2.2 PROPERTIES OF CONCRETE

Properties of Concrete:

Strength

Permeability

Durability

Thermal property

Micro cracking of concrete.

Stress and strain characteristic of concrete.

Shrinkage and temperature effects.

Creep of concrete.

Acid attack,fire resistance, efflorescence.

Strength

Strength of concrete is one of the most important factors. Concrete is used as a structural element, and all structural uses are associated with its compressive strength. Strength of concrete is defined as the resistance that concrete provides against load so as to avoid failure. It depends on the water-cement ratio, quality of aggregates, compaction, curing etc. The primary factor that affects the strength of concrete is the quality of cement paste, which in turn, depends on the quality of water and cement used.

Sometimes it is economical to add pozzolana or use Portland pozzolana cement instead of ordinary cement concrete. Pozzolanas are materials that have little cementing value but rich with calcium hydroxide to form compounds that are cementitious. This reaction contributes to the ultimate strength and watertightnesss of concrete. Pozzolanas also increases the plasticity and workability of concrete. Excessive addition of pozzolanas affects durability. So it should be used along with cement as a partial replacement or in small percentage.

Generally construction industry needs faster development of strength in concrete so that the projects can be completed in time or before time. This demand is catered by high earlystrength cement, use of very low W/C ratio through the use of increased cement concrete and reduced water content. But this result in higher thermal shrinkage, drying shrinkage, modulus of elasticity and lower creep coefficients. With higher quantity of cement content, the concrete exhibits greater cracking tendencies because of increase in thermal and during shrinkage. As the creep coefficient is low in such concrete there will not be much slope for relaxation of stresses. Therefore high early strength concretes are more prone to cracking than moderate or low strength concrete.

Of course, the structural cracks in high strength concrete can be controlled by use of sufficient steel reinforcement. But this practice does not help the concrete durability, as provision of more steel reinforcement; will only results in conversion of the bigger cracks to smaller cracks. And these smaller cracks are sufficient to allow oxygen, carbon dioxide and moisture get into the concrete to affect the long term durability of concrete.

Field experience have also corroborated that high early strength concrete are more cracks-prone. According to a recent report, the cracks in pier caps have been attributed to use of high cement content in concrete. Contractors apparently thought that a higher than the desired strength would speed up the construction time, and therefore used high cement content.

Permeability

Concrete is a permeable and a porous material. The rates at which liquids and gases can move in the concrete are determined by its permeability. Permeability affects the way in which concrete resists external attack and the extent to which a concrete structure can be free of leaks. The permeability is much affected by the nature of the pores, both their size and the extent to which they are interconnected. There can therefore be no one measure of porosity which fully describes the way in which the properties of concrete or of hardened cement paste are affected.

If a material were judged, the decision would rest primarily on the choice of medium used for testing.

For (ex) Vulcanized rubber would be found impervious and nonporous if tested with mercury, but if tested with hydrogen it would be found to be highly porous. Early work on the permeability of concrete was generally related to its use in dam construction.

The coefficient of permeability K1 is obtained from applying Darcy‟s law for lowvelocity flow,

(dr/dt).(1/A)=K1.(^h/L)

(dr/dt)= The rate of volume flow (m3s-1)

A= Area of porous medium normal to the direction of flow (M2)

^h= Drop in hydraulic head across the thickness of the medium (m).L= Thickness of the medium (m).

K1=Coefficient of permeability depending on the properties of the medium and of fluid(ms-1)

Permeability of concrete:

The penetration by materials in solution may affect the durability of concrete, the aggressing liquid attack the concrete.

In case of reinforce concrete increase of moisture air will result in corrosion of steel which leads to an increase in the volume of steel and to cracking and spalling of concrete cover.

The moisture penetration depends on permeability and if the concrete can be comes saturated with water IF a more frost action.

The permeability is also of interest in connection with water tightness of liquid retaining structures and the problem of hydrostatic pressure in the interior of the dams.

The flow of water through concrete is similar to flow through any porous body.

