# UNIT 2-STRENGTH AND DURABILITY OF CONCRETE

## 2 MARKS

**1. How can use prevent the effect of freezing and thawing in concrete?**

Concrete can be restricted from frost action, damage of the structure by the entrainment of air. This entrainment of air is distributed through the cement paste with spacing between bubbles of no more than about 0.4mm.

**2. Define an effective cover?(Nov/Dec 2018)**

The cover to reinforcement measured from centre of the main reinforcement up to the surface of concrete in tension is called "Effective cover"

**3. Distinguish between structural and non- structural cracks (April/May 2019) (April/May 2017)**

Non-structural Cracks: these cracks are caused by changes in the moisture content and thermal movement. They can occur anywhere in the foundation wall where there are openings in the wall.

Structural Cracks: Structural cracks are due to poor construction sites, swollen soil, poor soil bearing or overloading. These cracks are usually accompanied by other signs of foundation issues such as sticking doors and windows, slanted doors, sloping floors and cracks in porches

**4. Write any two tests for assessment of frost damage?(May/June 08)**

The frost damage can be assessed by several ways:

(i) Assessment of loss of weight of a sample of concrete subjected to a certain number of cycles of freezing and thawing is one of the methods.

(ii) Measuring the change in the ultrasonic pulse velocity or the damage inthe change inthe dynamic modulus of elasticity of specimen is anothermethod.

**5. How does a concrete structure get affected by heat?(Nov/Dec 2018)**

Heat may affect cone and as a result of

- ➢The removal of evaporable water
- ➢The removal of combined water
- ➢Alteration of cement past
- ➢Alteration of aggregate
- ➢Change of the bond between aggregate and paste

**6. How can you control cracks in a structure? (May/June 09)**

- ➢ Use of good coarse aggregates free from clay lumps
- ➢ Use of fine aggregate free from silt, mud & organic constituent.
- ➢ Use of sound cement.
- ➢ Provision of expansion & contraction joint.
- ➢ Provide less water-cement ratio.

**7. What is the role of cover in RC structures? (April/May 2018)**

The concrete cover must have a minimum thickness for three main reasons:

- To protect the steelreinforcement bars (rebars) from environmental effects to prevent their corrosion;
- To provide thermal insulation, which protects the reinforcement bars from fire, and;
- To give reinforcing bars sufficient embedding to enable them to be stressed without slipping.

**8. Define durable concrete?(Nov/Dec 2017)**

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, abrasion and other degradation processes while maintaining its desired engineering properties.

**9. Define the term quality assurance in concrete structures.(Nov/Dec 2017)**

Quality Assurance (QA) isa program covering activities necessary to provide qualityin the work to meet the project requirements. QA involvesestablishing project related policies, procedures, standards,training, guidelines, and system necessary to produce quality.

**10. What is carbonation of concrete (April/May 2017)**

**Carbonation** is the reaction of carbon dioxide in the environment with the calcium hydroxide in the **cement** paste. This reaction produces calcium carbonate and lowers the pH to around 9. ... In saturated **concrete** the moisture presents a barrier to the penetration of carbon dioxide and again **carbonation** will be slow.

**11. What are the factors affecting durability of concrete? (April/May 2018)**

- Cement Content.
- Aggregate Quality.
- Water Quality.
- Concrete Compaction.
- Curing Period.
- Permeability.
- Moisture.
- Temperature.



**12. State merits and application of sulphur infiltrated concrete (April/May 2017)**

The sulphur-infiltration can be employed in the precast industry. This method of achieving high strength can be used in the manufacture of pre-cast roofing elements, fencing posts. Sewer pipes, and railway sleepers, sulphur-infiltrated concrete should find considerable use in industrial situations. Where high corrosion resistant concrete is required. This method cannot be conveniently applied to cats-in place concrete.

**13. Define aggregate splitting?**

This phenomenon occurs most frequently when hard aggregates are used in concrete. The thermal stresses except close to corners are predominantly compressive near to the heated surface. This stress causes the aggregate to split in this direction and the fractures may propagate through the mortar matrix leading to deterioration.

**14. What the factor affecting chemical attack on concrete?**

- High porosity
- Improper choice of cement type for the conditions of exposure
- Inadequate curing prior to exposure
- Exposure to alternate cycles of wetting and drying

**15. Writethe methods of corrosion protection? (Nov/Dec2011)**

- Corrosion inhibitors
- corrosion resisting steels
- coatings for steel
- Cathode protection

**16. List out some coating for reinforcement to prevent corrosion?**

- Organic coating
- Epoxy coating
- Metallic coating
- Zinc coating

**17. Define corner reparation?**

This is a very common occurrence and appears to be due to a component of tensile stress causing splitting across a corner. In fire tests, corner separation occurs most often in beams and columns made of Quartz aggregate and only infrequently with light weight aggregates

**18. List any four causes of cracks? (Nov/Dec2007)**

- Use of unsound material
- Poor & bad workmanship
- Use of high water-cement ratio
- Freezing & thawing
- Thermal effects

**19. What are the types of cracks? (May/June 2012)**

- Class-1: Cracks leading to structural failure
- Class-2: Cracks causing corrosion
- Class-3: Cracks affecting function
- Class-4: Cracks affecting appearance

**20. Whatchanges occur, when hot rolled steel is heated to 500$^{o}$c?**

At temp of 500$^{o}$c-600$^{o}$c the yield stress is reduced to the order of the working stress and the elastic modulus is reduced by one-third. Bars heated to this temp virtually recover their normal temperature.

**21. List out the various types of spalling?**

(i) General or destructive spalling

(ii) Local spalling which is subdivided as

- aggregate splitting
- comer separations
- surface spalling
- Sloughing off

**22. List some faults in construction planning**?

- Overloading of members by construction loads
- Loading of partially constructed members
- Differential shrinkage between sections of construction
- Omission of designed movement joints

**23. Define corrosion?**

The gradual deterioration of concrete by chemically aggressive agent is called "corrosion"

**24. Give some examples for corrosion inhibitors? (Nov/Dec2007)**

i) Anodic inhibitors

ii) Cathode inhibitors

iii) Mixed inhibitors

iv) Dangerous & safe inhibitor

**25. Define corrosion inhibitor?**

Corrosion inhibitor is an admixture that is used in concrete to prevent the metal embedded in concrete from corroding.

**26. What are the operations in quality assurance of feedback system?**

- Auditing; Review line; Organization

**27. List the various components of quality control. (Apr/May2010)**

Five components of a quality (control) assurance system are:

Standards ;Production control; Compliance control; Task and responsibilities; Guarantees for users

**28. Relate permeability and durability.**

Measurement of permeation properties of concrete would result in the assessment of durability of concrete.

**29. What is the effect of external causes on durability of concrete**

The external causes may be due to weathering, occurrence of extreme temperature, abrasion, electrolytic action and attack by natural or industrial liquids and gases.

**30. What is the effect of internal causes on durability of concrete**

The internal causes include the alkali- aggregate reaction, volume change due to the differences in the thermal properties of aggregate and cement paste and above all the permeability of concrete.

**31. Define D- cracking.**

The fine closely spaced cracks parallel to the edge of the exposed concrete is filled with a dark deposit of calcium carbonate and are commonly called as D-cracks.

**32. What is known as abrasion and erosion in concrete?**

Abrasion refers to wearing away of the surface by friction.

Erosion refers to wearing away of the surface by fluids.

**33. What are cavitations in concrete?**

The cavitations refer to the damage due to non-linear flow of water at velocities more than 12 m/sec.

**34. List any four durability parameters?**

Resist weathering action, chemical attack, abrasion and other degradation processes

**35. Discuss the effect of temperature on concrete? /Mention any two effects due to temperature changes in structures?**

- The objectionable cracks may occur in concrete
- Occasionally large and harmful stress may develop
- Change of the bond bet aggregate and paste

**36. Write the need for emphasising cover thickness for marine structures? Or What is the effect of cover thickness in concrete?**

A sufficient thickness of concrete cover is thus required in order to slow down the carbonatation process towards the rebar.A thicker cover or a more compact concrete will also reduce the diffusion of $CO_2$ in the concrete, protecting it better from carbonatation and maintaining a higher pH for a longer time period, increasing so the rebar service life.

**37. List out the causes of cracks.**

- Cracks over openings in wall
- Growth of vegetation
- Settlement of foundation
- Overloading
- Effect of water or moisture
- Effect of change of temperature
- Vibration

**38. Define the term quality assurance in concrete structures.**

Quality Assurance (QA) isa program covering activities necessary to provide qualityin the work to meet the project requirements. QA involvesestablishing project related policies, procedures, standards,training, guidelines, and system necessary to produce quality.

39. **Tabulate the cover to be provided for various exposure conditions to concrete as per IS.**

Table: Nominal cover to all reinforcement including links to meet durability requirements

| Conditions of exposure | Nominal cover (mm) | | |
|---|---|---|---|
| Mild | 25 | 20 | 20 |
| Moderate | | 35 | 30 |
| Severe | | | 40 |
| Very severe | | | 50 |
| Most severe | | | |
| Abrasive | Nominal cover allowance for loss of cover due to abrasion. | | |
| Maximum free water-to-cement ratio | 0.65 | 0.60 | 0.55 |
| Minimum cement content (kg/m$^3$) | 275 | 300 | 325 |

Table: Nominal cover to all reinforcement including links to meet specified periods of fire resistance



## SIXTEEN MARKS

**1. List the functions of quality control during construction(or) How quality assurance plays an important role in construction industry. Explain the parameters affecting the quality of concrete construction(Nov/Dec 2018)(April/May 2017)**

- Quality Assurance (QA) isa program covering activities necessary to provide qualityin the work to meet the project requirements. QA involvesestablishing project related policies, procedures, standards,training, guidelines, and system necessary to produce quality.
- The design professional and constructor are responsiblefor developing an appropriate program for eachproject.
- QA provides protection against quality problemsthrough early warnings of trouble ahead. Such earlywarnings play an important role in the prevention of bothinternal and external problems".
- Qualityassurance is all planned and systematic actions necessary toprovide adequate confidence that a structure, system orcomponent will perform satisfactorily and conform withproject requirements.
- Obviously, quality can be achieved when preventable mistakes are avoided in the first instance. Serious measures must be taken to minimize the risk of managerial and communication problems; this is basic concept of quality assurance.

