

①

Deterioration of Concrete in Structures

Deterioration of concrete mainly occurs when the material is exposed to weather, water or chemicals over an extended period of time.

processes of DeteriorationPhysical processes

- Freezing & Thawing
- Wetting & Drying
- Abrasion
- Erosion
- Pitting

Chemical processes

- Carbonation
- Chloride ingress
- Corrosion
- Alkali aggregate reaction
- Sulphate attack, acid attack

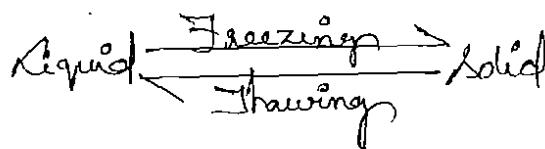
Physical deterioration of Concrete :-

The deterioration of Concrete due to physical factors like weather conditions, action of heavy loads etc.

Freezing & Thawing :-

Freezing is the process of solidification of water present in concrete, expands upto a volume of about 10% by converting into ice, which leads to form tensile stresses on concrete, finally results in the formation of cracks.

Thawing is the process of conversion of solid ice into liquid form.



Mechanism of Freezing & Thawing :-

Freezing & Thawing takes place in three stages of Concrete

(i) Fresh Concrete

Fresh concrete contains considerable amount of water, if this free water is subjected to freezing temperature discrete ice lenses are formed. The formation of ice lenses formed in the body of fresh concrete disrupt it causing permanent damage to concrete.

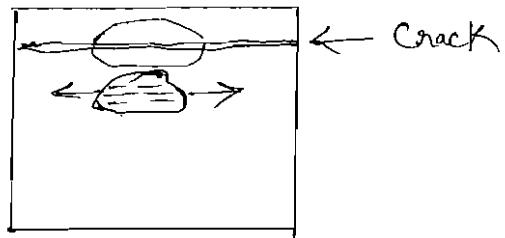
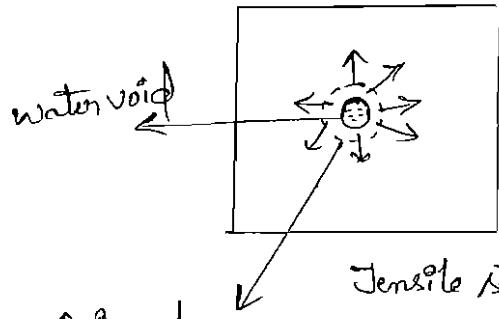
So the temperature of fresh concrete should be maintained above 0°C.

(ii) Hardening Stage

The hardening of concrete also should not be subjected to an extremely low temperature. Freezing of water in the hardened concrete may exert a pressure of about 14 MPa. The strength of concrete should be more than the stress exerted by ice on concrete.

(iii) Dry (Hardened) Concrete

The fully hardened concrete is vulnerable to frost damage, particularly to the effect of alternate cycles of freezing & thawing. When this occurs, concrete becomes wet subsequently and loses durability. The severest conditions for frost action arise when concrete has more than one face exposed to the weather and concrete is wet for a long period like parapets, road kerbs etc.



Formation of crack parallel to surface

Effects :-

- Losses durability
- Deterioration of Concrete

Measurement of amount of F&J :-

The amount of F&J can be estimated by the following methods

- (i) Loss of weight of sample subjected to certain no. of cycles of F&J
- (ii) ultrasonic pulse velocity method
- (iii) Durability factor method by ASTM - American Society for Testing & Materials (ASTM) proposed

Durability Factor

$$DF = \frac{\text{no. of cycles} \times \% \text{ of original modulus}}{300}$$

Values of DF

Remarks

< 40

Unsatisfactory

40 - 60

Questionable performance

60 - 100

Satisfactory

Factors Influencing F&J :-

→ water-cement ratio

$$w/c \text{ ratio} \propto F&J$$

High w/c \Rightarrow high water content \Rightarrow high amount of freezing & thawing

→ Degree of saturation of concrete (S_n)

$$S_n = \frac{\text{volume of water } (V_w)}{\text{volume of voids } (V_v)}$$

$$S_n \propto F&J$$

$\therefore S_n \propto V_w \Rightarrow$ more amount of F&J

→ Length of exposure

It is the increase in volume of concrete during prolonged freezing as a function of age.

$$\text{Length of exposure (hours)} \propto \uparrow \text{ in vol (\%)} \propto F&J$$

→ No. of cycles

Concrete subjected to freezing & thawing in a given day is said to complete 1 cycle.

$$\text{No. of cycles} \propto F&J$$

Causes of Failure :-

- (i) Inadequate empty space for volume expansion of ice,
- (ii) growing of ice lenses parallel to surface due to production of pressure ; which is similar to frost heaving in soils.

- Preventive measures :-

The use of air entrained concrete prevents the possibility of [sic].

Air-entrained concrete is prepared by adding some air entraining agents to ordinary concrete in order to create air voids (entrained air) which allow free expansion of ice when freezing occurs.

Advantages of air-entrained Concrete :-

- Increased resistance to freezing & thawing.
- Increased durability
- Increase resistance to chemical attack.
- Decreases permeability etc.