The pores in cement paste consist of gel pores and capillary pores.

The pores in concrete as a result of in incomplete compaction are voids of larger size which gives a honey comb structures. Leading to concrete of low strength.

The permeability of cement paste also varies with the age of concrete.

A durable concrete should be relatively impervious.

The permeability can be measured by a simple test by measuring the quantity of water flowing through a given thickness of concrete in given time.

Thermal Properties

Concrete is a material used in all climatic regions for all kinds of structures. Thermal properties are important in structures in which temperature differentials occur including those due to solar radiation during casting and the inherent heat of hydration. Knowledge of thermal expansion is required in long span bridge girders, high rise buildings subjected to variation of temperatures, in calculating thermal strains in chimneys, blast furnace and pressure vessels, in dealing with pavements and construction joints, in dealing with design of concrete dams and in host of other structures where concrete will be subjected to higher temperatures such as fire, subsequent cooling, resulting in cracks, loss of serviceability and durability.

Thermal properties of concrete:

Thermal conductivity is a measure of the ability of the concrete. To conduct heat and it measure.

Thermal conductivity depends upon the composition of concrete. .

Lower the water content of the mix the higher conductivity of harden concrete.

The density of the cornet does not appreciable affects the conductivity of the ordinary concrete.

The structural concrete containing normal aggregate, conduct heat more readily then light weight concrete

The thermal properties of concrete are more complex than those of most other materials becausethese are affect ted by moisture content and porosity.

To study about the thermal properties of concrete the following properties needs to be known,

Thermal conductivity

Thermal diffusivity

Specific heat

Coefficient of thermal expansion

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Thermal Conductivity:

This measures the ability of material to conduct heat. Thermal conductivity is measured in joules per second per square meter of area of body when the temperature deference is 10C per meter thickness of the body.

The conductivity of concrete depends on type of aggregate, moisture content, density and temperature of concrete. When the concrete is saturated, the conductivity ranges generallybetween about 1.4 and 3.4j/m2s 0c/m.

Thermal Diffusivity:

Diffusivity represents the rate at which temperature changes within the concrete mass.

Diffusivity is simply related to the conductivity by the following equation.Conductivity

Diffusivity = CP

Where C is the specified heat and P is the density of concrete. The range of diffusivity ofconcrete is between 002 to 0.006 m2/h.

Specific heat

It is defined as the quantity of heat required to raise the temperature of a unit mass of a material by one degree centigrade. The common range of values for concrete is between 840 and 1170 j/kg per 0C.

Coefficient of thermal expansion:

Coefficient of thermal expansion is defined as the change in length per degree change of temperature. In concrete it depends upon the mix proportions. The coefficient of thermal expansion of hydrated cement paste varies between 11*10-6 and 20*10-6 per 0C. Coefficient of thermal expansion of aggregate varies between 5*10-6 and 12*10-6 per 0C. Limestone and gabbors will have low values and quartzite will have high values of coefficient of thermal expansion. Therefore the kind of aggregate and content of aggregate influences the coefficients of thermal expansion of concrete.

DURABILITY

Definition:

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposures environment and properties desired.

For example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor. Concrete ingredients, their proportioning, placing and curing practices, and the service environment are determine the ultimate durability and life of concrete.

Some important degradation mechanisms in concrete structures include the following:

1. Effect of Temperature (physical effects, weathering).
2. Alkali-aggregate reactions (chemical effects).
3. Sulphate attack(chemical effects).
4. Microbiological induced attack(chemical effects).
5. Corrosion of reinforcing steel embedded in concrete (chemical effects).

a)carbonation of concrete

b) chloride induced.

6. Abrasion (physical effects).

7. Mechanical loads(physical effects).

Effect of Temperature:

The temperature difference within a concrete structure, result in differential volumechange.

When the tensile strain due to differential volume change exceeds the tensile strain capacity of concrete, it will crack. The temperature differentials associated with the hydration of cement, affect the mass concrete such as in large columns, piers, footings, dams etc. Whereas the temperature differentials due to changes in the ambient temperature can affect the whole structure.