- Before quality assurance can be practice, an organization has to be constituted and maintain a quality management system in its day to day operation. A quality system contains, among other things, a set documented procedure for the different processes carried out by the organization.
- In short, quality assurance is oriented towards prevention of quality short coming. It also aims at minimizing the risk of making mistakes in the first place, therefore avoiding the necessity for rework, repair or reject.
- The purpose of quality assurance is there to provide assurance to a client that the standard of workmanship within the contractors premises of the highest level of quality and that all the products leaving the industry is above a certain minimum level of specification.
- Construction industry has been struggling with it implementation of quality assurance for many years. The cost could potentially be reduced reasonably if the industry were to hold onto the concept of quality assurance with the use of great success by the means other companies.

**2. Explain the different steps in the application of quality assurance? Or Explain the components of quality assurance for building(Nov/Dec 2018)**

The construction industry is unique and therefore the application of quality assurance requires to be implemented in the industry. Some of the major steps of this process are discussed below:

1. First of all, project managers in various companies have to form a team or groups who will be dedicated for quality assurance.The team has to report to the senior management of the company and keep all results in files.**(Team Building)**
2. Once the team is formed, the main responsibility of the team will be to define the tasks and assign them to respective persons. **(Define the task)**

3. The team then defines the plans for the quality assurance process. Mostly the list includes quality objectives, defining the tests and verificational activities, process evaluation, defining the individual responsibility of the team members, identifying training requirements, budgeting and funding for quality

control jobs, scheduling all activities, documenting and tracking etc. **(Definition of the process)**

4. Generating the test process, checklists and related activities to explain the way quality assurance will be performed is the next step.

**(Checking the performance)**

5. The team in simple sense has to perform according to the plans made to ensure the next steps of quality assurance process. Any non conformance with the standards or requirement are notified and reported to the appropriate department. The problems are then corrected and again sent for testing to the quality control team. This way, testing and correcting goes on, till the project is proven to be in conformance with the standard.**(Testing and correcting)**
6. The next step is to identify the training requirement for the team members to perform the evaluation processes as specified in the quality control plan. **(Identify the training requirements)**
7. The performance of the team should be monitored regularly by the project manager against the plans, schedule and budget. **(Monitoring)**
8. The team activities and results are reviewed by the senior management of the company and their stakeholders on regular intervals. Any unsolved issue for the team procedure is taken care of by the senior management at this point of time. **(Review of the structure)**

9.The team collects review information from various sources. Again, suggestions for improvement at any step of quality assurance process is accepted and implemented in the next session, if it satisfies the various limitations. **(Implementation of suggestions)**

10. The team refines the total process to give it a defined structure with the team´s descriptions, templates and checklists.

## 3. Explain the factors Influencing Strength of Concrete? (April/May 2019)(Nov/Dec 2017)

The factors affecting the strength of concrete can be broadly grouped into the following two categories.

**(A) Depending on the testing methods:**

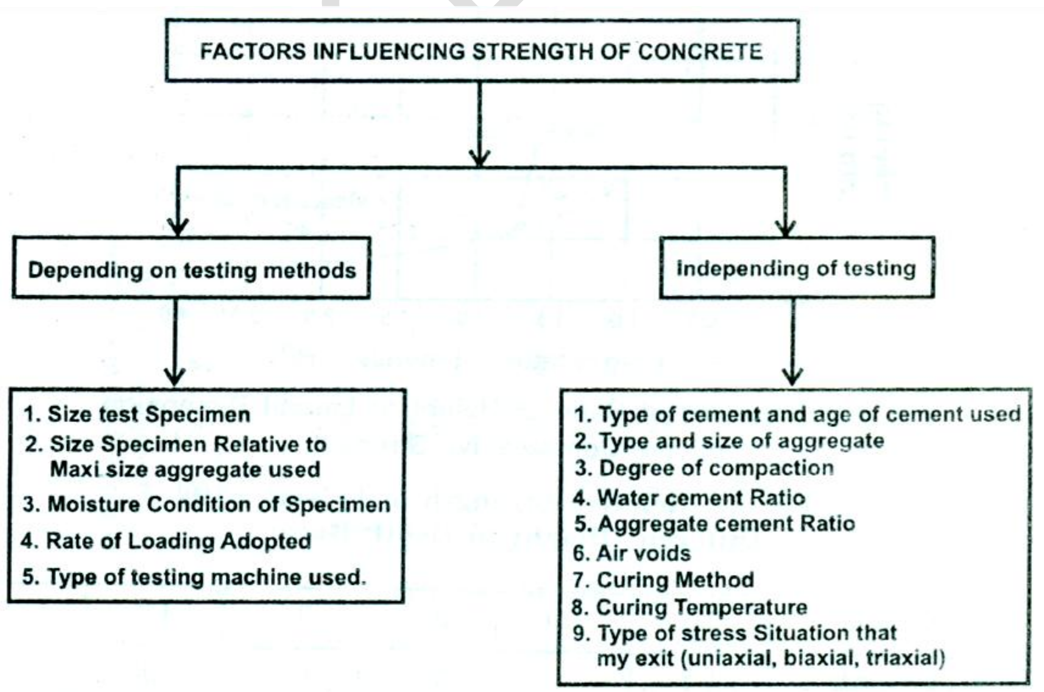
They are:

1. Size of test specimen
2. Size of specimen relative to maximum size of aggregate utilized.
3. Moisture condition of specimen.
4: Rate of loading adopted.
5. Type of testing machine used.

**(B)Those independent of testing:**

1. Type of cement and age of cement.
2. Type and size of aggregate.
3. Degree of compaction.
4. Water cement ratio.
5. Aggregate cement ratio.
6. Air voids.
7. Curing method.
8. Curing temperature
9. Type of stress solution that may exist. (uniaxial, bi-axial and triaxial).






**Factors Influencing strength of concrete**

**(A) Depending on testing methods:**

**(i) Size of Test specimen:**

A cube of concrete is expected to have strength of 15 percent greater than a cylindrical specimen. If size of cube is decreased the compressive strength tends to increase and IS given in Table.

| Cube size (mm) | 100 | 150 | 200 | 300 |
|---|---|---|---|---|
| Relative strength to 150 mm cubes | 1.05 | 1.0 | 0.95 | 0.87 |

**Relative strength of concrete from cubes of different sizes**

**(ii) Size of Specimen Relative to Maximum Size of Aggregate:**

The test specimen, as regards the size and shape, is different in different countries. Generally 150 mm cubes are specified irrespective of size of aggregates.

However, for aggregate less than 25 mm in size 100 mm cube is allowed.

**(iii) Moisture Condition of Specimen:**

Strength of concrete depends upon moisture content at the time of testing.

The dry cubes may have drying shrinkage and bond failure leading to smaller strength. The moisture content in concrete provides lubrication effect and reduces strength. The specimen should be tested immediately after taking it out of curing time to give uniformity to results as compared to testing of samples which may have dried to different degrees.

Strength of dry sample = (1.1- 1.2)x strength of saturated sample.

**(iv) Rate of Loading:**

Strength of concrete increases with the rate of loading. Normally in a static loading test, rate is such that the test is completed in 2 to 3 minutes. Within this range, the effect is found to be negligible. At low rates of loading there is more time for creep to occur, so that the increase of strength with rate of loading provides evidence for the theory that failure occurs at limiting values of strain, rather than stress.

**IV) Type of Testing Machine:**

Considerable discrepancies have be-en found to occur between the results of compressive strength test made with different types of machines. It may be up to even 20 percent. It may be because of errors in centering the cubes, wear of the lower compression plate, friction in the spherical seating of the upper compression plate, and inaccurate calibration of the machine itself.

**(B) Independent of Testing:**

**(i) Type of cement and age of cement:**

With age the strength of cement reduces, since it will be set by absorption of moisture from the atmosphere.

.**Gain in Strength with Age:**

Concrete gains strength with age. Initially strength developed is more. However, the ratio of gain in strength diminishes with age. It is customary to assume the 28 days strength as full strength of concrete.

**(ii) Type and size of aggregate:**

The crushed stone and gravels give higher strength. The coarse aggregate to sand ratio is increased and although the overall mix may be leaner the mortar may be richer, and by virtue of reduction in water/cement ratio which may be permitted to increase, the strength of concrete.

A rounded spherical shaped aggregate when compacted contains less voidsthan an 'irregular and flaky aggregate of the same nominal size. Therefore, theformer given higher strength.

The larger aggregates give lower surface area fordevelopment of gel bonds leading to lower strength. High strength concrete gives lower strength as compared to lean concrete ifa big size aggregate is used.

**(iii) Degree of Compaction:**

Inadequate compaction leading to air void contents of 5 percent and of 10 percent result in a loss of strength of 30 percent and 55 percent respectively.

**(iv) Effect of Water/Cement Ratio:**

The aim is generally to use the lowest water/cement ratio which will give a concrete sufficiently plastic to place in position. A approximate relation of strength of concrete with water/cement ratio is given by

$$S = k\left(\frac{c}{w+c+a}\right)^2$$

where S = strength of concrete

w = volume of water

c = volume of cement

a = volume of air

For concrete which IS to be compacted by vibrator a lower water to cement ratio may be used.

**(v) Cement/Aggregate Ratio:**

Provided other factors are kept constant, cement-aggregate will greatly influence concrete strength. With an increase in cement to aggregate ratio the ultimate strength will increase to some extent.

**(vi) Air Voids:**

These are formed because of the evaporation of the water used in making Concrete and by entrained air. If the water used more than the optimum water required for maximum strength the concrete becomes permeable and susceptible to deterioration.

**(vii) Curing Method and Curing Temperature:**

The higher the temperature, the greater is the rate of hydration of concrete. 10 hour curing at temperatures of about 90°C, concrete may attain 70 percent of it 28 days strength.

