraining agents, water reducers, and fly ash. Concrete strength can be improved by silica fume.

MIXING PROCEDURES : Mixing procedures refer to the sequence of putting raw materials into a mixer and the mixing time required for each step. Mixing procedures directly influence the workability of fresh concrete and indirectly influence some mature properties of concrete. The following mixing procedure can be used to obtain a very good workability with a good coating on the coarse aggregate to protect alkali aggregate reaction.

STEP 1: COARSE AGGREGATE + 50% WATER + 50% CEMENT: MIXING FOR 30 SEC TO 1 MIN.

STEP 2: ADDING 50% CEMENT + 25% WATER + SUPERPLASTICIZER + FINE AGGREGATE: MIXING FOR 2 MIN.

STEP 3: ADDING 25% WATER: MIXING FOR 3 MIN.

CONTINUED……FACTORS INFLUENCING CONCRETE PROPERTIES :

CURING : Curing is defined as the measures for taking care of fresh concrete right after casting. The main principle of curing is to keep favorable moist conditions under a suitable temperature range during the fast hydration process for concrete. It is a very important stage for the development of concrete strength and in controlling early volume changes. Fresh concrete requires considerable care, just like a baby. Careful curing will ensure that the concrete is hydrated properly, with good microstructure, proper strength, and good volume stability. Some methods could be helpful in curing like:

(a) Moisten the sub-grade and forms

(b) Moisten the aggregate

(c) Erect windbreaks and sunshades

(d) Cool the aggregate and mixing water

(e) Fog spray

(f) Cover

(g) High temperature (70–80◦C) steam curing

(h) Use shrinkage compensating concrete

On the other hand, careless curing always leads to improper hydration with defects in the microstructure, insufficient strength, and unstable dimensions. One of the common phenomena of careless curing is plastic shrinkage, which usually leads to an early age crack that provides a path for harmful ions and agents to get into the concrete body easily and causes durability problems. Curing is a simple measure to achieve a good quality of concrete.

Recently, a new technique called internal curing has been developed, which utilizes the saturated porous aggregate to form a reservoir inside a concrete and provide water for concrete curing internally.

PROPERTIES OF REINFORCEMENTS :

Steel reinforcement are steel bars that are provided in combination with plain cement concrete to make it reinforced concrete. Hence these structures form steel reinforced cement concrete structure (R.C.C). Steel reinforcement is commonly called as 'Rebars'. Plain concrete is weak in tension and strong in compression. Tensile property for concrete structures is obtained by incorporating steel reinforcement. The steel reinforcement is strong in both tension and compression. The tensile property provided by the steel reinforcement will prevent and minimize concrete cracks under tension loads. The coefficient of thermal expansion of steel reinforcement and concrete are similar in that they undergo similar expansions during temperature changes. This property will ensure that the concrete is subjected to minimal stress during temperature variations. The surface of the steel reinforcement bars is patterned to have a proper bond with the surrounding concrete material. The two main factors that provide strength to the concrete structures are steel and concrete. The design engineer will combine both the elements and design the structural element such a way that the steel resists the induced tensile and shear force, while the concrete takes up the compressive forces.

TYPES OF STEEL REINFORCEMENT : The steel reinforcement used in concrete is mainly of 4 types. They are:

1. Hot Rolled Deformed Steel Bars
2. Cold Worked Steel Bars
3. Mild Steel Plain Bars
4. Pre-stressing Steel Bars

HOT ROLLED DEFORMED BARS : Hot rolled deformed bars are most commonly used steel reinforcement for R.C.C structures. As the name says, the hot rolling of the reinforcement is undergone leaving certain deformations on its surface in the form of ribs. These ribs help to form a bond with the concrete. The typical yield strength of hot-rolled deformed bars is 60000psi.

COLD WORKED STEEL BARS : A cold worked reinforcement bar is obtained by letting the hot rolled steel bars to undergo cold working. In the cold working process, the bars will undergo twisting and drawing. The process is performed at room temperature. The cold worked steel bars do not undergo a plastic yield thus have less ductility when compared with hot rolled bars.

PROPERTIES OF REINFORCEMENTS :

MILD STEEL PLAIN BARS : The mild steel plain reinforcement bars do not have ribs on their surface. They have a plain surface. These bars are used for small projects where the major concern is the economy. The tensile yield strength of these bars has a value of 40000psi.

