Research Title

(Concrete and Concrete Structure)

Prepared

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Abstract

Today, second only to water, concrete is the most consumed material, if we analyze the most used materials in constructing our cities, we will find that concrete and steel are on the top of the list. It is considered the base of modern built, with three tones per year used for every person in the world. Twice as much concrete is used in construction as all other building materials combined. There is little doubt that concrete will remain in use as a construction material well into the future. However, with such extensive use of the material, discovery of any shortcoming or problem associated with concrete or reinforced concrete structures will become a matter of considerable public concern - both from a safety perspective and associated costs of rectification. Accordingly, this paper will initially review the historic development of cements and concrete and will then focus on the mechanical response of concrete and reinforced concrete to its working environment. At appropriate points within the narrative, case study input will be used to illustrate or highlight principal themes. .. Furthermore, there exist many recipes for the cement paste and many possible choices for the aggregates, which lead to concretes with very different chemistry and micro-structure.

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Introduction

Concrete is one of the oldest and most common construction materials in the world, mainly due to its low cost, availability, its long durability, and ability to sustain extreme weather environments.

The worldwide production of concrete is 10 times that of steel by tonnage. On the other hand, other construction materials such as steel and polymers are more expensive and less common than concrete materials. Concrete is a brittle material that has a high compressive strength, but a low tensile strength. Thus reinforcement of concrete is required to allow it to handle tensile stresses, such reinforcement is usually done using steel

Concrete is a composite material composed of coarse granular material (the coarse or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together. Aggregates can be obtained from many different kinds of materials although we mostly make use of the materials of nature – common rocks. Similarly, cement is a generic term that can apply to all binders. Therefore, descriptors must be used to qualify this term referring to specific materials. A civil engineer may have a cause to use Portland cement concrete, calcium aluminate cement concrete, or polymer concrete where the binders are Portland cement, calcium aluminate cement, or a polymer resin.

Concrete component:-

Components of concrete are cement, sand, aggregates and water. Mixture of Portland cement and water is called as paste. So, concrete can be called as a mixture of paste, sand and aggregates. Sometimes rocks are used instead of aggregates.

The cement paste coats the surface of the fine and coarse aggregates when mixed thoroughly and binds them. Soon after mixing the components, hydration reaction starts which provides strength and a rock solid concrete is obtained**.**

What is Grade of Concrete:-

Grade of concrete denotes its strength required for construction. For example, M30 grade signifies that compressive strength required for construction is 30MPa. The first letter in grade "M" is the mix and 30 is the required strength in MPa.

Based on various lab tests, grade of concrete is presented in Mix Proportions. For example, for M30 grade, the mix proportion can be 1:1:2, where 1 is the ratio of cement, 1 is the ratio of sand and 2 is the ratio of coarse aggregate based on volume or weight of materials.

The strength is measured with concrete cube or cylinders by civil engineers at construction site. Cube or cylinders are made during casting of structural member and after hardening it is cured for 28 days. Then compressive strength test is conducted to find the strength.

Regular grades of concrete are M15, M20, M25 etc. For plain cement concrete works, generally

M15 is used. For reinforced concrete construction minimum M20 grade of concrete are used.

Concrete grade	Mix ratio	Compressive strength	
		MPa(N/mm2)	psi
Normal Grade of Concrete			
M5	1:5:10	5MPa	725psi
M7.5	1:4:8	7.5MPa	1087 psi
M10	1:3:6	10MPa	1450 psi
M15	1:2:4	15MPa	2175 psi
M20	1:1.5:3	20MPa	2900 psi
Standard Grade of Concrete			
M25	1:1:2	25MPa	3625Psi
M30	Design Mix	30 MPa	4350 Psi
M35	Design Mix	35 MPa	5075 Psi
M40	Design Mix	40 MPa	5800 Psi
M45	Design Mix	45 MPa	6525 Psi
High strength concrete grade			
M50	Design Mix	50 MPa	7250 Psi
M55	Design Mix	55 MPa	7975 Psi
M60	Design Mix	60 MPa	8700 Psi
M65	Design Mix	65 MPa	9425 Psi
M70	Design Mix	70 MPa	10150 Psi

There are 25 different types of concrete discussed below.

1. Plain Cement Concrete (PCC):

Plain Cement Concrete is a basic concrete mix consisting of cement, fine aggregates, coarse aggregates, admixtures (optional), and water. PCC is very strong in compression. But, due to the absence of reinforcements like steel, it is very weak in tension. he general mix design ratio of PCC is 1:2:4 and 1:3:6. It is commonly used in the foundation of a building. After the hard strata have been reached, a layer of sand is laid followed by Plain Cement Concrete. Above the Plain cement concrete, the reinforcement cage of the footing is placed.

Applications:

- Foundations,
- Grade slabs,
- Concrete blocks,
- Verandas,
- Open Parking.

2. Reinforced Cement Concrete (RCC)

Reinforced cement concrete is a composite material made up of cement, fine aggregates, coarse aggregates, admixtures, and steel reinforcements. It is simply Plain cement concrete with the presence of steel in it. All the limitations in Plain cement concrete can be overcome by reinforced cement concrete. Of all metals, steel is the most suitable reinforcement material because of the near same thermal coefficient of expansion. The thermal coefficient of concrete is 14.5 /˚C and that of steel is 12 /˚C. Due to this property of steel, it is more compatible with concrete than other metals.

Applications:

- Slabs, beams, columns, and foundations of buildings
- Dams
- Pavements
- Bridges
- Water tanks
- Retaining walls

• Underwater constructions

• Concrete sewers and pipes

• Canals.

• Chimneys.

• Power plants.

3. Fibre Reinforced Concrete (FRC):

Fiber-reinforced concrete is a composite material made up of cement, water, aggregates, and flat or rounded fibres. Various types of fibres like steel fibres, polypropylene fibres, glass fibres, asbestos fibres, carbon fibres and organic fibres are widely used to reduce permeability, bleeding and the formation of minor cracks. Fibres are added in the ratio of 0.1% to 3% of the total volume of the concrete. The dimensions of the fibres are represented using the term "aspect ratio" which is the ratio of the length to the diameter of the fibre. The aspect ratio of the fibre is generally 30 to 150. The orientation of the fibres is mostly random but they can be arranged in parallel or perpendicular fashion depending on the design criteria.

Applications:

• Dams, spillways, basins

• Pavements in airports and highways

• Bridge decks

• Thin shelled structures

• Foundation

• In refractories

• Industrial floors

• Machine foundation

4. Glass Fibre Reinforced Concrete (GFRC)

Glass Fibre reinforced concrete is a composite material made up of cement, water, aggregates, and glass fibres. The glass fibres have high tensile strength of nearly 4080 N/mm2The glass fibres also increase the durability of the structure due to their alkaline nature. However, glass fibres are one of the cheapest reinforcements available thus making the structure more economical. The properties, applications, advantages and disadvantages of glass fibre reinforced concrete are similar to that of fibre reinforced concrete that is discussed above.