Abrasion :- it is the process of scuffing, scratching, wearing down, or rubbing away. it can be intentionally imposed in a controlled process using an abrasive.

wearing away of the surface by friction. (g)

Causes of Abrasion :-

- wind-borne particles can cause abrasion.
- due to heavy traffic conditions.

Traffic surfaces :- abrasion of floors and pavements may result from production operation of vehicular traffic. Many industrial floors are subjected to abrasion by steel hard rubber wheel traffic, which can cause significant rutting.

mostly seen in

- Pavements
- Industrial floors.

Prevention of abrasion :-

- Using high compressive strength of concrete
- Hardness of coarse aggregates is also important to abrasion resistance

Graded aggregates improves the wear resistance

- adopting mixes of lowest water/cement ratio.
- lowest practicable slump.
- uniformity of the concrete also increase the wear resistance.

Erosion :-

to wearing away of surface by fluids.

Causes of erosion :- high velocity of fluid passing on concrete surface the top surface wear due to continuous flow. mainly observed in

- Hydraulic structures:
 - Spillway aprons
 - Stilling basins
 - Sluice ways
 - Drainage conduits
 - Tunneled linings
 - Floors of channels carrying high-velocity water.
 - Water contains grit.
 - Bridge piers

Prevention of erosion :-

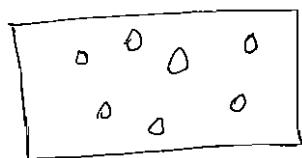
- for resisting abrasion in the velocity range 4-6 m/s concrete should be manufactured using a w/c ratio of 0.45 and should have a strength not less than 40 MPa.
- for the velocity range 6-15 m/s, special high performance concrete having 400 kg/m³ of cement and a maximum w/c ratio of 0.4 in which the microstructure is modified by suitable mineral admixtures should be used.

and as the flow is continuous over long periods and a velocity exceeding 5 m/s, the special protective measures suggested below are used.

 - a) A 75 mm thick sacrificial layer of high strength concrete (8%) granite integrated with the concrete below.
 - b) three coats of epoxy resins 75 mm thick applied evenly.
 - c) A protective layer of epoxy resin mortar made with abrasion resistant aggs.
 - d) In extreme cases, steel plates fixed on the wall 8% lined with concrete made with steel fibre reinforcement are used. Steel fibre reinforced concrete is especially suitable in channels where changes in cross-section occur.

pitting :- is defined as the formation of holes on the surface of the concrete. in this pits and cavity develops.

- there are small diameter
- most destructive.
- very difficult to detect
- difficult to evaluate by laboratory tests



causes of pitting :-

- 1) concrete and climate :- in cold countries ice and snow that are left on the surface can cause pitting from the cycle of freezing and melting from night to day. in the sunlight, ice may melt and the water penetrates the surface of the concrete, and will freeze again at night. the expansion of the ice within the top surface of concrete slowly ruptures, forming tiny crater which continue to expand.
- 2) concrete pitting from Inadequate mix :- local building codes usually specify strength of mixes for their climate conditions. A lower strength concrete is less water proof, all less resistance to the effect of snow.

3) concrete degradation from Improper Placement and Finishing Techniques :-

it is occur finishⁿ curing improperly. if surface not cored too much water can escape through evaporation. and also give proper surface finishing on concrete.

) Aggregates and concrete degradation :- A bad aggregate will either create a chemical reaction that breaks down the concrete or has excess porosity that poorly resists the freeze-thaw cycle.

5) Age, maintenance and prevention :-

- snow and ice removal can drastically reduce pitting over the years.
- salt and other ice melting compounds can be an obvious necessity for safety

Prevention of pitting :-

1) Polycote Easipatch :-

- A pourable twin pack resin that can cure to the strength of an industrial power floated floor in only 2 hours.
- it will go on and harden to anything b/w 80-90 N/mm in only one day.

2) Floortex Professional :-

- it is used in heavy traffic conditions
placing - by mixing in the sand, you can turn the resin
into a form of mortar and of course depending
upon how much sand you add, you can make the repair
runny and very thin through to as thick as you like.

3) Easi-screed standard :-

- 1) heavy domestic
- 2) light Industrial use

1) Easi-screed Industrial :-

- 1) heavy Industrial areas
use.

3) Easi-screed flexible :-

- 1) under heating condition
- 2) excessive vibration

4) Easi-screed External :-

application :- All of the Easi-screed products are excellent
for smoothing out surfaces that are either delaminating
or pitted. simply mix the specialist dry mix supplied with
water and pour onto the surface. this is then levelled
out with the use of pin-levelles. A pin leveller is like
a snake where the length of the pins can be quickly and easily
adjusted in accordance with the depth of screed required.

Carbonation:

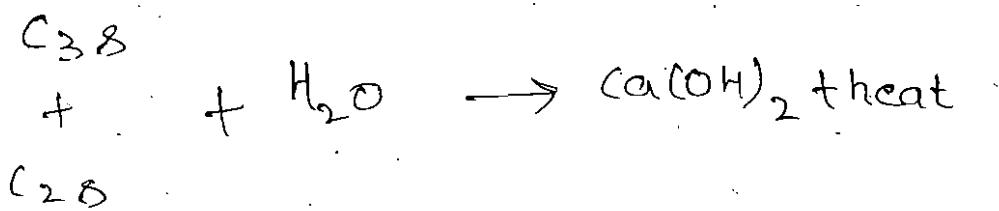
Definition: whenever concrete is exposed to the atmosphere CO_2 enters into the concrete and it react with $\text{Ca}(\text{OH})_2$ and produce calcium carbonate (CaCO_3). This process is known as carbonation



Source of $\text{Ca}(\text{OH})_2$:

As we all know that hydration of cement is major cause for $\text{Ca}(\text{OH})_2$.

