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CONCRETE CONSTRUCTION ENGINEERING

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INTRODUCTION

Concrete engineering is acquiring tremendous significance as we continue to use more concrete in diverse conditions. The use of new materials and new technologies, we have more expertise from previously built structures. We realize that concrete is not a maintenance free material, we find rising concern about quality and durability of concrete construction. A concrete engineer needs to update his understanding of concrete as a material and its properties, he should be aware of the development of special concrete and their properties and applications. Be conscious of limitations of existing test methods and specifications for new concretes, he also need to understand the issues in shifting to a more performance base thinking and integrate words such as maintenance and repair in the overall life cycle of concrete.

This course aims at revising the basic principles underlying concrete science and engineering, developing a framework which helps us understand the present scenario in concrete engineering, going through some issues in special and high performance concrete and their quality control and testing, including performance base thinking, durability, maintenance.

A VIEW OF RENFORECED CONCRETE

Reinforce concrete consist of steel embedded in concrete. Concrete normally is made up of coarse aggregate, fine sand, cement (ordinary Portland cement) and water. Though it is becoming common to use minerals and chemical admixture to obtain desired properties in fresh state and in hardened state. In concrete engineering, paste is cement and water, mortar is paste and sand, concrete is mortar and course aggregate. So, concrete is a suspension of coarse aggregate particles in mortar, mortar is a suspension of fine aggregate particles in paste and paste is a suspension of cement particles in water. The suspension as included here deviates from a normal understanding of the word in the following ways:

Concentration of particles is very large making it almost a paste.In the case of cement paste, the particles suspended in water also react with it and the composition and properties of the paste need to understand to be time dependent. Paste is the only reactive phase. All aggregate are simply inert fillers. In other words, in the paste , cement particles react with water (hydration). Properties of paste change over time as a result of this hydration continue. Hydration starts as soon as water and cement come in contact.

From the point of view of a project, we normally have a specific condition, a set of specifications, and a structural design and construction methodology which we try to go through. Thus, the discussion often is project specific, and the engineer needs to pick up the best option those available.

The concrete basic processes are:

Choosing the constituents

Proportioning

Mixing

Transportation

Placing

Vibration/consolidation

Curing

There is a certain range of the variable over which the operation (process) can be normal. If any of the processes goes out of that range or another , special process becomes involved, the concrete needs to be treated as special. The following factors makes the concrete special:

a) Materials-other than the usual ordinary Portland cement, fine and coarse aggregate and water, such as fibers and admixtures.
b) Mixing-manual, small mixer, ready mixed concrete plant
c) Transportation-conveyor belt, agitator truck
d) Placing-shot Crete, tremie
e) Vibration- form vibrator, internal nidle vibrator
f) Environment of placing- factory, underwater, extreme hot or cold weather, highly congested reinforcement.
g) Property required-strength(high or low, early), low heat of hydration, setting(early or late), high flowing concrete
h) Curing-curing with gunny bags, plastic sheets, curing compound application.

CONSTITUENTS OF CONCRETE

As far as normal concrete is concern, cement is about 7-17%, water is 14-21%, sand is 24-30%, course aggregate is 31-50% and air is 0.5-6%. With this background, we see the composition of concrete.

Cement

Portland cement concrete is a composite material made by combining cement, supplementary cementing materials, aggregates, water, and chemical admixtures in suitable proportions and allowing the resulting mixture to set and harden over time. Because hardened concrete is a relatively brittle material with a low tensile strength, steel reinforcing bars and sometimes discontinuous fibers are used in structural concrete to provide some tensile load-bearing capacity and to increase the toughness of the material.

Water

Although the water itself is often not considered when dealing with materials that go into the production of concrete, it is an important ingredient. Typically, 150 to 200 kg/m3 of water is used. The old rule of thumb for water quality is “If you can drink it, you can use it in concrete,” although good-quality concrete can be made with water that is not really potable. Indeed, more bad concrete is made by using too much drinkable water than by using the right amount of undrinkable water.