5. Ferro Concrete:

Ferro concrete also called Ferrocement is a type reinforced concrete structure made up of cement, fine aggregates, chicken wire mesh, and water. First, a tightly packed wire mesh is installed over which a rich cement mortar mix of ratios 1:2 or 1:3 is applied to both sides of the wire mesh. The diameter of the holes in the wire mesh is restricted to 1 mm. The application of the mortar to the wire mesh can be through hand plastering, centrifuging, machinal, or guniting.

Applications:

- Slabs
- Manhole covers
- Showcases
- Roof shells
- Water tanks and septic tanks
- Gobar gas units
- Stone benches
- Concrete pipes
- Industrial structures
- Bridge decks

6. Ready Mix Concrete

Ready mix concrete is a factory-made concrete made of cement, aggregates, water, and admixtures and transported to the site. The ready-mix concrete is preferred when there is less space for storing and mixing the construction materials. The plant-made concrete is loaded into special delivery trucks called the transit mixers which have the provisions to constantly rotate and keep the concrete in motion and thus prevent setting. Usually, retarders are added to the concrete mix to slow down the setting process to give allowance to the transportation and placing the time of the concrete. Quality check is performed both in the factory and at the site.

The difference in the slump value of both should not differ by more than 25 mm or 1/8th of the specific value whichever is greater.

Applications:

- Normally used for monolithic concreting of the roof slabs and beams
- Runways
- Pavements
- Lining of tunnels
- Dams and hydraulic structures

7. Precast Concrete

Precast concrete structures are cast, cured, transported to the site, and erected using cranes. The precast structures are manufactured at the sites using moulds with reinforcement cages present inside them. They may or may not be prestressed based on requirements. The dried concrete members are cured in controlled conditions to achieve the desired strength. Special hooks are provided to the members to lift them. The design of precast members takes into account the handling and erection stresses that may arise during the construction process.

Applications:

- Precast slabs, beams, columns, wall panels can be used for conventional buildings
- Bridge decks
- Parking
- High rise buildings
- Retaining walls
- Sound walls
- Culverts

Figure (1) precast concrete

8. Prestressed Concrete

Prestressed concrete structures are made up of high-strength concrete and high-strength steel tendons in addition to the normal reinforcements. When the tendons are prestressed, the stress from the tendon is transferred to the concrete. Thus it improves the deflection resistance, load capacity, and overall structural performance of the member. Prestressed concrete structures are commonly used in the construction of prefabricated buildings.

A concrete member can be prestressed in two ways:

1. Pre-tensioning

2. Post-tensioning

Pretensioned prestressed structures are prestressed before the concrete hardens. First, the high strength tendons are pulled and the concrete is cast in the mold with the normal reinforcement and the pulled tendons. After the concrete has sufficiently hardened, the prestressing tendons are spliced and the stress is transferred to the member. Here the stress transfer is through the bond strength between the concrete and steel. This is called pre-tensioning. In Post tensioned prestressed structures, the concrete member is the first cast with the conventional reinforcement and special ducts. After hardening, high strength steel tendons are introduced into the ducts and are prestressed and anchored to the ends of the member. Here the stress transfer is through the bond strength and anchorage blocks of the members This is called post-tensioning. The post-tensioned slabs are mostly precast and are of various shapes. Post-tensioned slabs are widely used because of their ability to be cast in a shorter period of time.

Applications:

- Bridge decks
- Parking
- High rise buildings
- Retaining walls
- Sound walls
- Culverts

9. Light Weight Concrete

Light weight concrete is a special type of concrete used to reduce the self-weight of the structure. The reduction in self-weight can be achieved by any of the following methods

i) Light Weight Aggregate Concrete:

Using light weight aggregates like silica sand, pumice, sawdust, scoria, volcanic cinder blocks, volcanic slag, tuff, crushed stone, and synthetic aggregates like coke breeze, foamed slag, bloated clay, expanded perlite, thermocol beads, broken bricks etc.

ii) Aerated Concrete:

The concrete can be made light by increasing the air density inside to concrete from 300 kg/cu.m to 800 kg/cu.m. The air can be introduced by chemical reactions, using foam or chemicals like aluminum powder, hydrogen peroxide, and zinc compounds.

iii) No fines Concrete:

In this concrete, the self-weight is reduced by removing the fine aggregates in the concrete. No fines concrete is made up of cement, coarse aggregate, and water. The Aggregate to cement ratio is set between 6:1 and 10:1.

Application:

• In precast elements

• Bridge decks

• Long span structures

• Filling for floor and roof slabs

• Partition walls

10. **Polymer Concrete**

Polymer concrete is a special type of concrete that will reduce the pores in the member through the incorporation of polymers into it. The porosity in the concrete can be due to the presence of air voids, water voids, or voids in the gel structure.

a. Polymer Impregnated Concrete:

In this type, conventional concrete is allowed to cure and harden. After this, the monomers such as styrene, acrylonitrile, thermoplastics are injected into the voids under high temperature and the voids are packed through polymerization.

Applications:

• Chemical industries

• Underwater constructions

• Marine works

• Desalination plants

• Sewage works

b. **Polymer Cement Concrete**:

In this type of concrete, the monomers/polymers such as polyester styrene, epoxy styrene, etc., are added to the concrete mix during the mixing process itself.