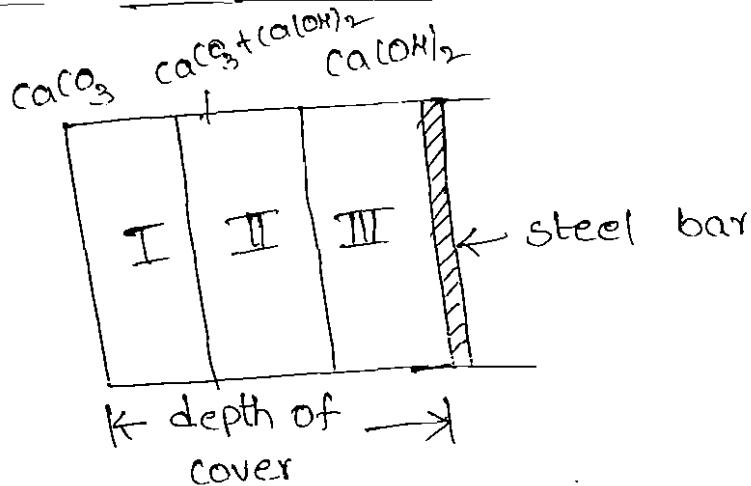
The various compounds like tricalcium silicate and dicalcium silicate reacts with cement when water is added $\text{Ca}(\text{OH})_2$ and some amount of heat is liberated.



general concrete has high alkalinity i.e, (12.5 - 13.5)

Due to this carbonation pH get reduced and it effects the durability of concrete

Schematic representation of carbonation:



In the zone I, the zone nearer to atmosphere the $\text{Ca}(\text{OH})_2$ reacts with CO_2 and it is deposited as CaCO_3 in pores

In the zone II, the middle zone some of the zone $\text{Ca}(\text{OH})_2$ reacts with CO_2 and deposited as CaCO_3 some remains same

In the zone III, the zone nearer to the reinforcement the $\text{Ca}(\text{OH})_2$ remains unreacted

Depth of carbonation:

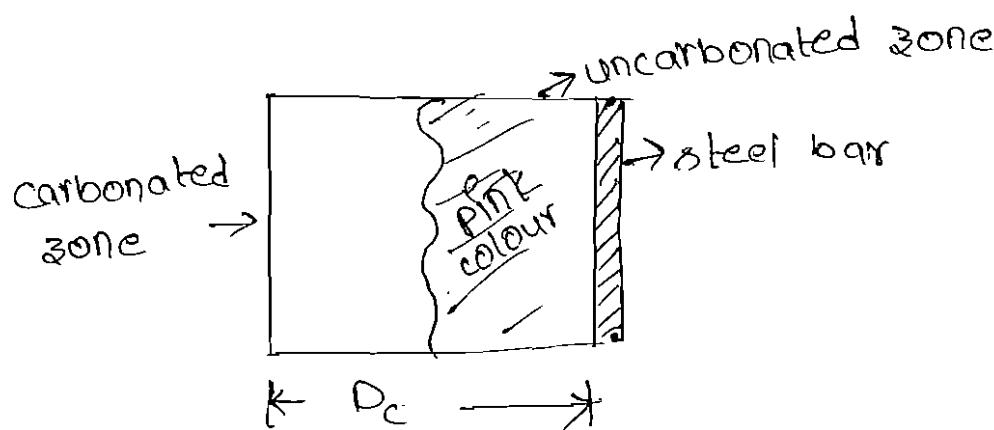
The carbonation attack in concrete is calculated in terms of depth

Measurement:

1. Carbonation is measured by using phenolphthalein solution.

2. When phenolphthalein is sprayed on test concrete

block, the carbonated zone remains same, while uncarbonated zone turns pink, this is because phenolphthalein turns pink in high alkalinity condition



Factors influencing Carbonation:

1. level of water in pores:

a. When the pore is completely filled with water, CO_2 diffuses slowly and it takes time to react, hence, carbonation less

b. When the concrete is completely dry, CO_2 remains gaseous and does not react. hence, carbonation less
carbonation is more when humidity 50-70%.

2. Depth of cover:

If Depth of cover is more, time to reach carbonation till reinforcement is more

depth of cover more, carbonation effect less
on concrete

Grade of concrete:

grade of concrete more, carbonation effect less

time of exposure:

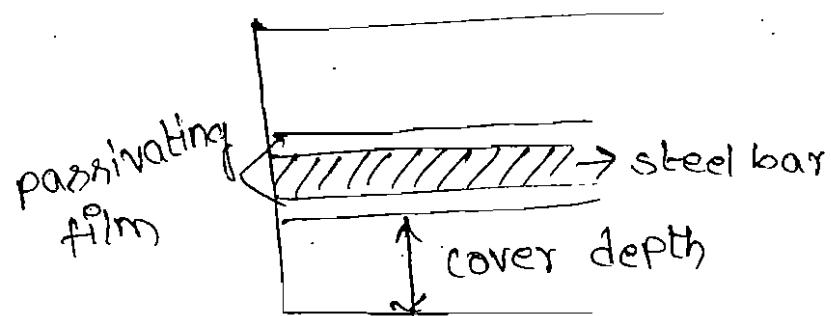
time is more, carbonation effect is less

protected/unprotected concrete:

for same depth of cover, same grade of concrete,
for same time carbonation effect is more in unprotected
compared to protected concrete.