**(viii) Type of Stress Situations that may exist:**

Concrete is tested for uniaxial compression with the line of action of load on a cube specimen at right angles to the axis of cube about which it is cast. However, in actual structure, the concrete at any point is in a complex stress condition and not in a uniaxial compression. Concrete under triaxial state offers more resistance and fails only after considerable deformations, which justifies uniaxial compression.

**(ix) Mixing Time:**

The strength of concrete increases with increase in time of mixing up to two minutes beyond which no significant improvement is observed.



## 4. Define durability of concrete? How much importance should be given for durability in design and construction (April/May 2019)

A durable concrete is the one that performs satisfactorily under anticipated exposure (working) conditions during its service of life span. The materials and mix proportions used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion. Even though concrete is a durable material requiring a little or no maintenance in normal environment, but when subjected to highly aggressive or hostile environments, it has been found to deteriorate resulting in premature failure of structures or reach a state requiring costly repairs. One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. The permeability of concrete depends upon micro and macro-cracks and voids developed during production and service.

Most of the durability problem in the concrete can be attributed to the volume change in the concrete. Volume change in concrete is caused by many factors. The entire hydration: process is nothing, but an internal volume change, the effect of heat of hydration, the pozzolanic action, the sulphate attack, the carbonation, the moisture movement, all types of shrinkages, the effect of chlorides, corrosion of steel reinforcement and host of other aspects come under the preview of volume change in concrete. The internal or external restraints to volume changein concrete results in the cracks. It is the crack that promotes permeability and thus it becomes a part of cyclic action, till such time that concrete deteriorates, degrades, disrupts and eventually fails. The durability aspects of the high performance concrete are discussed already.



## 5. Explain Permeability and the factors affecting the same.(Nov/Dec 2018)

Permeability is the ease with which liquids or gases can travel through concrete

The coefficient of permeability, K, of concrete (simply called as "permeability" in concrete technology) for steady-state flow of water through a sample of concrete is determined from Darcy's expression:

$$dq/dt = K\,(A \cdot \Delta h/L)$$

Where

dq/dt = rate of flow of water through the sample

A = cross-sectional area of the sample

$\Delta h$ = drop in hydraulic head through the sample

L = thickness of the sample

Permeability of concrete plays an important role in durability because it controls the rate of entry of moisture that may contain aggressive chemicals and the movement of water during heating or freezing. Higher the permeability lesser will be the durability.

**Factors affecting concrete permeability**

- For concrete containing dense aggregate, permeability of concrete is governed by permeability of the cement paste.Permeability of cement paste primarily depends upon its porosity.
- The paste permeability is very low at and below a paste porosity of 30%. A small increase in porosity above around 30% causes a steep increase in the permeability.
- From the above fact it is clear that decreasing porosity of paste up to a typical value of 30% is highly beneficial in decreasing the permeability. Causing any decrease in porosity below this typical value is not accompanied by a substantial decrease in the permeability.
- Since porosity of a cement paste depends on the w/c ratio and the age (due to their effect on gel/space ratio) of the cement paste, these factors affect the paste permeability and therefore the concrete permeability.
- For a given w/c ratio, the permeability decreases with age as the cement continues to hydrate and fills some of the original water space the reduction in permeability being faster at the lower w/c ratio.
- Besides porosity of the paste, segmentation of capillary pores is another major factor, which affects the permeability.
- For the same porosity of a paste, the permeability will be lesser in case of capillary pores being segmented disrupting the continuity of pores, as compared to the case of interconnected capillary pores.

**6. Explain the thermal properties of concrete? (April/May 2019)(Nov/Dec 2018)**

**Thermal properties:**

The thermal properties like coefficient of thermal expansion, specific heat, density and thermal conductivity of concrete are important for evaluation of the performance concrete over the period of time.

Thermal expansion is a physical phenomenon common to all materials. It is however, complicated in concrete due to the differential expansion of its components producing high internal stresses. Thermal expansion has a significant effect on all types of concrete structures.Concrete has a positive coefficient of thermal expansion and it depends on the compositions of mix and on the value of the coefficient of expansion of cement paste and aggregate and they have dissimilar thermal coefficients. The coefficient of thermal expansion of cement paste varies between about 11x 10-6and 20 x 10-6per °C and is higher than the coefficient of aggregate. An average value of coefficient thermal expansion of normal weight concrete varied from 7 x 10-6to 14 x 10-6per °C depending on the type of aggregates used.Thermal expansion properties are important to the fire performance of concrete structures in two ways:

(i)The expansion of individual and adjacent members can induce stresses capable of buckling reinforced members while at high temperatures.

(ii)Differences in thermal expansion potential of the cement paste and the aggregate may produce stresses in the concrete.

At sufficiently high temperatures these stresses can induce cracking within the paste and around aggregate margins. This cracking further accentuates the refractory effect of the damage surface layers, since air held in the crack voids is of lower thermal conductivity than the concrete.It can be appreciated that the response of concrete to fire attack is such that heat penetration is reduced by the production of low thermally conductive surface layers. A consequence of low conductivity at the surface is the creation of high temperature gradients between the exposed surface and the concrete interior. For ordinary concrete the value of coefficient of thermal expansion varies from 9 x 10-6per °C to 12 x 10-6per °C. The thermal expansion increases with increase in temperature. The thermal expansion of concrete is influenced by, aggregate type, cement content, water content and age of concrete.



**Thermal conductivity**

The thermal conductivity of concrete is one of the key parameters needed to predict temperature variation during hydration. This measures the ability of the material to conduct heat and is defined as the ratio of the flux of heat to temperature gradient. It is measured in joules per second per square meter of area of body when the temperature difference is 1°C per meter of thickness of the body. [3]The conductivity of concrete is determined by the conductivities of its constituents. The major factors influencing the conductivity are the moisture content of concrete, the type of aggregate, the mix proportions, the type of cement and the temperature of the concrete.The conductivity of concrete is highly affected by its moisture content, as water has a higher conductivity than air. Thoughthe effects a variation in the moisture content are not as large as those caused by the aggregate type for normal weight concrete, in light weight concrete the affects can be quite pronounced. The thermal conductivity varies with the density of concrete, with heavier aggregates resulting in higher thermal conductivity. The conductivity of concrete is known generally to decrease with increased temperature, through the loss of pore water and the dehydration of cement paste. A concrete surface exposed to sufficiently high temperature will undergo these changes and effectively produce an insulating layer of lower thermal conductivity, which acts as a refractory material and reduces the ingress of heat. The mineralogical character of the aggregate greatly affects the conductivity of concrete.Both light-weight and calcareous aggregate concrete possess low thermal conductivity (and hence low thermal diffusivity), which results in less temperature rise in light weight or calcareous aggregate concrete than in one with siliceous aggregate, after equal exposure to fire.



**7. Elaborately explain about the effect of temperature on concrete. (April/May 2018)**

Similar to other materials, cone expands with increase in temperature and contract with decrease in temperature. The range of variation in temperature varies from localities to localities, season to season and day to day.

- The objectionable cracks may occur in concrete due to contraction combined with the effect of shrinkage.
- Occasionally large and harmful stress may develop due to deformation because temperature changes.
- The coefficient of thermal expansion of contraction depends on the type and quantity of cement, aggregate, relative humidity and sizes of section.

**<u>Concrete at high temperature:</u>**

- In some industrial application such as aluminium plants and brick works the cone may be occasionally or frequently subjected to temperatures. These temperatures are likely to be applied linearly generally with and rather a long period.

- Similarly jet aircraft and vertical take aircraft may subject the payment to very high temperature.
- Heat may affect concrete and as a result of, the removal of evaporable water and the removal of combined water.
- Alteration of cement paste.
- Disruption (of beam) from disparity of expansion and resulting thermal stresses.
- Alteration of aggregate.
- Change of the bond bet aggregate and paste.
- Other effects on cone due to temperature.
- Cycles of temperature can have a progressive effect on the reduction of strength even longer curing did not improve the loss.
- Tensile strength of cone is more effect by heat than its com strength.
- During rapid rise and fall of temperature the response of cone is affected by the interaction of thermal expansion, drying thermal incompatibility and enhanced every at high temperature.
- If the heating is sufficiently rapid, high stresses can be included; hence failure and instability may result.



**Effects of steel at high temperature:**

- The influence of temperature on steel appears as a change in yield stress, ultimate strength and modules of elasticity.
- The changes depend on the type of steel and are greater in cold-weathered steel.
- The strength of hot-rolled steel bars are not reduced if the temperature does not reach to 300$^{o}$C. But at temperature of 500-600$^{o}$C the yield stress is reduced to the order of the working stress and the elastic modules is reduced by one-third.
- Bars heated to this temperature virtually recover their normal temperature.
- Bars heated to 800$^{o}$C have a lower residual strength after cooling to room temperature.
- Pre-stressing wire and stand starts to lose strength at 150$^{o}$C and may have only 50% of its room temperature strength when heated to about 400$^{o}$C.

**Behavior of fire:**

- Failure in a fire occurs either through the spread of fire from the compartment or through structural failure of a member or assembly of members.
- Structural failure of a member most frequently occurs when the temperature of the steel reduces the yield stress to the working stress.

The length of time of this fire occurs depend upon the severity of fire, the thermal conductivity of the protecting concrete and weather spalling of the protection covers.

**8. Explain the different types of Cracking? State their preventive measures.(Nov/Dec 2018)(April/May 2018)**

**Cracking:**

All concrete structures will crack to some extent. Concrete cracks due to tensile stress induced by shrinkage or stresses occurring during setting or use. In many large structures joints or concealed saw-cuts are placed in the concrete as it sets to make the inevitable cracks occur where they can be managed and out of sight. Water tanks and highways are examples of structures requiring crack control.