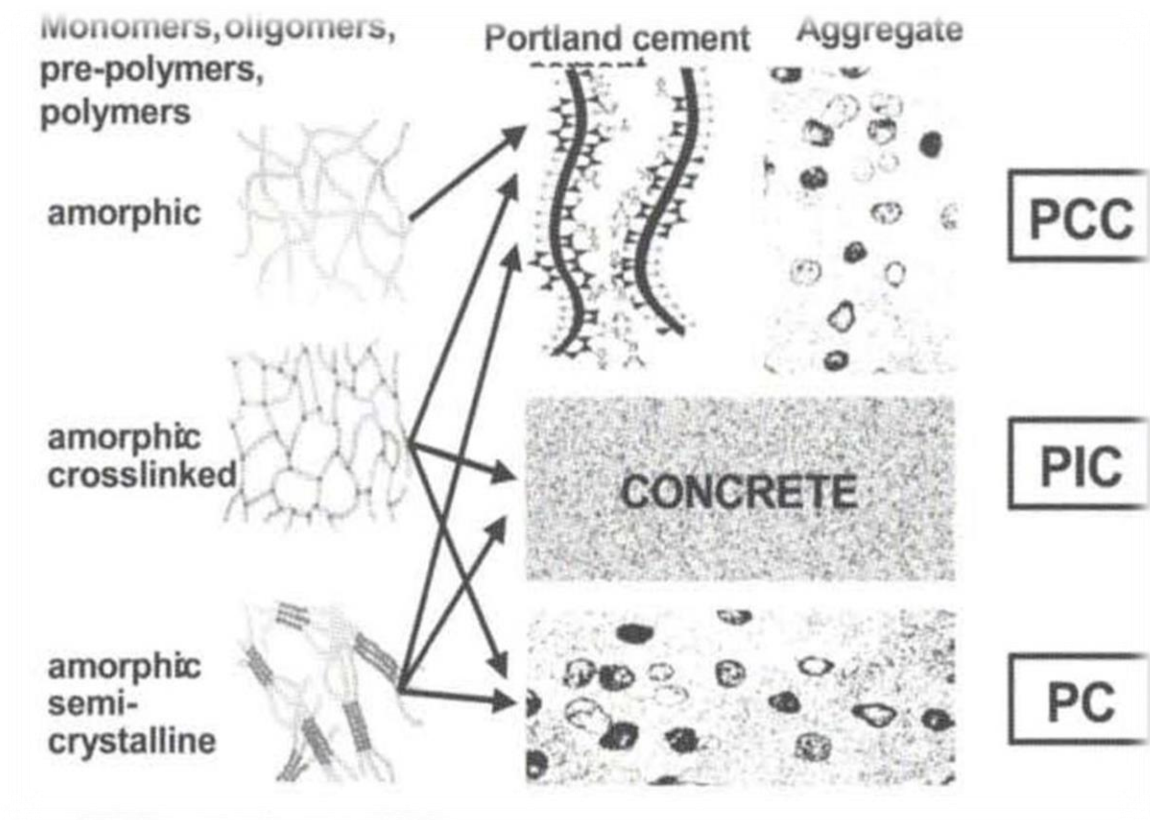
c. **Polymer Concrete:**

In this type of concrete, instead of cement polymers are used as binders to reduce the porosity of the member. Polymers, aggregates, water, and coupling agents that improve the bond strength like silane are mixed together to form the polymer concrete. Due to the absence of cement, this concrete is not strong enough.

d. **Partially impregnates and surface coated polymer concrete**:

Just like the polymer impregnated concrete, the members are allowed to dry and then dipped in high temperature monomer solutions to pack the voids through polymerization.

There are four types of polymer concrete:



Figure(2)Polymer Impregnated Concrete

11. High Density Concrete

High-density concrete is a special type of concrete made up of cement, water, fine aggregate, coarse aggregate, and high-density aggregate. The density of normal Plain cement concrete is 2400 kg/m3. For high-density concrete, the density ranges from 3360 kg/m3 to 3840 kg/m3. The density of the concrete is increased by increasing the cement content, reducing voids, and using high-density aggregates like barite, magnetite, serpentine, limonite, goethite, etc.,

Applications:

- Power plants
- Coal plants
- Research institutes

12. High Performance Concrete

High-performance concrete is a special type of concrete made using cement, water, fine aggregate, coarse aggregate, mineral admixtures, and superplasticizers. The mix design ratio of the high-performance concrete is designed in such a way that it performs well both structurally and in durability criteria. The performance of the concrete can be improved by making the three phases of the concrete – the paste phase, transition phase, and aggregate phase stronger.

It can be done by increasing the cement content, restricting the water-cement ratio to not more than 0.3, using superplasticizers, mineral admixtures, and non-porous aggregates

Applications:

- Power plants
- Chemical industries
- Coal plant
- Research Institutes

13. High Strength Concrete

High strength concrete is a special type of concrete that is made up of cement, water, fine aggregate, coarse aggregate, mineral admixtures, and superplasticizers. Mineral admixtures like fly ash, ground granulated blast furnace slag, silica fume, rice husk ash have a high specific surface area which plays a major role in increasing the strength. High-strength concrete has a compressive strength of at least 70 MPa co 

Figure (3) high strength Concrete

. **14. Air Entrained Concrete:-**

Air entrained concrete is a special type of concrete used made using cement, water, aggregates, and air-entraining agents. The air-entraining concrete can also be made using air-entraining cement. The need for air-entraining agents is prominent in cold-weather regions that are vulnerable to freeze-thaw cycles. The liquid water penetrating into the cement structure under freezing temperatures will turn into solid ice. The volume occupied by the solid ice is greater than that of the liquid water thus increasing the internal pressure. As a result, cracks will be formed to release the pressure. This is called as the freeze-thaw cycle. This can be avoided by using air-entraining agents like wood resins, hydrogen peroxide, aluminum powder, sulphonic acid, etc., These air-entraining agents will form artificial air pockets inside the mix. These artificial air pockets produced by the sir entraining agents can make up for the extra space needed by the formation of ice. Air entraining admixtures can also be added to ordinary cement to achieve the same results. This increases the durability of the structure but obviously, the air pockets will reduce the strength of the concrete.

Applications:

• In cold-weather regions where the freeze-thaw cycle is common.

• In sulphate rich soils and water.

15. **Self-compacting Concrete (SCC)**

Self-compacting concrete is a special type of concrete made up of cement, fine aggregates coarse aggregates, chemical admixtures to improve the workability, flowability, rheology, and mineral admixtures. SCC is also known as zero slump concrete. It has high workability and does not require any extra compaction. It is used in congested reinforcements where it is quite complicated to achieve full compaction. The flowability of the concrete can be achieved using viscosity modifying agents like sikaplast, retarders, air-entraining agents, very fine mineral admixtures, and superplasticizers.

Applications:

• In congested reinforcements like beam-column junctions.

• In places of heavy reinforcements.

• Places where compaction is not possible.

• Deep beams.

16. Shotcrete

Shotcrete is a special type of sprayed concrete where mortar or small aggregate concrete is sprayed at high velocities using compressed air to the place of interest. In shotcrete, a pre-mixed wet mortar or concrete mix is sprayed through a nozzle.

Applications:

• Repair works

• Slope stabilization

• Marine structures

• Tunnel construction

• Underground excavations

• Swimming pools

• Domes

• Retaining walls

• Mining

17. Guniting Concrete

Guniting is very similar to shotcrete but uses a dry mix. It is a method of spraying concrete on surfaces using compressed air. Unlike shotcrete, guniting uses a dry mix which will be uniformly mixed with water near the nozzle and discharged to the receiving surface. This process provides more bond strength than shotcrete.