Effects of carbonation:

concrete is generally alkaline in nature. This alkaline nature generates protective film called passivating film around steel and it prevents the entry of oxygen & water to reach steel and thereby preventing corrosion



when carbonation occurs the pH get reduced and the alkalinity get reduced this causes the destruction

of passivating film and water & oxygen reaches steel and causes rust

whenever rust occurs steel volume is increased by 5%. It causes cracks and finally concrete get deteriorated

Preventive measures:

1. By applying coatings to steel (paints)
2. By applying coatings to concrete
3. high strength (grade) concrete
4. increasing depth of cover

Corrosion Control:-

From the literature survey and case studies it has been reported that 40% of failure of structures is on account of corrosion of embedded steel reinforcement in concrete. Therefore corrosion control of steel reinforcement is a subject of paramount importance.

First and foremost for corrosion control is the good quality of concrete through good construction practices. In general availability of Superplasticizers, it should be used to cut down the w/c ratio to make dense concrete.

Proper mix design, use of right quality and quantity of cement for different exposure conditions is to be adopted. Recently it has been realised that lower w/c ratio which has been always associated with lower permeability is not enough to make impermeable concrete contributing to high durability. Use &

use of Supplementary cementitious materials such as fly ash, ground granulated blast furnace slag (ggbs), Silica fume etc. are required to be used as admixtures or in the form of blended cement in addition to lower possible w/c ratio to concrete dense make concrete ~~perfect~~^f make concrete dense.

- ggbs reduces the ~~contribute~~ diffusion of chloride ions into the concrete.
- silica fume contributes to the allround improvements in the quality of concrete which are responsible for reducing corrosion of steel reinforcement.
- The improvement in the microstructure of hydrated cement paste is ultimately responsible for protecting the steel reinforcement from corrosion.

Further, the inherent long term drying shrinkage and microcracks in concrete, the problems become more serious. This demands certain other measures to control the corrosion of steel reinforcement

They are listed and briefly explained.

- ① Metallurgical methods.
- ② Corrosion inhibitors
- ③ Cathodic protection
- ④ Coatings of to Concrete
- ⑤

Metallurgical Methods:-

Steel can be made more corrosion resistant by altering its structure through metallurgical processes. Different methods such as rapid quenching of the hot bars by series of water jets, or by keeping the hot steel bars for a short time in a water bath, by this the mechanical properties and corrosion resistance property of Steel can be improved.

Corrosion inhibitors:-

Corrosion can be prevented or delayed by chemical method by using certain corrosion inhibiting chemicals such as nitrates, phosphates, benzoates etc.,

- The most widely used admixture is based on calcium nitrite.
- The typical dosage is of the order of 10-30 litres per m^3 of concrete depending on chloride levels in concrete.
- The nitrite ions present in the corrosion inhibiting admixture will oxidise the ferrous oxide to ferric oxide, thus stabilising the passivating layer even in the presence of chlorides. The concentration of nitrite must be sufficient to cope up with the continuing ingress of chloride ions.
- Without an inhibitor the reinforcing steel starts to corrode when the chloride content at the rebars reaches a threshold level of 0.7 kg/m^3 .
- Adding of calcium nitrite increases this corrosion threshold. When you add 20 litres/ m^3 , corrosion will not begin until over 7.7 kg/m^3 of chloride is present in the concrete at the rebars.

11

Phosphated Surface

Inhibitor solution is then brushed over the minutes and then removed by wet cloth. An with fine brush. The soil is left for 45-60 seconds in sunning water and air dried.

④ Phosphating: Phosphate jelly is applied to the bars cloth and cleaning powder. The rods are then deloy by cleaning the rods with wet washcloth brushing solution. This is followed with a

⑤ Decoating: The reinforcement are cleaned with a mixture in this process are corrosion in steel reinforcement in concrete. The steps Kastikudi have suggested a method for prevention of Central Electro Chemical Research Institute (CECRI) in Shillong.

For temporary protection against rusting of reinforcement simple cement slurry coating is a cheap method. It is objective of coating to shield bars from aggressive media such as dusting particles, to aggressive media such as

Cleanings to reinforcements:-

Cement Coating:-

A slurry is made by mixing the inhibitor solution with portland cement and applied on the bars. A Sealing Solution is brushed after the rods are air cured. The sealing Solution has an insite curing effect. The second coat of Slurry is applied and the bars are air dried.

Sealing :-

Two coats of Sealing Solution are applied to the bars in order to seal the micro-pores of the cement coat and to make it impermeable to corrosive salts.

The above is a patent method evolved by CECRI and license is given to certain agencies. Somehow or other this method has not become very popular. Some experienced consultants and engineers are doubting the efficacy of this method.