**Shrinkagecracking**

A crack that occurs only in unhardened concrete. It is often seen as relatively straight lines running parallel with the span of the floor. Shrinkage cracks occur when concrete members undergo restrained volumetric changes (shrinkage) as a result of drying, autogenous shrinkage or thermal effects. The number and width of shrinkage cracks that develop are influenced by the amount of shrinkage that occurs, the amount of restraint present and the amount and spacing of reinforcement provided.These are minor indications and have no real structural impact on the concrete member.

**Preventive Measures**

1. Moisten the sub grade and formworks.
2. Erect temporary roof to protect green concrete from hot sun.
3. Minimize evaporation by covering with burlap, fog spray and curing components.

**Plastic Shrinkage:**

Plastic-shrinkage cracks are immediately apparent, visible within 0 to 2 days of placement, while drying-shrinkage cracks develop over time. It is seen as diagonal lines in the top of a slab. It is often caused by rapid drying of the surface due to delays in applying the curing membrane

**Preventive Measures:**

1. Use air entraining admixtures or water reducing admixtures.
2. Revibration, if possible is an effective step.
3. Restricting the rate of evaporation of water.

**Autogeneous Shrinkage:**

Autogenous shrinkage also occurs when the concrete is quite young and results from the volume reduction resulting from the chemical reaction of the Portland cement. Magnitude of this is small and is not much of significance.

**Tension cracking**

Only occurs in reinforced concrete and is caused by elongation of the reinforcement in tension zones. It is sometimes seen around columns in flat slabs and on beam soffits near the middle of a span. Concrete members may be put into tension by applied loads. This is most common in concrete beams where a transversely applied load will put one surface into compression and the opposite surface into tension due to induced bending. The portion of the beam that is in tension may crack. The size and length of cracks is dependent on the magnitude of the bending moment and the design of the reinforcing in the beam at the point under consideration.

**Preventive Measures:**

1. Reinforced concrete beams are designed to crack in tension rather than in compression.
2. This is achieved by providing reinforcing steel which yields before failure of the concrete in compression occurs and allowing remediation, repair, or if necessary, evacuation of an unsafe area.

**Rust cracking:**

The most common and most serious cause of structural cracking is caused by inadequate reinforcement cover. It gradually develops at varying rates over time depending upon the degree of protection offered by the concrete cover.

**Preventive Measures:**

1. Providing adequate cover thickness to steel reinforcement.

2. Maintain the cement content for concrete for different exposure condition.
3. Stipulating the w/c ratio requirement for different condition of exposure.

**Thermally-induced cracking:**

This type of cracking results from stresses produced by temperature changes. Due to thermal movement changes in shape and volume of concrete causes cracks on the concrete structure.

**Preventive Measures:**

1. Use of pozzolana
2. Use of low heat cement
3. Provide joints to relieve the restrains in the structure.
4. Providing suitable insulation cover.

**Settlement cracking:**

Caused by local restraining of unhardened concrete around reinforcement or some other obstruction.

**Preventive Measures:**

1. Providing adequate drainage system.
2. Avoiding plantation of fast growing trees in the immediate vicinity of the building.

**Structural cracking:**

As the differential movement increases concrete members can be expected to be subjected to an overstressed condition. Ultimately, the members will crack or spall.

**Preventive Measures:**

1. Appropriate structural and geotechnical engineering manuals should be consulted for guidance.
3. Providing adequate drainage system.
4. Avoiding plantation of fast growing trees in the immediate vicinity of the building.

Wall may crack due to crushing of sympathy cracking due to the movementsof the adjoining wall like building out etc. or distress cracking like separation ofmasonry sections due to transfer of bending tensile stresses while adjusting theload transfer mechanism.

Also atmospheric agencies like direct sun, rain, alternate wetting and dryingand varying thermal properties of brick and mortar resulting in loosening of plasterand weakening of the most or joints and help causing cracks.

**(i) Cracks over openings in wall:** Appearance of crack indicates adjustment in theload transfer system. Opening causing considerable stresses which try to transferthe stresses by releasing the energy in the cracks or settlement.

**(ii) Growth of vegetation**: Growth of vegetation is a common phenomenon not onlyin old buildings, but may be observed in new buildings as well. Growth ofvegetation takes place on the masonry, plaster and at masonry joints when itremains in damp condition and seed are either dropped by birds or carried bywind. It grows up in favorable condition and nests roots in the masonry. They arelocated normally along the walls near the bath rooms, washing places, parapetsand overhead water tanks. These trees, through insertion of their roots, exerttremendous pressure on the brick work splitting it, showing signs of cracks.

**(iii) Settlement of foundation:** When movement of a part of masonry occurs inrelation to the other, equality of the load distribution system in the masonry wallis distributed resulting imbalance in internal stresses and develops into cracks. Ifthe settlement of the building is uniform, crack may not appear. butsuch casesare very rare. Settlement of foundation is related to the sufohouring capacity ofthe soil below. Hence, the possibility of differential settlement invariably causescracks. Cracks occur in walls due to swelling of soil below the foundation (blackcotton soil or like).

Cracks occur due to foundation laid on shrinkable day sub soil or on modeup soil.

**(iv) Overloading:** Overloading of the ground on which the foundation rests will causevarious defects and cause cracks. The reason for overloading may be of externalorigin wind of snow load or may be internal due to change of occupancy, dumpingof heavy materials etc.

Overloading of the wall also may cause crack. This may be due to change ofoccupancy, dumping of heavy materials on the upper floors or addition of floors.

**(v) Effect of water or moisture:** Water or moisture make the structure cause crack.

The example of such phenomenon is moisture entering KC.C. members resultingin corrosion 'of steel and water containing sulphate attacking Portland cement. Inboth the cases, increase in volume produces pressure on the embedded materialsand cracks occur.

**(vi) Effect of change of temperature:** Change of temperature occurs due to changeof season and due to sudden fire. Due to different co-efficient of thermal expansionof different material used, expansion of contraction occurs differently and cracksappear. Thus the expansion of 1lat roof more commonly causes cracking in thebrick work immediately below the roof structure itself.

**(vii) Vibration:** Vibration from machines, traffic, driving etc. causes cracks in buildingin the neighborhood.

9. **Describe about the design deficiency for which causes distress in RCC structure.(April/May 2017)**

These types of design errors are discussed below:

**(1) Inadequate structural design**

Due to inadequate structural design the concrete is exposed to greater stress than it can handle or strain in concrete increases more than its strain capacity and fails.

**The symptoms** of such kind of failures due to inadequate structural design shows either spalling of concrete or cracking of concrete. Excessively high compressive stress due to inadequate structural design results in spalling of concrete. Also, high torsion or shear stresses results in spalling or cracking of concrete. High tensile stresses also results in cracking of concrete.

To identify the inadequate design as cause of the structural damage, the structure shall be inspected and locations of the damage should be compared to the types of stresses that should be present in the concrete. For rehabilitation projects, thorough petrographic analysis and strength testing of concrete from elements to be reused will be necessary.

**Prevention:** Inadequate structural design can be prevented by thorough and careful review of all design calculations. Any rehabilitation method that makes use of existing concrete structural members must be carefully reviewed.

**(2) Poor design details:**

Poor design details can cause localised concentration of high stresses in structural members even if the design is adequate to meet the requirements. These high stresses may lead to cracking of concrete that allows water or chemicals to pass through the concrete. Thus poor design detail may lead to seepage through the structural members.

Poor design detail may not lead to structural failure, but it can become the cause of deterioration of concrete. These problems can be prevented by a thorough and careful review of plans and specifications for the construction work.

Types of poor design detailing and their possible effects on structures are discussed below:

**(a) Abrupt changes in section:**

Abrupt changes in section may cause stress concentrations that may result in cracking. Typical examples would include the use of relatively thin sections rigidly tied into massive sections or patches and replacement concrete that are not uniform in plan dimensions.

**(b) Insufficient reinforcement at corners and openings:**

Corners and openings also tend to cause stress concentrations that may cause cracking. In this case, the best prevention is to provide additional reinforcement in areas where stress concentrations are expected to occur.

**(c) Inadequate provision for deflection:**

Deflections in excess of those anticipated may result in loading of members or sections beyond the capacities for which they were designed. Typically, these loadings will be induced in walls or partitions, resulting in cracking.

**(d) Inadequate provision for drainage:**

Poor attention to the details of draining a structure may result in the ponding of water. This ponding may result in leakage or saturation of concrete. Leakage may result in damage to the interior of the structure or in staining and encrustations on the structure. Saturation may result in severely damaged concrete if the structure is in an area that is subjected to freezing and thawing.

**(e) Insufficient travel in expansion joints:**

Inadequately designed expansion joints may result in spalling of concrete adjacent to the joints. The full range of possible temperature differentials that a concrete may be expected to experience should be taken into account in the specification for expansion joints. There is no single expansion joint that will work for all cases of temperature differential.

**(f) Incompatibility of materials:**

The use of materials with different properties (modulus of elasticity or coefficient of thermal expansion) adjacent to one another may result in cracking or spalling as the structure is loaded or as it is subjected to daily or annual temperature variations.

**g) Neglect of creep effect:**

Neglect of creep may have similar effects as described for inadequate provision for deflections. Additionally, neglect of creep in prestressed concrete members may lead to excessive prestress loss that in turn results in cracking as loads are applied.

**(h) Rigid joints between precast units:**

Designs utilizing precast elements must provide for movement between adjacent precast elements or between the precast elements and the supporting frame. Failure to provide for this movement can result in cracking or spalling.

**(i) Unanticipated shear stresses in piers, columns, or abutments:**

If, through lack of maintenance, expansion bearing assembles are allowed to become frozen, horizontal loading may be transferred to the concrete elements supporting the bearings. The result will be cracking in the concrete, usually compounded by other problems which will be caused by the entry of water into the concrete.

**(j) Inadequate joint spacing in slabs:**

This is one of the most frequent causes of cracking of slabs-on-grade.