Applications:

• Repair works

• Slope stabilization

• Marine structures

• Tunnel construction

• Underground excavations

• Swimming pools

• Domes

• Retaining walls

• Mining

18. Pumped Concrete

Pumped concrete is a special type of concrete that is suitable for pumping. Admixtures are added to improve the workability, flowability, and pumpability of the concrete.

Applications:

• Tall buildings

• Tunnels

• Underwater construction

19. Pervious Concrete

Pervious concrete is a special type of concrete that has high porosity and allows water to pass through it and recharge the groundwater. It is widely used in pavements where it can allow stormwater to pass through it. In pervious concrete, the fine aggregates used are minimized or totally neglected and thus making it porous. The porous nature of the concrete demands high maintenance and regular cleaning.

Applications:

- Pavements
- Parking
- Light traffic areas
- Walkways
- Green houses

20. Smart Concrete

Smart concrete is a special type of concrete that can self-monitor its health. Smart concrete can be self-sensing, self-healing and/or self-adjusting. Functional fillers such as carbon fibres, steel fibres, carbon nanotubes, nickel powder, etc., are added to the concrete to improves its ability to sense the stress, strain, and damage due to cracks. Some concrete in addition to monitoring the health has the ability to heal themselves. These functional fillers should be well distributed inside the concrete to prevent any lump formation.

Applications:

- High rise buildings
- Regions prone to earth quakes
- Highways
- Bridges
- Air field pavements
- Dams
- Nuclear power plants

21. Stamped Concrete

Stamped concrete also called imprinted concrete or textured concrete is a special type of concrete used for ornamental purposes in floorings of patios, sidewalks, parking, green houses, gardens, pools decks, and interior flooring. Mineral pigments shall be added to the concrete to get the required colour. The concrete of required colour is laid and the surface is prepared for stamping. The stamping can be done using concrete stamps made of polyurethane, The stamping gives an embossed and classy look to the concrete which is often considered to be decorative

22. Limecrete

Limecrete is a special type of concrete made using natural hydraulic lime, sharp sand, and glass fibres (optional). Limecrete makes the building energy efficient by improving its thermal performance.

The limecrete unlike conventional concrete will not be set in 24 hours. Limecrete is a hydraulic concrete using carbon dioxide in the air to harden and it takes time. It is more flexible than concrete. However, excess lime may hinder the breathing of people inside the building

23. Asphalt Concrete

Asphalt concrete is widely used in pavement construction. It is made using aggregates, crushed stones, and asphalt. Asphalt is a bituminous material that acts as a binder in concrete. It is used on normal roads, highways, airport roads, and parking lots. Asphalt is 100% recyclable and a widely recycled material in construction

24. Bacterial Concrete

Bacterial concrete is also known as self-healing concrete has the ability to repair cracks and fissures by itself. This made adding special bacteria and calcium lactate to the concrete mix. The most common bacterium is Bacillus Pasteruii. When cracks are formed, water seeps through the cracks and initiates the self-healing process.

In the presence of water, the bacteria germinate by feeding on the added calcium lactate converting it into calcium carbonate – limestone. Limestone hardens over time and thus repairing the concrete by itself. With the help of bacterial concrete, the life span of the building can be increased to 200 years.

25. Smog Eating Concrete

Smog eating concrete is a recent development in concrete technology to fight against pollution in modern cities. It is made by adding a photocatalytic additive called Titanium dioxide to the concrete. This titanium dioxide in the presence of sunlight gets activated and reacts with the pollutants in the atmosphere to neutralize them into harmless salts. By doing so, it reduces the air pollution levels in the area surrounding the building. It can neutralize pollutants like Carbon dioxide, Nitrogen dioxide, and Sulphur dioxide Some other types of concrete are Sulphur impregnated concrete, Roller compacted concrete.

7 Methods for Testing Concrete Strength

There are many different practices aside from cylinder break tests that can be used.

Methods for Testing Compressive Strength of Concrete

1. **Rebound Hammer or Schmidt Hammer (ASTM C805)**

Method: A spring release mechanism is used to activate a hammer which impacts a plunger to drive into the surface of the concrete. The rebound distance from the hammer to the surface of the concrete is given a value from 10 to 100. This measurement is then correlated to the concretes' strength.

Pros: Relatively easy to use and can be done directly onsite.

Cons: Pre-calibration using cored samples is required for accurate measurements. Test results can be skewed by surface conditions and the presence of large aggregates or rebar below the testing location.

2. Penetration Resistance Test (ASTM C803)

Method: To complete a penetration resistance test, a device drives a small pin or probe into the surface of the concrete. The force used to penetrate the surface, and the depth of the hole, is correlated to the strength of the in-place concrete.

Pros: Relatively easy to use and can be done directly onsite.

Cons: Data is significantly affected by surface conditions as well as the type of form and aggregates used. Requires pre-calibration using multiple concrete samples for accurate strength measurements.

3. Ultrasonic Pulse Velocity (ASTM C597)

Method: This technique determines the velocity of a pulse of vibrational energy through a slab. The ease at which this energy makes its' way through the slab provides measurements regarding the concrete's elasticity, resistance to deformation or stress, and density. This data is then correlated to the slab's strength.

Pros: This is a non-destructive testing technique which can also be used to detect flaws within the concrete, such as cracks and honeycombing.

Cons: This technique is highly influenced by the presence of reinforcements, aggregates, and moisture in the concrete element. It also requires calibration with multiple samples for accurate testing.

4. Pullout Test (ASTM C900)

Method: The main principal behind this test is to pull the concrete using a metal rod that is cast-in-place or post-installed in the concrete. The pulled conical shape, in combination with the force required to pull the concrete, is correlated to compressive strength.

Pros: Easy to use and can be performed on both new and old constructions.

Cons: This test involves crushing or damaging the concrete. A large number of test samples are needed at different locations of the slab for accurate results.

5. Drilled Core (ASTM C42)

Method: A core drill is used to extract hardened concrete from the slab. These samples are then compressed in a machine to monitor the strength of the in-situ concrete.

Pros: These samples are considered more accurate than field-cured specimens because the concrete that is tested for strength has been subjected to the actual thermal history and curing conditions of the in-place slab.

Cons: This is a destructive technique that requires damaging the structural integrity of the slab. The locations of the cores need to be repaired afterwards. A lab must be used to obtain strength data.

6. Cast-in-place Cylinders (ASTM C873)

Method: Cylinder molds are placed in the location of the pour. Fresh concrete is poured into these molds which remain in the slab. Once hardened, these specimens are removed and compressed for strength.

Pros: Is considered more accurate than field-cured specimens because the concrete is subjected to the same curing conditions of the in-place slab, unlike field-cured specimens.

Cons: This is a destructive technique that requires damaging the structural integrity of the slab. The locations of the holes need to be repaired afterwards. A lab must be used to obtain strength data.