5) Galvanised reinforcement:-

Galvanising of reinforcement consists of dipping the steel bars in molten zinc. This results in a coating of zinc bonded to the surface of steel. The zinc surface reacts with calcium hydroxide in the concrete to form a passive layer and prevents corrosion.



Cathodic Protection:-

Cathodic protection is one of the effective, well known, and extensively used methods for prevention of corrosion in concrete structures in more advanced countries. Due to high cost and long term monitoring required for this method, it is not very much used in India.

The cathodic protection comprises of application of impressed current to an electrode laid on the concrete above steel reinforcement. This electrode serves as anode and the steel reinforcement which is connected to the negative terminal of a DC source acts as a cathode. In this process the external anode is subjected to corrode and the cathodic reinforcement is protected against corrosion and hence the name "Cathodic Protection".

The recent development in corrosion control methods are Realkalisation and Desalination.

Coatings to Concrete:-

In the past it was believed that concrete by itself is a durable material which needs no protection or maintenance. This belief is no more hold good particularly on account of environmental pollution, industrial fumes and contamination of ground water. In addition

to the coating of reinforcement by appropriate material, a surface coating to the concrete member is given to increase the durability further. The coatings serve the dual purpose of protection and decoration.

Giving protective coatings to major concrete structures such as bridges, flyovers, industrial buildings and chimneys have become a common specification in India as in other countries.

Four km long bridge on national highway at Cochin was recently coated with Emceecolor Flex, a material manufactured by Mc-Bauchemie Pvt. Ltd. Almost all the flyovers at Mumbai are being coated for additional durability.

Freshly made concrete structures should not be coated with epoxy or other materials which will seal off and prevent the internal moisture from going out in consonance with atmospheric conditions. The moisture trapped

inside the concrete can do untold harm to the durability of concrete in addition to damaging the protective coating itself. For better durability, the concrete should be able to "breathe" i.e., water vapour should be able to migrate from inside to outside and from outside to inside. But water as it is, should not be able to migrate from enter from outside to inside. The protective coating given to the concrete should be of the above characteristics.

Therefore, it is pointed out that the epoxy coating which does not allow the concrete to breathe should not be used for coating concrete members.

In addition, epoxy based coating material is not resistant to ultraviolet rays when exposed to sunlight and also it is not flexible. Whereas the coating material based protective cum decorative coatings on acrylic polymers is resistant

to ultraviolet rays of sun and is flexible.

Coating is not only required for bridges, Flyovers and industrial structures, it is also required for very thin members like fins, Facade, Sunbreakers and other delicate concrete structures where specified amount of cover can not be given. Therefore, acrylic based protective cum decorative coatings can be given for additional durability of such concrete members.

Acid Attack:

Concrete is not fully resistant to acids. Most acid solutions will slowly or rapidly disintegrate portland cement concrete depending upon the type and concentration of acids. Certain acids such as oxalic & phosphoric acids are harmless.

The most vulnerable part of cement is $\text{Ca}(\text{OH})_2$, but C-S-H gel can also be attacked. Siliceous aggregates are more resistant than calcareous aggregates.

Concrete can be attacked by liquids with $\text{pH} < 6.5$. This effect is severe when $\text{pH} < 5.5$. When $\text{pH} < 4.5$ this attack is very severe. If this attack proceeds all the cement compounds completely broken down and leached away with any other carbonate aggregate material.

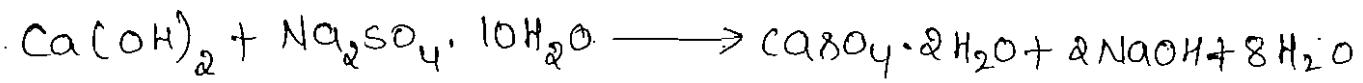
With the sulphuric acid attack, calcium silicate formed can proceed to react calcium aluminate in cement to form calcium sulphaaluminate which on crystallization can cause expansion and disruption of concrete.

If acids & salt solutions are able to reach the reinforcing steel through cracks or through porosity of concrete, corrosion can occur which will cause cracking.

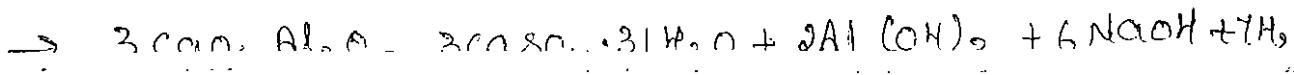
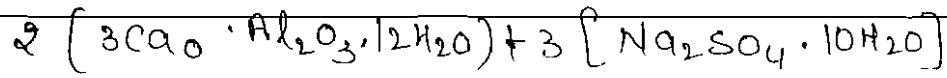
sulphate attack :

1. most of the soils contain sulphate in the form of calcium, sodium and potassium. Ground water contains less calcium sulphate compared to other forms as it is less soluble
2. Ammonium sulphate is frequently present in water and agriculture lands due to use of fertilizer or from sewage and industrial effluents
3. water used in concrete cooling towers is also a major source of sulphate attack on concrete. therefore sulphate attack is a common occurrence in natural or industrial situation.
4. solid sulphates do not attack the concrete severely but when the chemicals are in solution they enter into concrete and react with hydrated cement products. of all these magnesium sulphate cause max damage to concrete
5. A characteristic whitish appearance is the indication of sulphate attack. It indicates the increase in the volume of concrete or mortar

The reactions of the various sulphates with hardened cement paste is shown below



The reaction of sodium sulphate with calcium aluminate hydrate



Methods of controlling sulphate attack:

1. Use of sulphate resisting cement:

The most efficient method of resisting the sulphate attack is to use cement with low C₃A content.