**10. Explain the possible construction deficiency which causes distress in RCC structure.(April/May 2017)**

Inflicted causes are problems created by human error. For example:

**(i) Low concrete strength:**

If too much water is added at the batch plant or on site to improve workability, the strength of concrete will suffer;

**(ii) Inadequate concrete cover:**

Sometimes reinforcement steel may not be secured properly. It may move during placement of the concrete, or the forms may move, causing the steel to lean against the form with only a thin layer of cement paste covering it;

**(iii) Poor construction techniques:**

Lack of supervision on any given day can lead to something small being overlooked or something major not being noticed until it's too late. As mentioned previously, untrained and/or unsupervised personnel can create a major headache. Education in industry best practice is vital to successful projects. Often, the people being trained are not the ones completing the task. Sometimes something as simple as where to place the welded wire mesh (WWM) in a slab-on-ground can be overlooked; and

**(iv) Improper alignment of formwork:**

Improper alignment of the formwork will lead to discontinuities on the surface of the concrete.

**(v) Improper curing:**

Curing is probably the most abused aspect of the concrete it will not develop the characteristics that are expected and that are necessary to provide durability

**(vi) Specifications**:

Unclear specifications can lead to mistakes in the field. Sometimes old habits are hard to break; and if a change is not clearly defined.

**(vii) Improper location of reinforcing steel:**

In many cases, the mesh ends up on the bottom of the slab which will subsequently crack because the steel is not in the proper location. The second type of problem is the durability. As the concrete cover over the steel reduced, it is much easier for corrosion to begin.

**(viii) Premature removal of shores or reshores:**

If shores are removed too soon, the concrete affected may become overstressed and cracked.

**(ix) Settling of concrete:**

If highly fluid concrete are used the heavier components will settle under the influence of gravity.

**(x) Vibration of freshly placed concrete:**

Most construction sites are subjected to vibration from various sources, such as blasting, pile driving, and from the operation of construction equipment. Freshly placed concrete is vulnerable to weakening of its properties if subjected to forces which disrupt the concrete matrix during setting.

**11. Explain how materials, w/c ratio, reinforcement steel, formwork, curing, vibration and compaction influence the quality control of the structure (April/May 2017)**

**(1) Adding water to concrete:**

Water is usually added to concrete in one or both of the following circumstances:

First, water is added to the concrete in a delivery truck to increase slump and decrease pouring or placement effort. This will lead to concrete with lowered strength and reduced durability. As the water/cement ratio of the concrete increases, the strength and durability will decrease.

In the second case, water is commonly added during finishing of structural member. This leads to scaling, crazing, and dusting of the concrete.

**(2) Improper alignment of formwork:**

Improper alignment of the formwork will lead to discontinuities on the surface of the concrete. While these discontinuities are unsightly in all circumstances, their occurrence may be more critical in areas that are subjected to high velocity flow of water, where cavitation-erosion may be induced, or in lock chambers where the "rubbing" surfaces must be straight.

**(3)Improper consolidation or compaction of concrete:**

Improper compaction of concrete may result in a variety of defects, the most common being bugholes, honeycombing, and cold joints.**Bugholes** are formed when small pockets of air or water are trapped against the forms. A change in the mixture to make it less "sticky" or the use of small vibrators worked near the form has been used to help eliminate bugholes.

**Honeycombing** can be reduced by inserting the vibrator more frequently, inserting the vibrator as close as possible to the form face without touching the form, and slower withdrawal of the vibrator. Obviously, any or all of these defects make it much easier for any damage-causing mechanism to initiate deterioration of the concrete.Frequently, a fear of overconsolidation is used to justify a lack of effort in consolidating concrete.

**Over-consolidation** is usually defined as a situation in which the consolidation effort causes all of the coarse aggregate to settle to the bottom while the paste rises to the surface. If this situation occurs, it is reasonable to conclude that there is a problem of a poorly proportioned concrete rather than too much consolidation.

**(4) <u>Improper curing:</u>**

Curing is probably the most abused aspect of the concrete construction process. Unless concrete is given adequate time to cure at a proper humidity and temperature, it will not develop the characteristics that are expected and that are necessary to provide durability. Symptoms of improperly cured concrete can include various types of cracking and surface disintegration.

In extreme cases where poor curing leads to failure to achieve anticipated concrete strengths, structural cracking may occur.

**(5) <u>Improper location of reinforcing steel:</u>**

This section refers to reinforcing steel that is improperly located or is not adequately secured in the proper location.

Either of these faults may lead to two general types of problems. First, the steel may not function structurally as intended, resulting in structural cracking or failure. A particularly prevalent example is the placement of welded wire mesh in floor slabs. In many cases, the mesh ends up on the bottom of the slab which will subsequently crack because the steel is not in the proper location. The second type of problem stemming from improperly located or tied reinforcing steel is one of durability. The tendency seems to be for the steel to end up near the surface of the concrete. As the concrete cover over the steel is reduced, it is much easier for corrosion to begin.

**(6) <u>Movement of formwork:</u>**

Movement of formwork during the period while the concrete is going from a fluid to a rigid material may induce cracking and separation within the concrete. A crack open to the surface will allow access of water to the interior of the concrete. An internal void may give rise to freezing or corrosion problems if the void becomes saturated.

**(7) <u>Premature removal of shores or reshores:</u>**

If shores or reshores are removed too soon, the concrete affected may become overstressed and cracked. In extreme cases there may be major failures.

**(8) Settling of the concrete:**

During the period between placing and initial setting of the concrete, the heavier components of the concrete will settle under the influence of gravity. This situation may be aggravated by the use of highly fluid concretes. If any restraint tends to prevent this settling, cracking or separations may result. These cracks or separations may also develop problems of corrosion or freezing if saturated.

**(9) Settling of the subgrade:**

If there is any settling of the subgrade during the period after the concrete begins to become rigid but before it gains enough strength to support its own weight, cracking may also occur.

**(10) Vibration of freshly placed concrete:**

Most construction sites are subjected to vibration from various sources, such as blasting, pile driving, and from the operation of construction equipment. Freshly placed concrete is vulnerable to weakening of its properties if subjected to forces which disrupt the concrete matrix during setting.

**(11) Improper finishing of flat concrete surface:**

The most common improper finishing procedures which are detrimental to the durability of flat concrete surface are discussed below:

**(i) Adding water to the surface:**

Evidence that water is being added to the surface is the presence of a large paint brush, along with other finishing tools. The brush is dipped in water and water is "slung" onto the surface being finished.

**(ii) Timing of finishing:**

Final finishing operations must be done after the concrete has taken its initial set and bleeding has stopped. The waiting period depends on the amounts of water, cement, and admixtures in the mixture but primarily on the temperature of the concrete surface. On a partially shaded slab, the part in the sun will usually be ready to finish before the part in the shade.

**(iii) Adding cement to the surface:**

This practice is often done to dry up bleed water to allow finishing to proceed and will result in a thin cement-rich coating which will craze or flake off easily.

**(iv) Use of tamper:**

A tamper or “jitterbug” is unnecessarily used on many jobs. This tool forces the coarse aggregate away from the surface and can make finishing easier. This practice, however, creates a cement-rich mortar surface layer which can scale or craze. A jitterbug should not be allowed with a well designed mixture. If a harsh mixture must be finished, the judicious use of a jitterbug could be useful.

**(v) Jointing:**

The most frequent cause of cracking in flatwork is the incorrect spacing and location of joints.

**12. With chemical equations, explain in detail about the mechanism of corrosion.(April/May 2019) (Nov/Dec 2017)**

Corrosion of steel in concrete is an electrochemical process. The electrochemical potentials, to form the corrosion cells, may be generated in two ways:

(i) Concentration cells may be formed due to differences in concentration of dissolved ions in the vicinity of steel, such as, chlorides and oxygen.

(ii) Composition cells may be formed when two dissimilar metals are embedded in concrete, such as steel rebars and aluminum conduit pipes, or when significant variations exist in surface characteristics of the steel.

As a result, one of the two metals (or some part of the metal when only one metal is present ) becomes anodic and the other cathodic. The fundamental chemical changes occurring at the anodic and cathodic areas are as follows:

At anode surface $Fe$ □□ $2e^- + Fe^{2+}$

(metallic iron)

At cathode surface $1/2\ O_2 + H_2O + 2e^-$ □□ $2(OH)^-$

(air) (water)

At anode $Fe^{++} + 2(OH)^-$ □□ $FeO.(H_2O)_x$ (rust)

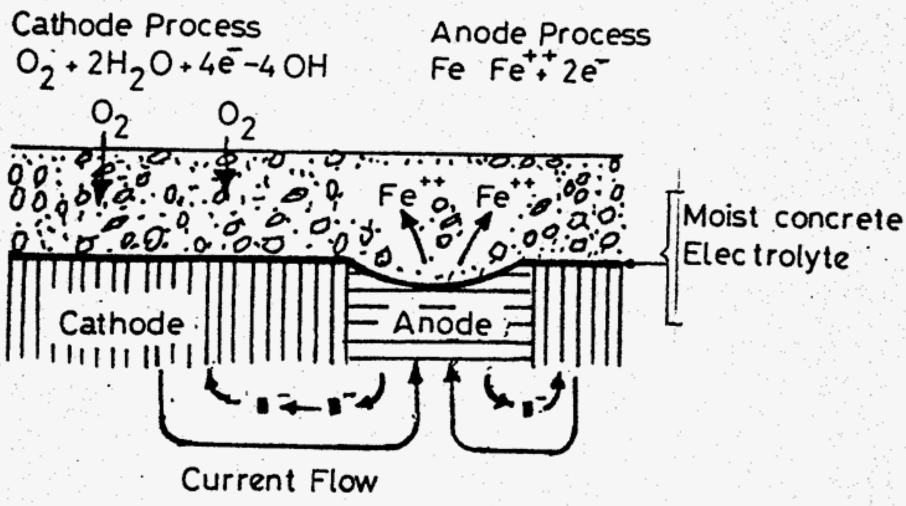
The transformation of metallic iron to rust is accompanied by an increase in volume, which depending on the state of oxidation, may be as large as 600 % of the original metal. This volume increase is believed to be the principal cause of concrete expansion and cracking. It should be noted that the anodic reaction involving ionization of metallic iron will not progress far unless the electron flow to the cathode is maintained by consumption of the electrons at the cathode;

The anode process cannot occur until the protective or the passive iron oxide film is either removed in an acidic environment (e.g., carbonation of concrete) or made permeable by the action of Cl- ions. The cathode process can not occur until a sufficient supply of oxygen and water is available at the steel surface. The electrical resistivity of concrete is also reduced in the presence of moisture and salts.