7. Wireless Maturity Sensors (ASTM C1074)

Method: This technique is based on the principle that concrete strength is directly related to its hydration temperature history. Wireless sensors are placed within the concrete formwork, secured on the rebar, before pouring. Temperature data is collected by the sensor and uploaded to any smart device within an app using a wireless connection. This information is used to calculate the compressive strength of the in-situ concrete element based on the maturity equation that is set up in the app.

Pros: Compressive strength data is given in real-time and updated every 15 minutes. As a result, the data is considered more accurate and reliable as the sensors are embedded directly in the formwork, meaning they are subject to the same curing conditions as the in-situ concrete element. This also means no time is wasted onsite waiting for results from a third-party lab.

Cons: Requires a one-time calibration for each concrete mix to establish a maturity curve using cylinder break tests.

Combined Methods of Strength Testing

A combination of these methods for measuring the compressive strength is sometimes used to ensure quality control and quality assurance of a concrete structure. A combined method results in a more comprehensive overview of your slab, allowing you to confirm strength data by using more than one testing method. The accuracy of your strength data will also increase as using multiple methods will help account for influencing factors, such as cement type, aggregate size, and curing conditions. For example, a combination of the ultrasonic pulse velocity method and the rebound hammer test has been studied. Similarly, when using the maturity method on your jobsite to test compressive strength, it is recommended to perform cylinder break tests on day-28 of your concrete's lifecycle for acceptance purposes and to confirm the strength of your in-situ slab

Advantages of Concrete

Ingredients of concrete are readily available in most places

-Unlike natural stones, concrete is free from defects and flaws.

-Concrete can be manufactured to the desired strength with an economy.

-The durability of concrete is very high.

-It can be cast to any desired shape.

-The casting of concrete can be done on the working site which makes it economical.

-The maintenance cost of concrete is almost negligible.

-The deterioration of concrete is not appreciable with age.

-Concrete makes a building fire-safe due to its non-combustible nature.

-Concrete can withstand high temperatures.

-Concrete is resistant to wind and water. Therefore, it is very useful in storm shelters.

-As a soundproofing material cinder concrete could be used.

Disadvantages of Concrete

-Compared to other binding materials, the tensile strength of concrete is relatively low.

-Concrete is less ductile.

-The weight of concrete is high compared to its strength.

-Concrete may contain soluble salts. Soluble salts cause efflorescence

Impact of Weather Conditions on Concreting

Concreting in adverse weather conditions such as hot weather, cold weather and windy conditions presents a unique set of challenges, which must be thoroughly planned for. These weather conditions can have negative impacts on the fresh concrete properties such as workability, as well as the hardened concrete properties such as strength and durability. Different parts of the world experience varied weather conditions, and ready-mix concrete producers as well as construction professionals need to adapt their construction material designs and construction methods to these weather conditions so that they can produce good-quality concrete despite the climatic drawbacks they face.

CONCRETING IN HOT WEATHER

SANS 10100-2 defines hot weather as weather in which the ambient temperature exceeds 32°C. Temperature above 25°C may also be defined as hot weather if: the ambient relative humidity is low and the wind speed is high; the temperature of the concrete is high, or solar radiation is present. High temperatures increase the rate of the hydration reactions between the cement and the water, and thus the movement of moisture within and from the surface of the concrete. The following are the negative impacts of hot weather concreting:

-Increased water demand for a given workability

-Increased rate of loss of workability

-Increased rate of setting

-Increase in plastic shrinkage cracking

-Lower long-term strength (although early strength is higher)

-Decreased durability

-Variations in concrete appearance

Figure(4)below demonstrates the impact of high temperatures on water demand. It shows the amount by which the water content needs to be increased in order for the consistence of the concrete to be maintained

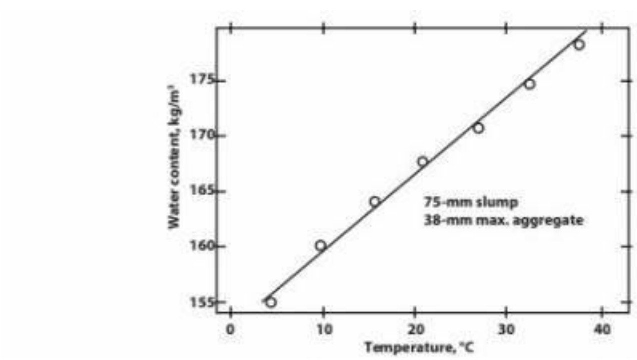


Figure (4): Effect of temperature increase on the water requirement of concrete

Avoiding the negative impacts of concreting in hot weather requires a reduction in the temperature of the concrete by controlling or adjusting the concrete mix and/or by adjusting construction methods to ultimately reduce the temperature of the concrete. The following measures may be implemented when concreting in hot weather

Cooling the mixing water or substituting flaked or well-crushed ice for part or all of the mixing water; ice particles have to be small enough to melt completely during the mixing process; Cooling the aggregates, for example by shading the stockpiles and by wetting the stone to cause evaporative cooling; Injecting liquid nitrogen into the mix during mixing; Concreting activities should be carried out during the cooler parts of the day; Painting construction material storage silos white to prevent rise in temperature; Shading of batching or mixing plant as far as possible, and/or painting it white; Reducing transport time of concrete as far as possible and covering concrete with damp material; Spraying of ready-mix vehicles and/or pump pipelines with water to cool them; and also shading pump pipelines where possible; Using a suitable retarder in the concrete mix to extend the concrete open time; Selecting aggregates and designing the mix to minimise the water content required and thus reducing the cement content required; Replacing some of the cement with an extender such as fly ash or ground granulated blastfurnace slag; and Sheltering the area being concreted from direct sunlight as far as possible.

CONCRETING IN COLD WEATHER

Cold weather is defined in SANS 10100-2 as weather in which the ambient temperature is less than 5°C. Although extreme cold temperatures are not regularly experienced in Southern Africa, it is necessary to be aware of impacts of cold weather concreting for the few occasions that it may occur. Cold weather concreting negatively affects the concrete by freeze and thaw action. At early ages, if the water in the concrete freezes before the concrete has had an opportunity to set, or even after the concrete has set but before it has gained sufficient strength, then there will be an increase in the overall volume of the concrete due to the expansion of the water, especially in the capillary pores of the concrete. When thawing takes place, i.e. when the water 'unfreezes', the concrete will set with an enlarged volume of pores. These pores reduce the strength and durability of the concrete. If the freezing cycle takes place after the concrete has gained sufficient strength of about 3 to 5 MPa, then it can resist any possible negative impacts from the freezing. This is mainly due to the fact that a majority of the mixing water in the concrete mix has already been combined with the cement through hydration, and also because the concrete has a high resistance to the pressure of ice.