2. Quality concrete:

- A well designed, placed and compacted concrete which is dense and impermeable exhibits a higher resistance to sulphate attack.
- A concrete with low $\frac{w}{c}$ ratio also demonstrates a higher resistance to sulphate attack.

3. Use of air-entrainment:

use of air entrainment to the extent of about 8% has beneficial effect on the sulphate resisting qualities of concrete by reducing segregation, improvement in workability thereby producing impermeable concrete.

4. Use of pozzolana:

Replacing a part of cement by a pozzolanic material reduces the sulphate attack. This pozzolana is responsible for impermeability of concrete. It converts leachable $\text{Ca}(\text{OH})_2$ into non-leachable cementitious product thereby reducing magnesium sulphate.

5. High pressure steam curing:

High pressure steam curing improves the resistance of concrete to sulphate attack. This is due to the change of $\text{Ca}_3\text{Al}_2\text{O}_6$ into a less reactive phase and reduction of $\text{Ca}(\text{OH})_2$.

6. Use of High alumina cement:

High alumina cement contains approximately 40% alumina. A compound very susceptible to sulphate attack, when in normal OPC, but it behaves differently in high alumina cement. It forms a protective film which inhibits the penetration of sulphate ions. But it does not show any resistance at high temp.

A (Kali-Aggregate reaction (AAR)):

For a long time aggregates have been considered as inert materials. but, after 1940s it was clearly brought out that the aggregates are not fully inert. Some of the aggregates contain reactive silica, which reacts with alkalies present in cement and causes deterioration of concrete.

The reactive constituents are in the form of opals, cherts, chalcedony, volcanic glass, zeolite etc.,

The reaction starts with attack on reactive siliceous mineral in aggregate by the alkaline hydroxides in

Cement. As a result, the alkali silicate gel is formed. It is of unlimited swelling type. When the conditions are congenital, progressive manifestation by swelling takes place, which results in disruption and spreading of cracks in concrete which leads to failure.

Types:

1. ASR (Alkali Silica Reaction)
2. ASR (Alkali Silicate Reaction)
3. ACR (Alkali carbonate reaction)

Factors promoting AAR:

1. High alkali content in cement:

1. The alkali content in cement is expressed as $(Na_2O + 0.658K_2O)$. A cement meeting this specification is designated as a low alkali cement.
2. Generally Indian cements do not contain high alkalies as in U.S.A & U.K
3. When alkali content is less than 0.6%, it never showed serious deterioration of concrete through AAR.

Temperature condition:

The ideal temperature for the promotion of AAR is in the range of 10 to 38°C. If the temperature is more or less than the above, it may not provide an ideal situation for the AAR.

3. Availability of moisture:

Progress of chemical reactions involving AAR in concrete requires the presence of water. Therefore deterioration due to AAR will more on surface and does not occur in the interior mass of concrete.

4. Reactive Type of Aggregates:

To determine the reactive type of aggregates the petrographic examination of thin rocks is done and the case history of aggregates is studied to know whether the aggregate source is harmless or not.

1. physical method

Mortar bar expansion test by Stanton is used to find reactivity of aggregates.

A specimen of size 25mm x 25mm and 250mm length is cast, cured and stored in a standard manner. The length of the specimen is measured periodically at the ages of 1, 2, 3, 6, 9, 12 months. The aggregate under test

is considered harmful if it expands 0.05% after 3 months or more than ($> 0.1\%$) after six months

Chemical Method :

The aggregates that has been crushed and passed through 300μ and retained on 150μ is taken. The potential reactivity of aggregates with alkalis in portland cement is indicated by the amount of reaction take place during 24 hrs at 80°C between sodium hydroxide and aggregate. The solution after 24 hrs is analysed for silica dissolution and reduction in alkalinity.

Control of AAR :

1. Selection of non-reactive aggregates
2. By the use of low alkali cement
3. By the use of corrective admixtures such as pozzolones
4. By controlling the void space in concrete
5. By controlling moisture condition and temperature

Chloride Attack:

chloride attack is one of the most important aspects for consideration when we deal with durability of concrete as it primarily causes corrosion. statistics have indicated that 40% failure of structure is due to corrosion of reinforcement

Due to the high alkalinity nature of concrete a passivating film is formed on the surface of steel reinforcement. The protective passivating film can be lost due to carbonation and chloride content also, in the presence of water and oxygen.

chloride enters the concrete from cement, water aggregates, admixture and it can also enter the concrete by diffusion from environment

Sl. No	Type of use of concrete	maximum total acid soluble chloride content (kg/m ³)
1.	concrete containing metal and steam cured at elevated temp of prestressed concrete	0.4
2	Rcc (or) Pcc containing Embedded metal	0.6
3.	concrete not contain embedded metal	3.0

prevention of corrosion lies in controlling the ingress of chlorides by thickness of cover to reinforcement and by making good quality of concrete with low $\frac{w}{c}$ to decrease the penetrability of chloride ions

< 0.2% by weight of cement = No risk of corrosion

0.2 - 0.4% " " " = low "

0.4 - 1.0% " " " = moderate "

> 1.0% " " " = high "

To assess the durability of concrete RCPIT test is mostly used. It calculates the ability of concrete to resist chloride ion penetration

Test Specimens:

Samples are prepared based on the purpose of test

for evaluation of materials core from test slabs or 100mm dia cylinders are casted

for evaluation of structures, 100mm dia cylinders cast & cured at field, dia is 95mm, 50 mm thick after curing.