Aggregates

Aggregates make up about 75% of the volume of concrete, so their properties have a large influence on the properties of the concrete (Alexander and Mindess, 2005). Aggregates are granular materials, most commonly natural gravels and sands or crushed stone, although occasionally synthetic materials such as slags or expanded clays or shales are used. Most aggregates have specific gravities in the range of 2.6 to 2.7, although both heavyweight and lightweight aggregates are sometimes used for special concretes, as described later. The role of the aggregate is to provide much better dimensional stability and wear resistance; without aggregates, large castings of neat cement paste would essentially self-destruct upon drying. Also, because they are less expensive than Portland cement, aggregates lead to the production of more economical concretes. In general, aggregates are much stronger than the cement paste, so their exact mechanical properties are not considered to be of much importance (except for very high-strength concretes). Similarly, they are also assumed to be completely inert in a cement matrix, although this is not always true, as will be seen in the discussion on the alkali–aggregate reaction. For ordinary concretes, the most important aggregate properties are the particle grading (or particle-size distribution), shape, and porosity, as well as possible reactivity with the cement. Of course, all aggregates should be clean—that is, free of impurities such as salt, clay, dirt, or foreign matter. As a matter of convenience, aggregates are generally divided into two size ranges: coarse aggregate, which is the fraction of material retained on a No. 4 (4.75-mm) sieve, and fine aggregate, which is the fraction passing the No. 4 sieve but retained on a No. 100 (0.15-mm) sieve.

Reinforcements

Plain concrete is a brittle material, with low tensile strength and strain capacities; hence, reinforcement has to be used to balance this deficiency. Main bar reinforcement is used in tensile zones to enhance the capacity of concrete elements so the structural beam or slab will be able to withstand high loads and deform adequately without brittle failure.

ADMIXTURES IN CONCRETE

There are essentially additives added in concrete to achieve desired properties which may be difficult with just normal concrete constituents. Consideration for adding these could be:

Technical

Economical

Environmental concern

Admixtures are divided into two, we have chemical and mineral admixtures

Within the mineral admixture, we use materials which replaced cement. That is they are so fine that, their fines is comparable to that of cement and therefore they are supposed to be treated as a part of cement in considering concrete. Other than these, there certain other materials which are use to replace fine aggregate (sand).

So, treating the two admixtures, we start with the chemical admixtures.

Chemical admixture

In principle, the chemical admixtures interfere with the action of cement within concrete, including its hydration. Depending upon the desired effect, chemical could be chosen such that they act as,

Set regulators; during vibration of cement, the cement sets and we need to have the setting time and the final setting time and understand the hardening time. So, set regulation means the process by which we either accelerate the process or we delay the process and therefore we could have accelerators and we could have retarders. These are use full when we are using cement or concrete in specific application. We see like in the repair job where concrete is required to have early strength we may like to use accelerators. Whereas in job where concrete is to be place at a site which is far away, we can use retarders. Another example is in hot or cool whether concrete when a temperature is very cold and the cement may not set normally within a reasonable period of time then we may like to use an accelerator. Similarly, if we are working in hot weather, then we may use retarders which will give us a little more time to work with the concrete so that it should not set very rapidly. Order chemicals are water reducers and high range water reducers. They those chemical admixtures which help us to reduce the water demand in a concrete mix. If a water reducer helps us to reduce the demand by

10-15% then a high range water reducer will reduce like 25-30%. So it is about how much water reduction can be archive by one way or the other. Another class of chemical admixtures is air entrainers, since concrete contains a certain amount of air, so entrapped air is that which is there in concrete in-avertedly there. However, in certain cases we have to entrain air. That is intentionally an consciously, we want the concrete to have a certain amount of air particles. Those chemicals which help us archive these objective of entraining air in the fresh concrete which remains there when the concrete hardens. some other chemical admixtures which are for very special purpose and are known as corrosion inhibitors. So all these classes of admixtures are use in concrete industry to modify the properties of concrete.