The following measures may be implemented when concreting in cold weather:

Heating the mixing water and the aggregate (if water or aggregate is heated above 60 °C, combine the water with the aggregate in the mixer before adding the cement. Cement shall not be mixed with water or mixtures of water and aggregate of temperatures exceeding 60 °C); Increasing the cement content in the mix; Using a cement that hardens more rapidly; Portland cement (CEM I 42.5R and CEM I 52.5N) is recommended, as extended cements have a slower rate of setting and slower rate of strength gain

Incorporating an accelerator. (Chloride-free accelerators should be used when the concrete contain reinforcement or other embedded metal.); Fresh concrete should not be placed against frozen surfaces; Water in aggregates should be prevented from freezing by covering stockpiles with tarpulins; and Preventing heat loss from freshly placed concrete by covering exposed concrete surfaces with insulated material.

CONCRETING IN WINDY CONDITIONS

Concreting during windy conditions has a negative impact on the curing of freshly placed concrete. High winds result in moisture loss and premature drying out of concrete, which interferes with the maintenance of continued hydration of cement required for the hardening of the concrete. Windy conditions encourage evaporation from the concrete, which further exacerbate the negative impact associated with concreting at high temperatures, discussed earlier. In coastal environments, concrete is also exposed to wind-driven, salt laden air, which can increase the chlorides content in concrete and lead to the corrosion of reinforcement in concrete and the subsequent cracking and spalling of concrete.

Strength of concrete

-Compressive strength

-Tensile strength

-Flexural strength

-Shear strength

Compressive Strength

Two types of test specimens are used in Bangladesh -(1) Cube and (2) Cylinder.

The cube specimens of concrete of the desired proportion are cast in steel or cast iron molds, normally 6-inch cube. The standard cylinder specimen of concrete is 6 inch in diameter and 12 inches in height and cast in a mold generally made of cast iron;

-Standard cubes and cylinders are tested at prescribed ages, generally, 28 days, with additional tests often made at 1, 3, and 7 days. The specimens are tested for crushing strength under a testing machine. The cube tests give much greater values of crushing strength, usually 20 to 30 % more than those given by cylinders.

-According to British standard, the strength of a cylinder specimen is equal to three-quarters of the strength of the cube specimen.

Figure(5): Cube and Cylinder Specimens for Compression Strength Testing.

Effect of age on concrete strength:

Concrete attains strength with time. Ordinary cement concrete gains above 70 to 75% of its final strength within 28 days and about 90 to 95 % in the course of one year. It is often desirable to check the suitability of a concrete long before the results of the 28-day test are available. When no specific data on the materials used in making concrete are available, the 28-day strength may be assumed to be 1.5 times of the 7 days' strength. Tests have shown that for concrete made with ordinary Portland cement the ratio of the 28 days to 7 days' strength generally lies between 1.3 to 1.7, and the majority of the results fall above 1.5. The extrapolation of 28 days' strength from the 7 days' strength is, therefore quite reliable;

Tensile strength

Concrete is very weak in tension. The tensile strength of ordinary concrete ranges from about 7 to 10 percent of the compressive strength.

Flexural strength

The flexural strength of plain concrete is almost wholly dependent upon the tensile strength. However, experiments show that the modulus of rupture is considerably greater than the strength in tension.

Shear strength

It is the real determining factor in the compressive strength of short columns. The average strength of concrete in direct shear varies from about half of the compressive strength for rich mixtures to about 0.8 of the compressive strength for lean mixtures.

Workability

The strength of concrete of a given mix proportion is very seriously affected by the degree of its compaction. It is therefore vital that the consistency of the mix be such that the concrete can be transported, placed and finished sufficiently easily and without segregation. A concrete satisfying these conditions is said to be workable.

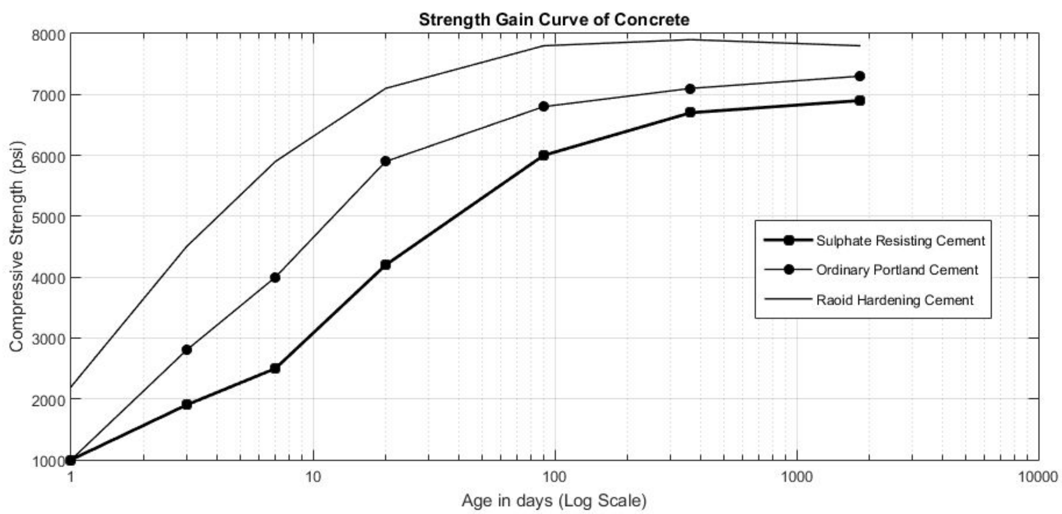


Figure (6)

Factors affecting the workability

1-Water Content

2-Mix Proportions

3-Size of Aggregates

4-Shape of Aggregates

5-(Grading of Aggregates

6-Surface Texture of Aggregates

7-Use of Admixtures

8-Use of Supplementary Cementitious Materials

9-Time

10-Temperature

Usually, Slump test is done to indirectly determine the workability of a concrete mix.

Properties of concrete:

Elastic Properties

Concrete is not perfectly elastic for any range of loading, an appreciable permanent setting taking place for even low loads. The deformation is not proportional to the stress at any stage of loading. The elastic properties of concrete vary with the richness of the mixture and with the intensity of the stress. They also vary with the age of concrete.

Durability

Durability is the property of concrete to withstand the condition for which it has been designed, without deterioration over a period of years. Lack of durability can be caused by external agents arising from the environment or by internal agents within the concrete.

Causes can be categorized as physical, mechanical and chemical.