Calculation of Results:

After setting up the apparatus, Read and Record the current at least for every 30 min. Plot current vs time.

Draw a smooth curve through data, and integrate the area

under the curve in order to obtain the columbs of charge passed during 6 hrs test period. The total charge passed is a measure of Electrical conductance of concrete during the period of test

sample calculation:

If the current is recorded at 30 min intervals the following formula can be used

$$Q = 900 (I_0 + 2I_{30} + 2I_{60} + \dots + 2I_{330} + 2I_{360})$$

Q = Charge passed (coulombs)

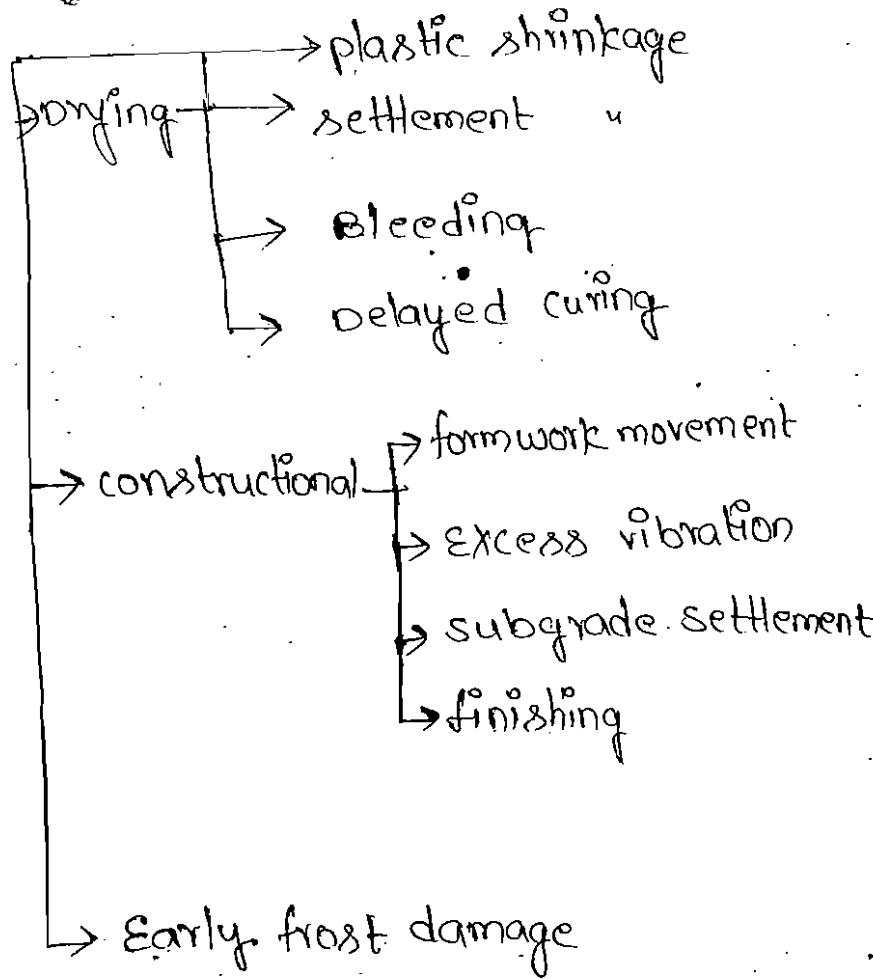
I_0 = Current immediately after voltage is applied