**Carbonation** The Carbon-di-oxide gas present in the atmosphere combines with hydrated concrete (alkaline hydroxides) and partly neutralize the alkaline nature of concrete. This process is known as carbonation. Carbonation brings down the pH value of concrete from above 12-13 to less than 9. When depth of carbonation increases and becomes equal or more than the depth of cover of reinforcement, it breaks down passive film surrounding steel and make steel embedded in concrete more active.

**Chloride attack** Free chloride ions present in concrete, surrounding reinforcement, react with alkaline solution at anode to form hydrochloric acid which destroys the passive protective layer on the reinforcement steel. The surface of steel then becomes activated locally to form the anode, with the passive surface forming the cathode, setting the electrolytic process.

Further, when large amounts of chloride are present, concrete tends to hold more moisture, which also increases the risk of steel corrosion by lowering the electrical resistivity of concrete. Once the passivity of the embedded steel is destroyed, it is the electrical resistivity and the availability of oxygen that control the rate of corrosion. In fact, significant corrosion is not observed as long as the electrical resistivity of concrete is above 50 to 70 x 103 □□cm.




: ELECTROCHEMICAL PROCESS OF STEEL CORROSION

The **parameters which influence** the corrosion process are:

- (i) The cover thickness
- (ii) The quality of concrete in the cover region
- (iii) Environmental conditions
- (iv) pH value in concrete
- (v) Chloride level in concrete
- (vi) Presence of cracks
- (vii) Type of steel

**Prevention of metal corrosion:**

- (i) Use of concrete with low permeability
- (ii) Use of properly proportioned concrete having a low w/c
- (iii) Use of low concrete slump as practical
- (iv) Good workmanship in placing the concrete
- (v) Curing concrete properly
- (vi) Adequate concrete cover to be provided
- (vii) Limiting chlorides in the concrete mixture.

(viii) More attention to the protruding items such as bolts or other anchors.

**Corrosion Protection Methods**

(a) Coating to reinforcement

(b) Galvanised reinforcement

(c) Improving metallurgically by addition of certain elements

(d) Using stainless steel

(e) Using non- ferrous reinforcement

(f) Using corrosion inhibitors

(g) Coating to concrete

(h) Cathodic protection

(i) Electrochemical chloride removal

(j) Improving the cover concrete

**(a) Coating to reinforcement**

The objective of the coating to steel rebar is to provide a sufficiently durable barrier to aggressive materials such as chlorides. Initially, the bar is shot based to remove mill –scale.

This ensures an adequate bond between the epoxy and the steel. Hence, epoxy powder particles are deposited evenly on the surface of the bar. Shortly after spraying, the epoxy starts to use and hardens sufficiently for the bars to be handled. The coating thickness typically varies from 130 micron to 300 micron.

**(b) Galvanised Reinforcement:**

This consist of standard black bar hot dipped in molten zinc. This process forms a coating which is metallurgically bonded to the surface of the present metal. The surface of the zinc reacts with calcium hydroxide in the concrete to form a passive layer preventing corrosion.

**(c) Improving metallurgically by addition of certain elements**

The bars can be improved of its corrosion resistance by adding certain elements such as chromium and copper during the formation process itself.

**(d) Stainless Steel Reinforcement:**

Stainless steel contains 12% of chromium. On contact with air the chromium forms a thin oxide layer on the surface of the steel. This is passive and resists corrosion.

**(e) Non-Ferrous Reinforcement:**

A range of an made fibres used, the most common being glass and carbon. The fibres are used either in the form of ropes or combined with suitable resin to form rods.

**(f) Corrosion Inhibitors:**

Certain admixtures can be made to inhibit corrosion of the reinforcement in the presence of chlorides.The addition of calcium nitrate extends the time of corrosion initiation.

(i) Total corrosion of samples with calcium nitrate is substantially less.

(ii) The corrosion rate, once corrosion is initiated is less with calcium nitrate.

**(g) Concrete coatings:**

A concrete surface coating of silane –siloxane type was evaluated for its corrosion performance. By several test conducted and the results show the chloride penetration depth was minimized in coated specimen compared with uncoated specimen.

**(h) Cathodic Protection:**

This is technique by which the electrical potential of the steel is increased to a level at which corrosion cannot take place. It is widely used for both steel and concrete offshore structures. While on land, it has been used for the protection of pipelines and similar structures. Two different methods are employed, an impressed current and the use of sacrificial anodes. In the first, the structure is connected to the negative terminal of the power source, ideally using an anode, which does not corrode. In the second the reinforcement is connected to anodes with a more negative corrosion potential than steel, such as zinc or aluminium. In both the cases electrical continuity of the reinforcement is required. This principle of cathodicpotential have been used to remove chlorides from contaminated concrete.

**(i) Electrochemical Chloride Removal:**

This is another emerging area with lot of potentialities. This technique needs only a temporary installation lating few days. 20 to 50% of the chloride present in concrete can be removed. An electric current in the range of 1 to 5 $A/m^2$ is needed.

**(j)Improving the concrete:**

Codes and standards aim to achieve good durability of reinforced and prestressed structures in aggressive environment by specifying :

(i) High cement content
(ii) Low water / cement ratio
(iii) Suitable minimum thickness of cover to the reinforcement
(iv) Careful curing.

## 13. Explain the importance of Concrete Cover in RCC structure. (April/May 2017)

**Concrete cover**, in reinforced concrete, is the least distance between the surface of embedded reinforcement and the outer surface of the concrete. The concrete cover depth can be measured with a cover meter.

The concrete cover must have a minimum thickness for three main reasons:

- to protect the steelreinforcement bars (rebars) from environmental effects to prevent their corrosion;
- to provide thermal insulation, which protects the reinforcement bars from fire, and;
- to give reinforcing bars sufficient embedding to enable them to be stressed without slipping.

A thicker cover or a more compact concrete will also reduce the diffusion of $CO_2$ in the concrete, protecting it better from carbonatation and maintaining a higher pH for a longer time period, increasing so the rebar service life.

**1. Nominal Cover against Corrosion:**

The actual cover should never be less than the nominal cover minus 5 mm.

The nominal cover should protect steel against corrosion and fire. The cover to amain bar should not be less than the bar Size or in the case of pairs or bundlesthe size of a single bar of the same cross-sectional area.The cover depends on the exposure conditions given in Table in the code.These are as follows.

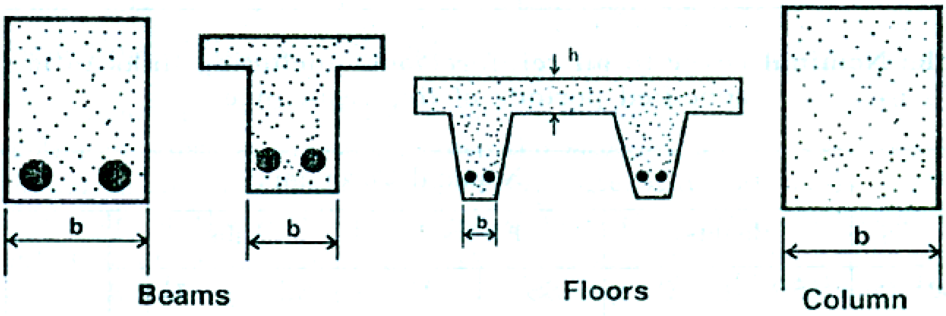
**Mild:**

Concrete is protected against weather

**Moderate:**

Concrete is sheltered from severe rain
Concrete under non-aggressive water
concretein non-aggressive soil
Limiting values for nominal cover arc given below.

Limiting values for nominal cover are given below.




| Fire resistance (hour) | Min. Beam b | Rib b | Min. floor Thickness h | Column width Fully exposed b | Min. wall Thickness |
|---|---|---|---|---|---|
| 1.0 | 200 | 125 | 95 | 200 | 120 |
| 1.5 | 200 | 125 | 110 | 250 | 140 |
| 2.0 | 200 | 125 | 125 | 300 | 160 |

**Fig. minimum dimensions for fire resistance**

## 2. Cover as Fire Protection:

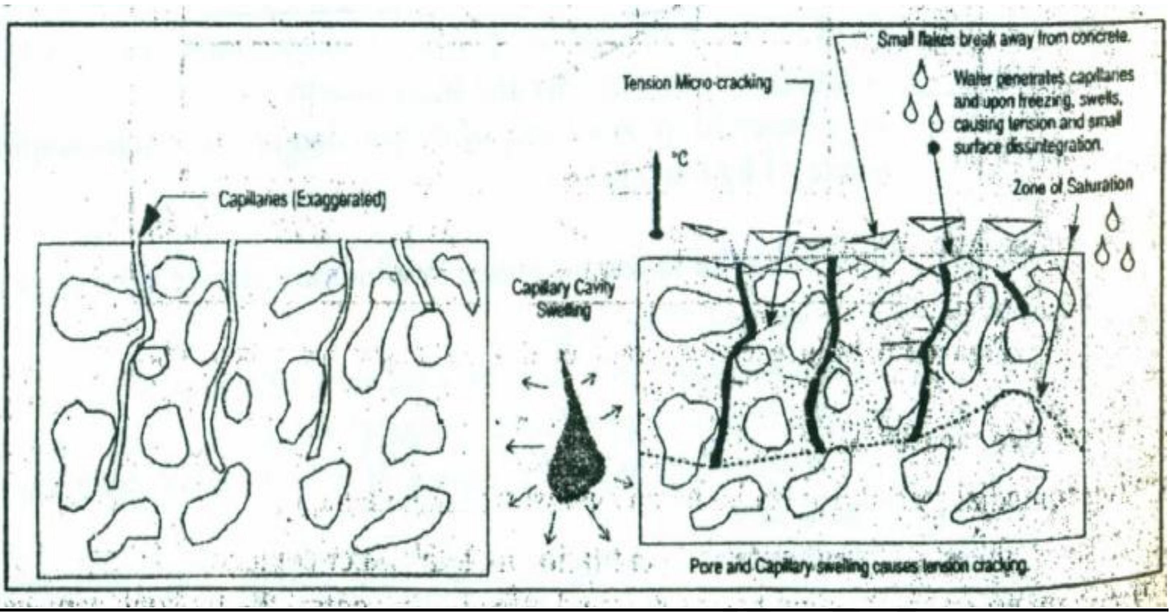
Nominal cover to all reinforcement to meet a given fire resistance period forvarious elements in a building is given.