PRESTRESSING STEEL BARS : The pre-stressing steel reinforcement are steel bars used in the form of strands or tendons. Multiple strands are employed in concrete in order to perform the pre-stressing action. The strands are made of multiple wires either 2 or 3 or 7 wire strands. The wires used here are cold formed and have a high tensile strength ranging from 250000 – 270000 psi. This high strength helps to effectively pre-stress the concrete.

PROPERTIES OF STEEL REINFORCEMENT :

COMPATIBILITY WITH CONCRETE: The fresh concrete is placed on the formwork mold already prepared with reinforcement. The steel reinforcement won't float in concrete during the concrete placing procedure. Hence, steel reinforcement does not demand special tying up with formworks.

ROBUSTNESS OF STEEL REINFORCEMENT: The steel bars are robust in nature that they have the ability to withstand the rigors, the wear and tear during the construction activities.

BENT PROPERTY OF STEEL REINFORCEMENT: The steel bars once manufactured to standard size, it can be bent to the required specifications. Hence fabricated steel bars are delivered easily at the site.

RECYCLING PROPERTY: The steel reinforced left over after the service life of a structure is recycled again and used for new construction.

EASILY AVAILABLE: Every region of a country will have a steel supplier or manufacturer. Hence steel reinforcement is easily available.

PROPERTIES OF REINFORCEMENTS :

MODULUS OF ELASTICITY: Steel has high modulus of Elasticity i.e. 200GPa (200 x 10^9 N/m²). This helps the steel to stretch in tension(upto 200GPa) without breaking and regain its shape on removal of load.

DUCTILITY OF STEEL: Ductility of steel is high. i.e. Steel rebar will behave ductile under higher loads.

DUCTILITY is the ability of material to allow plastic deformations (i.e. permanent change in its dimensions) under application of load before breaking.

COEFFICIENT OF THERMAL EXPANSION: Steel and concrete has almost same coefficient of thermal expansion (change in dimension due to temperatures). Due to this both (concrete and steel) will experience same length changes in high temperatures.

RESISTANCE: Steel is resistant to rough conditions during transport, storage, bundling and placing on construction site. If minor damage happens, it does not significantly affect its performance.

STRENGTH: It is strong enough to withstand high impact load.

READILY AVAILABLE: Structural Steel industry has enough production capacity to meet the demands of construction industry and is available at ease for any house construction.

READY BUILD: These days ready build steel is also available. Ready build steel eliminate the time of cutting and bending. This saves lots of construction time as well as minimizes the wastage of steel in bending and cutting.

STEEL CAN BE RECYCLED EASILY.

PROPERTIES OF REINFORCEMENT :

LIMITATIONS OF STEEL REINFORCEMENT : Despite being so much advanced in version, there are a few limitations of reinforcement of steel reinforcement as:

REACTIVE NATURE OF STEEL REINFORCEMENT: In concrete structures where the cover is small and subjected to external moisture and salt action, the reinforcement undergoes reaction and starts to corrode. These can lessen the strength of concrete and finally to failure.

EXPENSIVE: The cost of steel reinforcement in high. This will increase the cost of construction

MELTS AT HIGH TEMPERATURE: At higher temperatures, the steel reinforcement may melt. This is the reason why the steel reinforcement are tied up and not welded.

REACTION: Too little concrete cover allows the water to penetrate and react with steel rebars causing concrete to crack. Occasionally concrete aggregates react with steel causing concrete to spall.

RUST: Steel exposed to weather rusts and reduces the strength of reinforced concrete. When rusts start building up around the steel rebars, it causes severe internal pressure on the surrounding concrete, leading to cracks in concrete.

WEIGHT: It is not a light weight material.

PROBLEMS RELATED TO THE TOPICS DISCUSSED :

ASSIGNMENT 1 :

1) Why is concrete so popular?
2) What are the weaknesses of concrete?
3) What are the factors influencing concrete properties?
4) Give some examples for concrete applications.
5) Can you list a few topics for concrete research?
6) When you do a structural design, which failure mode should be applied?
7) How would you like to improve concrete workability (fluidity or cohesiveness)?
8) How can you enhance concrete compressive strength?
9) Which principles are you going to follow if you are involved in a concrete research?

“Thank you”

Have Any Query ?

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