I_t = current at 't' min

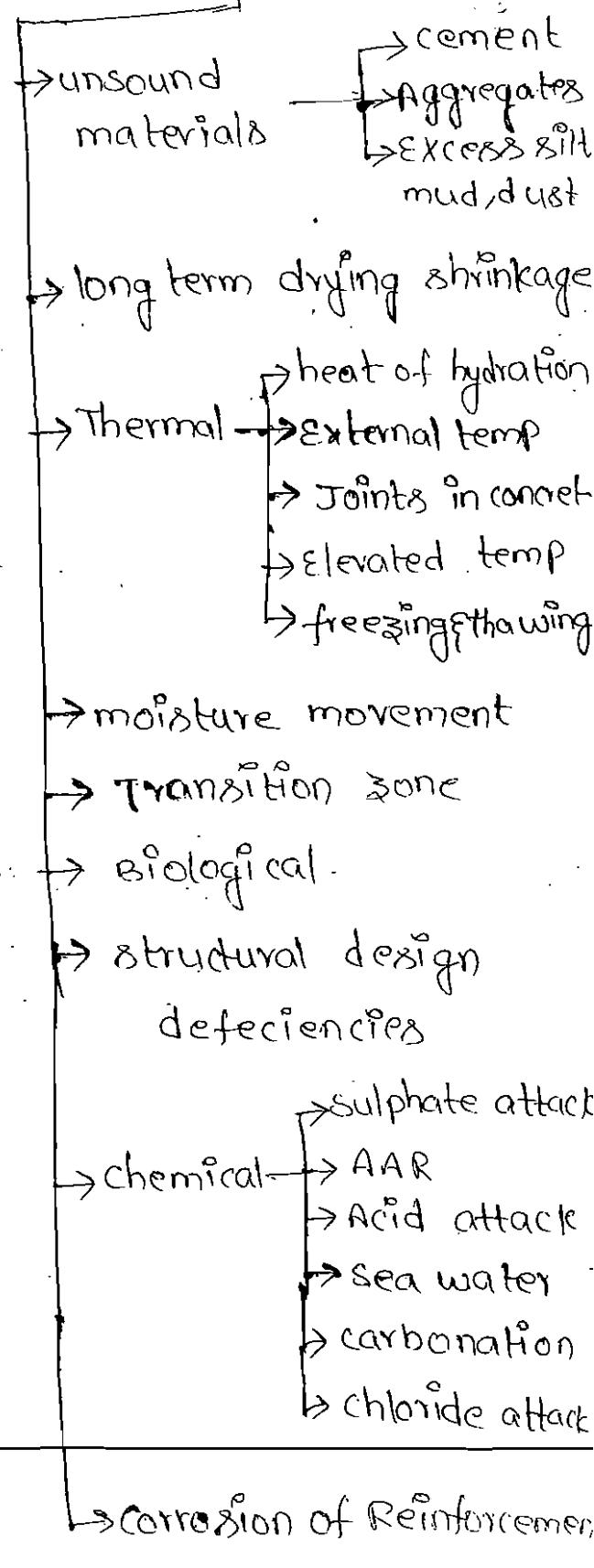
Cracks :

Cracks in concrete

Before hardening



After hardening



Cracking :- This is the most common visually detectable distress encountered in any building needing repair or retrofit. Cracks may be minor, as in the case of problems associated with shrinkage, or major as in structures subjected to overloading. Cracking by itself does not warrant repair. Many cracks are inevitable such as those due to shrinkage or around reinforcement in case of reinforced brickwork. These are classified as

Dormant

- do not increase in size once formed
- typically cracks caused by shrinkage, initial movement of supports, previous overload
- may or may not need repair.

Active :-

- change size under load
- continuing movement and overload
- difficult to repair.

Fine :- generally less than 1mm

Medium :- Between 1 and 2mm

Wide :- greater than 2mm

Surface cracks :- Local cracks on the top layer alone, mostly non-structural components. crack widths can be anywhere between 0.1 and 25mm. cracks smaller than 0.1 mm are not visible to the naked eye and, generally, do not affect the structural & functional utility of the building. it is necessary to ascertain whether a crack is active & dormant. Active cracks propagate and hence a repeated inspection of cracks is necessary to classify cracks as active or dormant. cracks usually occur due to environmental effects. Excessive restraint within concrete to thermal movements may cause these cracks. Proper location of movement joints can help avoid cracks resulting from restrained movement, overloading, vibration, unintended interaction with other structural members.

Spalling :- De-lamination of the surface of concrete is called spalling. it can occur due to internal stress or due to external loads. Concentrate eccentric external load can cause a highly stressed narrow compression zone, which encourages spalling. Additionally, corrosion of steel embedded in concrete can also cause spalling. Spalling may also occur due to freezing - thawing effect of entrapped water. A careful observation of the location of spalling will

will throw some light on the agents responsible for spalling. Joint mortar also can suffer from spalling especially if the mortar is weak or if the joint is too thick. Normally the mortar joint thickness should be less than 8mm.

Staining :- staining of concrete is caused by absorption of water, which contains minerals/salts and results in leaching & drainage over other components. It is aesthetically unpleasant. Efflorescence is a major cause of staining. Efflorescence is the process of deposition of water-soluble salts on the surface of masonry or concrete as the water carrying these salts evaporates.

Moisture Problem :- Moisture causes wetness and encourages moulds and fungi. It can wet insulation and cause reduction in the quality of the performance of concrete elements. Moisture caused due to condensation resulting from the vapour pressure difference is difficult to detect.

construction and design defects :-

- 1) use of incorrect wall thickness.
- 2) out of plumb of walls.
- 3) failure to connect inserting walls and columns.
- 4) lack of movements joints.
- 5) defective joints.
- 6) defective bond.
- 7) reflecting flashing.
- 8) plugged weep holes.
- 9) staining that defines drainage paths.
- 10) misalignment of joints.

Crack width & measurement:

According to IS 456 of 2000, If the surface width of the crack is less than 0.3 mm, it is not harmful and does not have any serious effect on durability of concrete.

In members cracking of tensile zone is harmful either because they are exposed to the effects of weather or moisture or in contact with soil. An upper limit of 0.2 mm is suggested for max width of crack.

FIP (International prestressing federation) recommend the max crack width at the main reinforcement should be 0.004 times the nominal cover.

The crack width is measured by using crack detection microscope, digital crack measuring gauge