The liberation of the heat of hydration of cement causes the internal temperature of concrete to rise during the initial curing period, so that it is usually slightly warmer than its surroundings.

In thick sections and with rich mixes the temperature differential may be considerable.

Any restraint on the free contraction during cooling will result in tensile stresses which are proportional to the temperature change, coefficient of thermal expansion, effective modulus of elasticity and degree of restraint.

The more massive the structure, the greater is the potential for temperature differential and degree of restraint.

Thermally induced cracking can be reduced by controlling the maximum internal temperature, delaying the onset of cooling by insulating the formwork and exposed surfaces, controlling the rate of cooling, and increasing the tensile strain capacity of the concrete.

Special precautions need to be taken in the design of structures in which some portions are exposed to temperature changes while the other portions of structures are either partially or completely protected.

Allowing for movement of structural components by using properly designed contraction joints and correct detailing will help alleviate these problems .

Internal temperature changes induced by:

Differential expansion and contraction

Heat of hydration of cement

Aggregate of abnormal thermal expansion

Low heat cement and control of temperature rise

Aggregates of normal thermal expansion

External temperature changes induced by:

Climate changes, frost action

Large slabs (or) walls without adequate joints

Spalling of surface

Adequate expansion, contraction joints

Air entrained and unsound concrete.

Major effects of temperature are,

Fire resistance

Freezing and thawing

Effects of salts

Moisture movement

Fire resistance:

Concrete though not a refractory material is in combustible and as good fire resistance.

The heating of reinforcement aggravates the expansion of both laterally and longitudinally of the reinforcement bars, resulting in loss of strength of reinforcement.

The effect of increase in temperature on the strength of concrete is not much up to a temperature of about 250 c0 but above 300c0 loss of strength take place.

Portland blast furnace slag cement is found to be more resistance to the fire in this regard.

In mortar and concrete and aggregate undergo a progressive expansion on heating.

This expansion as a disruptive action on the stability of concrete.

The best fire resistance aggregates among the igneous rocks are the basalts and dolomites.

Limestone expands until temperature of about 900 ^{0c}

It has been found that dense limestone is considered as a good fire resistance aggregates.

Broken bricks also form a good aggregate in respect of fire resistance.

The gel pores are so small that water in them does not freeze at normal winter temperatures.

As water when freezing expands by 9% of its volume, excess water in the capillaries has to move.

Since the cement paste is relatively impermeable, high pressures are necessary to move the excess water even over quite small distance.

For normal strength concrete it has been found that movement of the order of 0.2mm is sufficient to require pressures which approach the tensile strength of the paste.

Concrete can be protected from freeze – thaw damage, by the entrainment of appropriate quantities of air distributed through the cement paste with spacing between bubbles of not more than about 0.4mm.

The air bubbles must remain partially empty so that they can accommodate the excess water moved to them.

This will generally be the case since the bubbles constitute the coarsest pore system and are therefore the first to lost moisture as the concrete dries.

Fully saturated concrete, if permanently submerged, will not need protection against freezing, but concrete which as been saturated and is exposed to freezing, as for example in the tidal range, may not be effectively protected by air-entrainment.

Effect of salt

Chemicals used for snow and Ice clearance can cause and aggravate surface in scaling.

The formation of salt crystals in concrete may contribute to concrete scaling and deterioration layer by layer.

In cold region in the winter, sodium chloride or calcium chloride is used for de-icing snow clearance on concrete road.

The use of air entrainment makes the concrete road more resistance to surface scaling on account of frost action.

Moisture (moment) movement:

The concrete member is outdoor condition such as pavement, bridge decks, transmission poles; water tank, swimming pool etc. are subjected to alternative wetting a drying condition, under goes expansion and shrinkage.

The exposure of concrete to repetitive expansion and shrinkage or repetitive stress and tensile stress which may cause fatigue in concrete and affect the durability of concrete.