**Table: Nominal cover to all reinforcement including links to meet durability requirements**

| Conditions of exposure | Nominal cover (mm) | | |
|---|---|---|---|
| Mild | 25 | 20 | 20 |
| Moderate | | 35 | 30 |
| Severe | | | 40 |
| Very severe | | | 50 |
| Most severe | | | |
| Abrasive | Nominal cover allowance for loss of cover due to abrasion. | | |
| Maximum free water-to-cement ratio | 0.65 | 0.60 | 0.55 |
| Minimum cement content (kg/m$^3$) | 275 | 300 | 325 |

**Table: Nominal cover to all reinforcement including links to meet specified periods of fire resistance**

## 14. **Write a note on effectsclimate in concrete?(April/May 2018)**




Freeze and thaw deterioration takes place with the following conditions:

a) Freezing and thawing temperature cycles within the concrete
b) Porous concrete that absorbs water (water filled pores and capillaries)

The freezing and thawing mechanism on concrete is shown in the above figure.

(a) Freezing and thaw deterioration generally occurs on horizontal surfaces that are exposed to water or on vertical surfaces that are at the water line in submerged portions of the structures.

(b) The freezing water contained in the pore structures expands as it is converted into ice. The expansion casues localized tension forces that fracture the surrounding concrete matrix.

(c) The first stage is the development of fine closey spaced cracks parallel to the edge of the exposed concrete.

(d) The cracks soon become filled with a dark deposit of calcium carbonate and are commonly called as D- cracks.

(e) As the deterioration continues small pieces of concrete between the cracks separate from the body of concrete.

(f) Deterioration isreduced as the w/c ratio is reduced but the only positive way to prevent the problem is to protect concrete by the adequate air void system

**<u>Preventive measures:</u>**

(a) Use of lowest practical w/c ratio and total water content.

(b) Adequate air entrainment as been found effective to control the freezing damage.

(c) Use of durable aggregate also is used to check the freezing effect.

(d) Adequate curing of concrete prior to exposure to freezing conditions is also important.

## 15. How properties of aggregate affect the relationship of water demand on slump , water cement ratio and compressive strength (April/May 2019)

When we design mix the concrete, its target strength is much less than the compressive strength of the aggregates used in the formation. It can also be clearly seen in the mix design procedure that greater the maximum size of coarse aggregate used, less is the cement required to achieve the target strength. So, undoubtedly, greater the maximum size of coarse aggregate, greater is the compressive strength of concrete made with 2 precautionary conditions:-

The coarse aggregates should be properly graded, and the gradation becomes more and more important as we increase the maximum size of coarse aggregate because of greater voids, which needs to be filled to attain the desired compressive strength. As void fraction increases on increasing the size ofaggregates.

Maximum size of aggregate used in the mix design should not be greater than 1/5th of the least dimension. So when we design a slab, its thickness comes in the range of 4-6 inches(say 100-150 mm), so the max size of aggregate should not be greater than 20 or 30 mm. Since 20 mm is commercially available, and we cannot use 40 mm for slabs below 200 mm thickness, we usually use 20 mm coarse aggregate in all the designs. If the max size of aggregate is greater than 1/5th of the least dimension, the chances of failure in shear are extremely high.

Water present in concrete is used to hydrate cement which mixes with the fine aggregates to form paste and some is absorbed by the aggregates(coarse) . An increase in the maximum size coarse aggregates means more paste will be required to fill the voids present from the aggregate matrix and more water absorbed by the increased surface area of the coarse aggregate. If the water content remains thesame,the paste will be dry as the coarse aggregates will absorb more water as its size increases, leading to dry paste and low plasticity or work ability. The voids present too increases with increasing aggregate size which means the same paste content will lead to porous mix and poor work ability.

## 16. A concrete should have low shrinkage and high extensibility in concrete. Why is not possible in practice (April/May 2019)

The inferior durability characteristics of concrete may be caused by the environment that the concrete is exposed to. The following environmental condition can affect the concrete durability:

– Temperature.

– Moisture.

– Physical factors.

– Chemical factors.

– Biological factors.

These factors may be due to weathering conditions (temperature, and moisture changes), or to abrasion, attack by natural or industrial liquids and gases, or biological agents.

Durability problems related to environmental causes include the following: steel corrosion, delamination, cracking, carbonation, sulfate attack, chemical attack, scaling, spalling, abrasion and cavitation.

Dimensional Stability

The influence of shrinkage and creep on concrete cracking: under restraining conditions in concrete, the interplay between the elastic tensile stresses induced by shrinkage strains and the stress relief due to the viscoelastic behavior is at the heart of the deformations and cracking in most structures.

To understand the reason why a concrete element may not crack at all or may crack but not soon after exposure to the environment, we have to consider how concrete would respond to sustained stress or to sustained strain. The phenomenon of a gradual increase in strain with time under a given level of sustained stress is called creep. The phenomenon of gradual decrease in stress with time under a given level of sustained strain is called stress relaxation.

**Extensibility and Cracking**

As stated earlier, the primary significance of deformations caused by applied stress and by thermal and moisture-related effects in concrete is whether or not their interaction would lead to cracking. Thus the magnitude of the shrinkage strain is only one of the factors governing the cracking of concrete. From 4-1 it is clear that the other factors are:

• Modulus of elasticity. The lower the modulus of elasticity, the lower will be the amount of the induced elastic tensile stress for a given magnitude of shrinkage.

• Creep. The higher the creep, the higher is the amount of stress relaxation and lower the net tensile stress.

• Tensile strength. The higher the tensile strength, the lower is the risk that the tensile stress will exceed the strength and crack the material.

The combination of factors that are desirable to reduce the advent of cracking in concrete can be described by a single term called extensibility. Concrete is said to have a high degree of extensibility when it can be subjected to large deformations without cracking. Obviously, for a minimum risk of cracking, the concrete should undergo not only less shrinkage but also should have a high degree of extensibility (i.e., low elastic modulus, high creep, and high tensile strength).

In general, high strength concretes are more prone to cracking because of greater shrinkage and lower creep; on the other hand, low strength concretes tend to crack less, probably because of lower shrinkage and higher creep.

## 17. Why do we use quality assurance in design?

In the construction industry, quality assurance is adopted in nuclear and offshore works mainly for safety and reliability reasons. The process of construction involves different types of professional and tradesman with a wide range of skills and level of education. The environments where these processes are carried out are often revealing to aggressive element, in such condition it is arguable whether the procedures can be standardized at all. On the other hand some contractors think that trying to do so merely place another layer of administration in the industry.

Despite, the differences of the work handled by a construction company, the corporate procedures apply to all varying degrees. Some examples of such are tendering, procurement, document control and record keeping.

Mostly, the adoption of quality assurance in the construction industry has been mainly client-led. Noting that the implementation of contract in law cannot undo any damage already done, a progressive client, when awarding a contract, tends to take into account, the contractor´s capability to do it right at the first time down the hidden philosophy of quality assurance. Besides, there is a general movement towards making the enforcement of quality systems in a contractual requirement. Most of the government bodies that are responsible for public works and housing have begun to persist on an effective quality system as an obligatory for tendering; perhaps public utilities companies are doing the same thing.

In this cases, the basis of competition for industries will move from “price” to the combination of “price and quality”, meanwhile if the contractors do not want to keep out from bidding for available work, they should then wait no longer in establishing a quality system in their companies. Such contractors will be fighting a lose battle against their competitors who have already enhanced their product through better quality assurance or quality management.

More so, trying to satisfy a condition for tending or contracts may not be the best argument for practicing quality assurance, but it would have probably be the most compelling reason in the first place. However, the companies that benefit mostly from quality assurance are those who do so for the purpose of improving their own efficiency. These improvement leads to higher productivity on the on hand and client satisfaction on the other.

Let's see some few constructions analyze with poor quality assurance.

1. Damage to the terrace roof surface.
2. Roof leakage through joints, bushings and so on, which lead to drenching of the thermal Insulation material and discolorations on internal surface layers.
3. Roof leakage at the eave with discolorations and flakiness on the façade surface layer underneath.

Sources: 5th semester project 2009

Moisture has caused many damages through the roof terrace covering because of different reasons. Some of which are discovered in the construction by some blemish on the façade and inside the building. The extent to which these damages can be determined is after the construction has been exposed. Besides, the deformation of this damage depends partly on changes in the supporting substrate and partly on movement of the building structure.



## 18. Explain the benefits of Quality Assurance?

Quality Assurance has become basic part of most of the construction industries. Every construction industries nowadays face tough competition and hence it is essential for them to provide goods or services of high quality at low cost to their clients.

Most of the construction industries understand the importance and necessity of maintaining good quality to survive in today market and that are laying even greater emphasis on their QA systems.

The first benefit is that, it helps in understanding the wants and expectations of the client. It thus aids the industries to focus on its processes to satisfy those needs and expectations, so as to keep it client happy and satisfied. For e.g. construction companies that offer good quality of buildings to their clients get lots of contracts from the community benefit from it. They can also over shadow their competitors and enjoy good sales and profits.

Secondly, quality assurance has increased the effectiveness of the construction industries. It requires that, the construction industries gives proper training to their employees so that they can understand their jobs better as well as get trained on the new technology to work and perform better. The entire construction industry works in a predefined fashion with the aid of these procedures. It helps the employees in knowing and understanding their roles and responsibilities. They also make the employees understand the different inter linkages within the departments. Thus, the employees understand the importance of teamwork in improving the quality of products and thus improve the brand value of the company.