Impermeability

Penetration of concrete by materials in solution may adversely affect its durability, for instance, when Ca(OH)2 is being leached out or an attack by aggressive liquids (acids) takes place. Permeability has an important bearing on the vulnerability of concrete to water and frost. In the case of reinforced cement concrete, the penetration of moisture and air will result in the corrosion of steel. This leads to an increase in the volume of the steel, resulting in cracking and spalling of the concrete. Permeability of concrete is also of importance for liquid retaining and hydraulic structures;

Segregation

The tendency of separation of coarse aggregate grains from the concrete mass is called segregation. It increases when the concrete mixture is lean and too wet. It also increases when rather large and rough-textured aggregate is used. The phenomenon of segregation can be avoided as follows.

Addition of little airin the mix.

Restricting the amount of water to the smallest possible amount.

All the operations like handling, placing and consolidation must be carefully conducted.

Concrete should not be allowed to fall from large heights.

Fatigue

Plain concrete when subjected to flexure, exhibits fatigue. The flexure resisting ability of concrete of a given quality is indicated by an endurance limit whose value depends upon the number of repetitions of stress. In concrete pavement design, the allowable flexural working stress is limited to 55% of the modulus of rupture

Bleeding

The tendency of water to rise to the surface of freshly laid concrete is known as bleeding. The water rising to the surface carries with it, particles of sand and cement, which on hardening form a scum layer is popularly known as laitance. Concrete bleeding can be checked by adopting the following measures.

-By adding more cement

-By using more finely ground cement

-By properly designing the mix and using the minimum quantity of water

-By using little air entraining agent

-By increasing the finer part of fine aggregate

What is the Modulus of Elasticity?

Modulus of elasticity (also known as elastic modulus, the coefficient of elasticity) of a material is a number that is defined by the ratio of the applied stress to the corresponding strain within the elastic limit. Physically it indicates a material's resistance to being deformed when stress is applied to it. Modulus of elasticity also indicates the stiffness of a material. The value of elastic modulus is higher for stiffer materials.

Modulus of Elasticity,E=fsModulus of Elasticity,E=fs

Here, f= applied stress on a body

s= strain to correspond to the applied stress elastic limit, maximum stress or force per unit area within a solid material that can arise before the onset of permanent deformation. When stresses up to the elastic limit are removed, the material resumes its original size and shape. Stresses beyond the elastic limit cause a material to yield or flow. For such materials the elastic limit marks the end of elastic behaviour and the beginning of plastic behaviour. For most brittle materials, stresses beyond the elastic limit result in fracture with almost no plastic deformation. The elastic limit is in principle different from the proportional limit,

Modulus of Elasticity of Concrete- Determination and Importance in Design

Modulus of elasticity of concrete(Ec) is defined as the ratio of the applied stress to the corresponding strain. Not only does it demonstrate the ability of concrete to withstand deformation due to applied stress but also its stiffness. In other words, it reflects the ability of concrete to deflect elastically. Modulus of elasticity of concrete is sensitive to aggregate and mixture proportions of concrete.

In the design of concrete structures, modulus of elasticity is considerably important that requires to be defined. The linear analysis of elements, which is based on elastic theory, is used in some cases to satisfy requirements of ultimate and serviceability limit state such as in the design of concrete structures. Common applicable codes around the world such as ACI Code, European Code, British Standards, Canadian standard association, and Indian standard have provided a formula for the computation of elastic modulus of concrete.

Calculation of Elastic Modulus of Concrete

1. Modulus of Elasticity Based on ACI 318-14

According to ACI 318-14 section 19.2.2, the modulus of elasticity of concrete is evaluated as follows :

For concrete, the unit weight(wc) ranges from 1440 to 2560 Kg per cubic meters.

$$E_c = w_c^{1.5} 0.043\sqrt{f_c'}\ (in\ MPa) \qquad \textit{Equation 1}$$

$$E_c = w_c^{1.5}\ 33\sqrt{f_c'}\ (in\ \text{psi}) \qquad \textit{Equation 2}$$

For normal weight concrete :

$$E_c = 4700\sqrt{f_c'}\ (in\ MPa) \qquad \text{Equation 3}$$

$$E_c = 57000\sqrt{f_c'}\ (in\ \text{psi}) \qquad \text{Equation 4}$$

2. Modulus of Elasticity Based on CSA

Modulus of elasticity for normal weight concrete based on Canadian Standard Association (CSA A23.3):

$$E_c = 4500\sqrt{f_c'}\ (in\ Mpa) \qquad \text{Equation 5}$$

For high strength concrete:

$$E_c = \left(3300\sqrt{f_c'} + 6900\right)(W/2300)^{1.5}\ (in\ Mpa) \qquad \text{Equation 6}$$

3. Modulus of Elasticity Based on EC

Modulus of elasticity of concrete based on Euro code can be evaluated using the following expression:

$$E_{cm} = 22[(f_{cm})/10]^{0.3} \qquad \text{Equation 7}$$

Where,

Ecm: mean modulus of elasticity

fcm: mean compressive strength of concrete at 28 days according to Table 3.1 BS EN 1992-1-1: 2004

4. Modulus of Elasticity Based on British Standard

The value of Elastic modulus at 28 days of concrete age is given in BS 8110: Part II 1985:

$$E_{c,28} = k_o + 0.2f_{cu,28} \qquad \text{Equation 8}$$

Where:

ko: is 20 KN per square millimeter for normal weight concrete

fcu,28: concrete compressive strength at 28 days.

5. Modulus of Elasticity Based on IS 456

Concrete modulus of elasticity based on Indian standard can be calculated using the following expression:

$$E_c = 5000\sqrt{f_c'} \qquad \text{Equation 9}$$

Importance in Design of Concrete Structure

It is highly crucial to define modulus of elasticity of concrete in the design of concrete structure. Linear analysis of elements, which is based on the theory of elasticity, is used to satisfy requirements of both ultimate and serviceability limit state for instance in the case of pre-stressed concrete that demonstrate uncracked section up to the failure.

In addition to compute deflections which are required to be limited under the serviceability requirements in all structures. Finally, knowledge of the modulus of elasticity of high strength concrete is very important in avoiding excessive deformation providing satisfactory serviceability and avoiding the most cost-effective designs.

Problems with Concrete Materials

Construction Errors

Errors made during construction can include adding improper amounts of water to the concrete mix, inadequate consolidation, and improper curing can cause distress and deterioration of the concrete. Proper mix design, placement, and curing of the concrete, as well as an experienced contractor are essential to prevent construction errors from occurring. Construction errors can lead to some of the problems discussed later in this fact sheet such as scaling and cracking. Honeycombing and bugholes can be observed after construction.