Characteristic of chemical admixture

These chemical admixtures are usually available as liquids, and are often batched by volume. Since the dosage is very small special care needs to be taken the time of batching. The pure admixture is often diluted with water and then added as a part of the unit water content required to be mixed, to ensure a better distribution in the concrete. So, we do not normally batch a chemical admixture into concrete, we dilute it into water and put the water in concrete so that the chemical admixtures is homogenously mix in the concrete. The dosages of chemical admixtures are relatively small dosages usually given in small content. For example, a dosage of 1% by weight of cement in the concrete containing 400kgs/m^3 of cement , means using 4kgs of the admixtures per cubic meter of concrete. It may be noted that the weight of a cubic meter of concrete is about 2400kgs and therefore these chemical admixtures constitute less than 0.2% of the concrete by weight.

Mineral admixtures

Motivation for using mineral admixtures in a concrete comes from one or more of the following:

Industrial by product utilization

Environmental concern (sustainable development)

Economy in cement consumption

Reduced heat of hydration

Durability considerations

High strength requirement

Their use in concrete is usually as a partial replacement of cement or they are used in addition to the cement to improve the properties of concrete. This can be in terms of development of compressive strength or liberation of the heat of hydration or any other parameter that is supposed to be identify, modify and monitored. Historically, the use of pozzolonic materials is well known from the very olden days. Classically, these materials have no hydraulic properties of their own,.i.e, they do not harden simply by reaction with water. Rather they react with calcium hydroxide and yield products similar to those formed from cement hydration. In recent years, the following have emerged as the primary mineral admixture used in concrete as replacement of ordinary Portland cement.

Ground granulated blast furnace slag

Fly ash

Silica fume

Metakaoline

Rice husk ash

The dosages of the mineral admixtures depend on the following: Efficiency of the mineral admixtures and, the desired result.

So, admixtures have very important properties for the standard concrete and required to be understood properly before applying them.

BASIC PROPERTIES OF CONCRTETE

In this topic, we study the basic principle underlying concrete science and engineering, we develop a frame work which help us understand the present day scenario in concrete engineering and some issues in special and high performance concrete and their quality control and testing including performance base thinking, durability and maintenance.

Concrete at fresh state: this shows the behavior similar to that of a fluid and can be pumped, acquires the shape of the mold in which it is poured and little resistance to deformation. This is at the root of popularity using construction material in the present day.

Concrete at hardened state: solid material with substantial compressive strength and so on. This transformation is brought about by hydration and it provides the basic structure of the chemical products that gives strength to the concrete.

However, functionally concrete should satisfy laid down criteria for:

a) Fresh state should have adequate workability
b) Hardened state should have adequate strength
c) It should have durability in terms of restrictions on some parameter such as w/c, cement content.
d) Temperature rise during setting periods.

So basically, the properties of concrete that we study has to be around these functional requirements that the concrete needs to satisfy. In some cases like:

Normal and special concrete

There is a certain range of the variables over which the operations can be called normal. If any of the processes goes out of that range or another special process becomes involved, the concrete need to treated as special. This is what every concrete expert should know.

Properties of fresh and hardened concrete

Concrete should have the required properties in the fresh and hardened state and should meet the durability and other requirements depending on the structure and the environment. The fresh state of concrete should have workability, air content, segregation resistance and flow ability. The hardened state of concrete comprises of compressive strength, tensile or flexural strength, modulus of elasticity, stress-strain curve, shrinkage and creep.

Workability versus consistency: Workability is the ease of being able to work concrete into different parts of the formwork. Consistency is the amount of work required to be done in order to compact concrete. The two differentiations are completely opposite in the sense that a concrete with a high degree of workability will have a low level of consistency.

DESIGN AND PLACEMENT OF CONCRETE MIXES

The design of concrete mixtures involves choosing appropriate proportions of ingredients for particular strengths, long-term qualities, and performance of the concrete produced. Several factors determine these properties. They include the following parameters:

• Quality of cement

• Proportion of cement in relation to water in the mix (water/cementitious material ratio)

• Strength and cleanliness of aggregate

• Interaction or adhesion between cement paste and aggregate

• Adequate mixing of the ingredients

• Proper placing, finishing, and compaction of the fresh concrete

• Curing at a temperature not below 50°F while the placed concrete gains strength

• Chloride content not to exceed 0.15% in reinforced concrete exposed to chlorides in service and 1% in dry protected concrete

A study of these requirements shows that most control actions have to be taken prior to placing the fresh concrete. Because such control is governed by the proportions of ingredients and the mechanical ease or difficulty in handling and placing the concrete, the development of criteria based on the theory of proportioning for each mix should be studied. Most mixture design methods have become essentially only of historical and academic value. The two universally accepted methods of mixture proportioning for normal weight and lightweight concrete are the American Concrete Institute's methods of proportioning, described in their recommended practices for selecting proportions for normal weight, heavyweight, and mass concrete, and in the recommended practice for selecting proportions for structural lightweight concrete (ACI Committee 211, 1991a,b; ASTM, 1993; Nawy, 1996).