Effect of chemicals:

The most important constituent of concrete namely cement is alkaline; so it will react with acids or acidic compounds in presence of moisture, and in consequence the matrix becomes weakened and its constituents may be leached out.

The concrete may crack, as a result of expansive reactions between aggregate containing active silica and alkalies derived from cement hydration, admixture or external sources(e.g. curing water, ground water, alkaline solutions stored).

The calcium hydroxide in hydrated cement paste will combine with carbon dioxide in the air to form calcium carbonate which occupies smaller volume tan the calcium hydroxide resulting called *carbonation shrinkage*.

This situation may result in significant surface grazing and may be especially serious on freshly placed concrete surface kept warm during winter by improperly vented combustion heaters.

Factors which increase concrete vulnerability to external chemical attacks are,

1. High porosity
2. High permeability and absorption resulting from too high W/C ratio.
3. Unsatisfactory grading of aggregate.
4. Improper compaction.
5. Improper choice of cement type for condition of exposure.
6. Inadequate curing period.

7. Exposure to alternate cycles of wetting and drying and to the lesser extended of heating andcooling.

8. Increased fluid velocity which may bring about both replenishment of the aggressive speciesand increases in the rate of leaching.

9. Suction forces which may caused by drying on one or more faces of a section.

10. Unsatisfactory choice of shape and surface to volume ratio of concrete structure.

Sulphate attack:

When the sulphate bearing waters come in contact with the concrete, the sulphate penetrates the hydrated paste and reacts with hydrated calcium aluminate to form calcium sulpho aluminate with a subsequent large increase in volume, resulting in high tensile stresses causing the deterioration of concrete. The blended or pozzolana cements impart additional resistance to sulphate attacks.

Most soil contains some sulphates in the form of calcium, sodium, magnesium and ammonium sulphate.

Sulphate attack is a common occurrence in natural industrial situation.

Methods of controlling sulphate attack:

Use of sulphate resisting cement.

Quality concrete.

Use air entrainment.

Use of pozzolona cement.

High pressure steam curing.

High alumina cement.

Alkali aggregate reaction:

The alkali – silica reaction results in the formation of a swelling gel, which tends to draw water from other portions of concrete. This causes local expansion and accompanying tensile stresses which if large may eventually result in the complete deterioration of the structure.

Control measures include proper selection of aggregate, use of low-alkali cement and use of pozzolana. Typical symptoms in unreinforced and highly reinforced concrete are *map cracking*, usually in a rough hexagonal mesh pattern and gel excluding from cracks.

The alkali-carbonate reactions occurs with certain limestone aggregate and usually results in the formation of alkali-silica product between aggregate particles and the surrounding cement paste. The problem may be minimized by avoiding reactive aggregate, use of smaller size aggregate and use of low-alkali cement.

Hydroxyl ions in the pore water within concrete.

Alkalis come from sand containing sodium.

Acid attack:

Concrete is not fully resistance to acids.

Portland cement concrete depending upon the oxalic acid and phosphoric acid.

With the sulphuric acid, calcium sulphate, calcium aluminates, calcium sulpho-aluminate which on crystallization can cause expansion and disruption of concrete.

Concrete in sea water:

Off-structure.

The sea waters subjected to chloride.

Corrosion of steel.

Salt weathering.

Abrasion by sand.

Sea water contains some amount of co2.

Calcium hydroxide and calcium sulphates soluble in sea water.
The rate of chemicals attack is increased in temperature zone.

Carbonation:

Carbonation of concrete is a process by which carbon-dioxide from the air penetrates into concrete and reacts with calcium hydroxide. To form calcium carbonation.

Carbonic acid which attack the concrete.

The carbonation of concrete is one of the main reasons for corrosion of reinforcement.

Rate of carbonation:

Level of pore water.

Grade of concrete.

Permeability of concrete.

A concrete is protected or not.

Depth of cover.

Protective coating is required for long span bridge girder, fly over, Industrial structures and chimneys.

Depth of cover plays an important role in protecting the steel from carbonation.