Honeycombing can be recognized by exposed coarse aggregate on the surface without any mortar covering or surrounding the aggregate particles. The honeycombing may extend deep into the concrete. Honeycombing can be caused by a poorly graded concrete mix, by too large of a coarse aggregate, or by insufficient vibration at the time of placement. Honeycombing will result in further deterioration of the concrete due to freeze-thaw cycles because moisture can easily work its way into the honeycombed areas. Severe honeycombing should be repaired to prevent further deterioration of the concrete surface.

Bugholes is a term used to describe small holes (less than about 0.25 inch in diameter) that are noticeable on the surface of the concrete. Bugholes are generally caused by too much sand in the mix, a mix that is too lean or excessive amplitude of vibration during placement. Bugholes may cause durability problems with the concrete and should be monitored.

Disintegration and Scaling

Disintegration can be described as the deterioration of the concrete into small fragments and individual aggregates. Scaling is a milder form of disintegration where the surface mortar flakes off. Large areas of crumbling (rotten) concrete, areas of deterioration which are more than about 3 to 4 inches deep (depending on the wall/slab thickness), and exposed rebar indicate serious concrete deterioration. If not repaired, this type of concrete deterioration may lead to structural instability of the concrete structure. A registered professional engineer must prepare plans and specifications for repair of serious concrete deterioration. For additional information, see the “Concrete Repair Techniques” fact sheet. Disintegration can be a result of many causes such as freezing and thawing, chemical attack, and poor construction practices. All exposed concrete is subject to freeze-thaw cycles, but the concrete’s resistance to weathering is generally determined by the concrete mix and the age of the concrete. Concrete with the proper amounts of air, water, and cement, and a properly sized aggregate, will be much more durable. In addition, proper drainage is essential in preventing freeze-thaw damage. When critically saturated concrete (when 90% of the pore space in the concrete is filled with water) is exposed to freezing temperatures, the water in the pore spaces within the concrete freezes and expands, damaging the concrete. Repeated cycles of freezing and thawing will result in surface scaling and can lead to disintegration of the concrete. Hydraulic structures are especially susceptible to freeze-thaw damage since they are more likely to be critically saturated. Older structures are also more susceptible to freeze-thaw damage since the concrete was not air entrained. In addition, acidic substances in the surrounding soil and water can cause disintegration of the concrete surface due to a reaction between the acid and the hydrated cement

Cracks

Cracks in the concrete may be structural or surface cracks. Surface cracks are generally less than a few millimeters wide and deep. These are often called hairline cracks and may consist of single, thin cracks, or cracks in a craze/map-like pattern. A small number of surface or shrinkage cracks is common and does not usually cause any problems. Surface cracks can be caused by freeze-thaw cycles, poor construction practices, and alkali-aggregate reactivity. Alkali-aggregate reactivity occurs when the aggregate reacts with the cement causing crazing or map cracks. The placement of new concrete over old may also cause surface cracks to develop. This occurs because the new concrete will shrink as it cures. Surface cracks in the spillway should be monitored and will need to be repaired if they deteriorate further. Structural cracks in the concrete are usually larger than 0.25 inch in width. They extend deeper into the concrete and may extend all the way through a wall, slab, or other structural member. Structural cracks are often caused by settlement of the fill material supporting the concrete structure, or by loss of the fill support due to erosion. The structural cracks may worsen in severity due to the forces of weathering. A registered professional engineer knowledgeable about dam safety should investigate the cause of structural cracks and prepare plans and specifications for repair of any structural cracks.

Efflorescence

A white, crystallized substance, known as efflorescence, may sometimes be noted on concrete surfaces, especially spillway sidewalls. It is usually noted near hairline or thin cracks. Efflorescence is formed by water seeping through the pores or thin cracks in the concrete. When the water evaporates, it leaves behind some minerals that have been leached from the soil, fill, or concrete. Efflorescence is typically not a structural problem. Efflorescence should be monitored because it can indicate the amount of seepage finding its way through thin cracks in the concrete and can signal areas where problems (i.e. inadequate drainage behind the wall or deterioration of concrete) could develop. Also, water seeping through thin cracks in the wall will make the concrete more susceptible to deterioration due to freezing and thawing of the water.

Erosion

Erosion due to abrasion results in a worn concrete surface. It is caused by the rubbing and grinding of aggregate or other debris on the concrete surface of a spillway channel or stilling basin. Minor erosion is not a problem but severe erosion can jeopardize the structural integrity of the concrete. A registered professional engineer should prepare plans and specifications for repair of this type of erosion if it is severe.Erosion due to cavitation results in a rough, pitted concrete surface. Cavitation is a process in which subatmospheric pressures, turbulent flow and impact energy are created and will damage the concrete. If the shape of the upper curve on the ogee spillway is not designed close to its ideal shape, cavitation may occur just below the upper curve, causing erosion. A professional engineer should prepare plans and specifications for repair of this type of erosion if the concrete becomes severely pitted which could lead to structural damage or failure.

Spalling and Popouts

Spalling is the loss of larger pieces or flakes of concrete. It is typically caused by sudden impact of something dropped on the concrete or stress in the concrete that exceeded the design. Spalling may occur on a smaller scale, creating popouts. Popouts are formed as the water in saturated coarse aggregate particles near the surface freezes, expands, and pushes off the top of the aggregate and surrounding mortar to create a shallow conical depression. Popouts are typically not a structural problem. However, if a spall is large and causes structural damage, a registered professional engineer should prepare plans and specifications to repair the spalling.

Inspection and Monitoring

Regular inspection and monitoring is essential to detect problems with concrete materials. Concrete structures should be inspected a minimum of once per year and after any significant weather event. The inspector should also look at the interior condition of concrete spillway conduit. Proper ventilation and confined space precautions must be considered when entering a conduit. It is important to keep written records of the dimensions and extent of scaling, disintegration, efflorescence, honeycombing, erosion, spalling, popouts, and the length and width of cracks. Structural cracks should be monitored more frequently and repaired if they are a threat to the stability of the structure or dam. Photographs provide invaluable records of changing conditions.

A rapidly changing condition may indicate a very serious problem, and the State Dam Safety Agency should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

Conclusion

Nowadays concrete is used in many different ways. All constructive elements can be made in concrete and in most cases they are realized with this material.But is it really necessary to replace other common construction methods with concrete it makes sense to use concrete in constructions, where load bearing elements have to bear big compressive strengths. A high rise a few hundred meters high? A tunnel? A dam? For sure! There are fields of application, where no other material performs as well as concrete but in many cases concrete is used in small scale projects, where it is unnecessary and over proportioned.

- Concrete has good properties to use as a construction material for this reason it has a wide using in all over the world.
- Using of steel reinforcement bars to resist tension force in the tension region.
- The combination of concrete and steel provide a new material has a good property called reinforced concrete.

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