CONCRETE FORM WORK

Forms are extremely important in concrete construction. They mold the concrete to the required size and shape while controlling its position and alignment. Forms are self-supporting structures that are also sufficient to hold the dead load of the reinforcement and fresh concrete and the live load of equipment, workers, and miscellaneous materials. In building and designing formwork, three major objectives must be considered:

1. Quality—Forms must be designed and built with sufficient stiffness and accuracy so the size, shape, position, and finish of the cast concrete are attained within the required tolerances.

2. Safety—Forms must be built with sufficient strength and factors of safety so they are capable of supporting all dead and live loads without collapse or danger to workers and to the concrete structure.

3. Economy—Forms must be built efficiently, minimizing time and cost in the construction process and schedule for the benefit of both the contractor and the owner.

Economy is important because the costs of formwork often range from 35 to 60% or more of the total cost of the concrete structure. Considering the impact of formwork on total cost, it is critical that the structural engineer of the facility also design the facility structure for economy of forming, not just for economy of the materials in the finished structure. Ideally, the builder will achieve maximum economy with no cost to either safety or specified quality. In designing formwork, the construction engineer can reduce costs by carefully considering the materials and equipment to be used; the fabrication, erection, and stripping procedures; and the reuse of forms. However, economy measures that result in either formwork failure or poor-quality products that require (often expensive) modification are self-defeating.

Correctly designed formwork will ensure that the concrete maintains the desired size and shape by having the proper dimensions and being rigid enough to hold its shape under the stresses of the concrete. It must be stable and strong to keep large sections of concrete in alignment. Finally, formwork must be substantially constructed so it can be reused and frequently handled while maintaining its shape. Formwork must remain in place until the concrete is strong enough to carry its own weight. In addition, the surface finish of the concrete is dependent on the contact material of the form. The quality of the formwork itself has a direct impact on safety, accidents, and failures. A floor formwork system filled with wet concrete has its weight at the top and is not inherently stable. As a result, one of the most frequent causes of failure is from effects that induce lateral forces or displacement of supporting elements; therefore, inadequate cross-bracing or horizontal bracing is one of the most frequently involved factors in formwork failure. Poor bracing can make a minor failure turn into a major disaster, in what might be thought of as a domino effect or a progressive failure: A failure at one point in the formwork that can become an extensive collapse through chain reaction. Vibration is one factor that can trigger failure through inadequate bracing. Two other formwork problems are unstable soil under mudsills and shoring that is not plumb. Formwork is stable if adequately braced and built so all loads are carried to solid ground through vertical and bracing members. Regardless of the quality of the formwork, premature removal of the forms or shores, often out of a wish for economy, can result in collapse or sagging. Sagging, while not an immediate problem, can lead to hairline cracks and extensive maintenance problems. Careless reshoring, often involving inadequate size, spacing, or attachment, can also cause damage or collapse. Specific related standards (e.g., OSHA, ACI, ASCE) for formwork are discussed in Section 7.3.

In addition to optimizing material in the form design process, there are three major factors to be considered when planning forms that are cost effective:

- Designing and planning for maximum reuse
- Economical form assembly
- Efficient setting and stripping

Each factor must be balanced with the other two to determine the most efficient form design. In planning for maximum reuse, the specifications, rate of concrete strength gain, and local code requirements regarding stripping must be taken into account. The sooner a form can be stripped safely, the more practical it is to reschedule many reuses. In addition, for a minimum of cost, the least number of forms required for a smooth work schedule should be built. For example, the formwork on the outside of a spandrel beam can be stripped sooner than the formwork on the bottom; hence, fewer side forms than bottom forms must be built because they can be reused more frequently.

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