Moreover, the quality assurance improves the flow of work within the companies.

It helps to identify the problem areas within the companies very early.

There are regular inspections and audits that pin point the problem areas of the companies. Not only the problems of the company, but also the low quality and other problems of the vendors are highlighted during these performance inspections. The aim of these systems is to continuously improve the entire quality of the companies, so as to attain high productivity while maintaining good quality.

Last but not the least, quality assurance help all the departments to work efficiently. There are fewer lags in the manufacturing of the products and as a result the construction companies benefits from a short cycle time. For e.g. if proper quality systems are implemented in a prefabricated company, it will benefit from fast and good production to its buyers. There are many big names in for instants the Danish companies that claim to serve their customers in a very short time. Such companies benefit tremendously from increased sales and clients satisfaction.

In short, quality assurance is essential for companies in order to get a strong foothold in the market. These systems help the companies to work effectively, which then reduces the operational costs of the construction companies. Also, it helps to infuse confidence in the employees though training and role clarity. All this helps the construction companies to serve their clients better every day.

**19. What are the parameters affecting the quality of concrete (April/May 2017)**

***Factors considered in preparation of concrete then those are as below.***

1. Type of cement(for ex. for construction in below ground in acidic nature soil select sulphate resistance soil, in mass concrete select low heat cement .

2. Type & size of aggregate( in base concrete P.C.C. select higher size aggregate like 40 mm).further avoid flaky,elongated aggregates.

3. Based on exposure of concrete to atmosphere,temperature,rain,sea water select w/c ratio.

4. Water content in the mix.

5. Curing time & method of curing.

6. Mixing & placing time of concrete

7. Method of compaction of concrete.

8. In R.C.C. grade of reinforcement

9. Quality of fine aggregate w.r.t. to silt content, organic & soft material in it.

10. Ratio of cement: sand: coarse aggregate: water as per design of mix

11. Temperature maintained during pouring & compaction

12. Quality of water added in concrete construction it should be potable water.

***Considering quality (durability) after construction then it depend upon***

1. Proper concrete cover (thickness) on face of reinforcement

2.Level of pollution high as considered in design.higher co2 in atmosphere means less durable concrete(less life of concrete)

3. Sudden change of temp (geographical location of structure) or sudden wetting & drying of structure.

4. Quality of cement plaster based on cement ,sand ratio & curing of plaster

5. Humidity of the area.

6. Proper design & construction method used in construction like high plinth level,protection to foundation by plinth protection,apron,provision of expansion joint in long building,earth quake,wind,storm resistance design of structure based on geographic location of structure.Quality of Workmanship in construction.

7. Size & shape of concrete members in structure.

## 20. Explain the duties and responsibilities of each position in construction quality assurance team

The CQA team will solely participate in the quality assurance function and will not be involved in any other aspect of the construction effort. This team will, however, possess all of the credentials, capabilities, and experience of an independent design/construction oversight team. The duties and responsibilities of each position are described below. One individual or entity may perform multiple CQA responsibilities.

**Project Engineer**

- The Project Engineer is responsible for overall implementation and management of the CQA/QC Plan and will supervise the preparation of the construction certification report.

The duties and responsibilities of the Project Engineer include the following:

•Review and approve shop drawings.

•Provide support to the CQA Manager in interpreting the meaning and intent of the construction plans and specifications and in the performance and supervision of the CQA testing program.

•Provide consultation and technical support to LSS.

•Any deficiencies deemed by the Project Engineer to require immediate attention will be reported to LSS immediately.

• Sign, certify, and seal the construction certification report

• •Prepare the final "as-built" drawings indicating the features constructed and the existing location of all features.

•Evaluate the contractor's project schedule.

•Review and make recommendations to LSS regarding any delays to theproject schedule.

•Review and evaluate change orders proposed by the contractor, owner, designer, or CQA team.

•Provide other technical support to LSS as required.

**CQA Manager-**

The CQA Manager will be assigned to the site on a full-time basis, and will report directly to the Project Engineer. The duties and responsibilities of the CQA Manager include the following:

•Perform and/or oversee all CQA testing activities.

•Coordinate CQA activities with the Construction Manager and the Project Engineer.

•Review contractor invoices and recommend payment schedule to the Project Engineer.

•Maintain copies of all CQA and CQC testing results and certifications.

•Prepare and distribute weekly construction reports to the Project Engineer and LSS.

•Provide input on the construction certification report.

The CQA Manager will complete material and equipment tests and maintain reports of testing results,any failures, and any corrective actions employed to obtain acceptable test results. All test data, reporting data, and contractor submissions will be included inthe construction certification report.

**Geotechnical CQA Manager**

The Geotechnical CQA Manager will be on site during all earthwork operations requiring quality assurance testing, including excavation and site preparation, and construction of the GWBW and cap. They will oversee the activities of the Field CQA Inspectors and coordinate the testingprograms of the CQA Laboratory.

**CQA Laboratory**

The CQA Laboratory will be an entity independent of both LSS and the construction contractor, located either on site or off site. It will be responsible for conducting tests on soil materials and soil-reagent mixes to ensure conformance with the contractplans and specifications.

**Field CQA Inspectors**

- Field CQA Inspectors will report directly to the CQA Manager and will be present during all major construction activities. The duties and responsibilities of this position include the following:

- Visually inspect materials imported to the site for conformance with contract specifications and for variations from tests completed prior to the materials being delivered to the site.
- Obtain samples for geotechnical CQA testing.
- Observe field sampling and testing performed by the contractor's CQC staff, and review test results.
- Observe and record observations regarding the storage and handling of equipment and materials.
- Independently verify quantity calculations.
- Prepare daily reports documenting all contractor activities. Assist with the generation of soil volume placement estimates.
- Assist with the preparation of "as-built" drawings.

## 21. **Effect on concrete due to climate?**

Thedeterioration rate of structures depends not only on the construction processes employed and the composition of the materials used but also on the environment. Increases in atmospheric $CO_2$ concentrations, and changes in temperature and humidity due to a changing climate will, especially in the longer term, cause an acceleration of deterioration processes and consequently acceleration in the decline of the safety, serviceability and durability of concrete infrastructure.An increase in temperature will increase the rate of infiltration of deleterioussubstances (increased material diffusivity) and increase the corrosion rate of steel. For example,corrosion rates will increase by up to 15% if temperature increases by $2^oC$. The effect of climatechange on chloride-induced corrosion has also been the subject of relatively little research, however, it is calculated that 5-15% increases in probability of corrosion initiationdue to climate change.This means that concrete structures will generally deteriorate faster with major implications for the safety, serviceability and durability of infrastructure, particularly in warmer inland and coastal areas.

## 22. **Effect on concrete due to chemicals?**

Various types of aggregate undergo chemical reactions in concrete, leading to damaging expansive phenomena. The most common are those containing reactive silica, that can react (in the presence of water) with the alkalis in concrete ($K_2O$ and $Na_2O$, coming principally from cement). Chemical attack on concrete can be classified as follows:

(i) Acid attack
(ii) Alkali attack
(iii) Carbonation
(iv) Chloride attack
(v) Leaching
(vi) Salt attack
(vii) Sulphate attack.

**(i) Acid attack:**

Portland cement is a highly alkaline material and is not resistant to attack by acids. The deterioration of concrete by acids is primarily the result of a reaction between the acid and the products of the hydration of cement.

Acids combine with calcium compounds in hydrated cement to form soluble substances which areeasily eroded, thus producing concrete disintegration. Concrete can be destroyed by prolonged contact with strong solutions of sulfuric, sulfurous, hydrochloric, nitric, and hydro bromic and hydrofluoric acids. These sameacids in solutions of less than 1 percentconcentration will attack more slowly but still significantly. Acids with low pH values are destructive.

**(ii) Alkali attack:**

The reaction of some forms of silica and carbonates in aggregates with the alkali produces a gel which causes expansion and cracks. Calcium, ammonium, barium and strontium hydroxides are normallyharmless, but sodium hydroxide may cause damage.

**(iii) Carbonation:**

This is the effect of carbondioxide in the air on the cement products maily the hydroxides in the presence of moisture.the calcium hydroxide is converted into calcium carbonate by absorption of carbondioxide. Calcium carbonate in slightly soluble in water and therefore when it is formed it tends to seal the surface pores of the concrete and destroying the impermeability system of the concrete. As a result of this the layer of concrete close to the surface of the concrete becomes carbonated and this is not sufficiently alkaline (pH below 9) to protect reinforcing steel.

Some of the influencing factors are: time, cover to reinforcement, concentration of carbondioxide in the atmosphere, permeability of concrete, alkali content in the concrete, condition of concrete cover.

**(iv) <u>Chloride attack</u>**

Chlorides may enter into the concrete from the following sources: (a) Cement to the concrete; (b) Water mixed in concrete; (c) Aggregates of the concrete; (d) Admixtures added to the concrete; (e) Chlorides may also enter by diffusion from atmosphere. A threshold level of 8000 ppm of chloride ions was required to initikate corrosion when the pH was 13.2. as the pH was lowered to 11.6, corrosion was initiated with only 71 ppm of chloride ions.

**(v) <u>Leaching:</u>**

Leaching of lime compounds leads to the formation of salt deposits on the surface of the concrete known as efflorescence. This is more likely to occur in concrete which is porous near the surface. Thus the type of form work plays a vital role in addition to the compaction and w/c ratio. The occurrence of efflorescence is greater when cool wet weather is followed by a dry and hot spell. Early efflorescence can be removed with a brush and water. Heavy deposits may require acid treatment of the surface of the concrete.

**(vi) <u>Salt attack:</u>**

Salts are chemical compoundsusually formed by reaction betweenacids and bases. Sodium chloride does not attackconcrete chemically but contributes to the corrosion of reinforcing steel and, when used asa deicer,participates in and aggravates physical damage resulting from freezing and thawing. Some waters have been reported to have extremely low concentration of dissolved minerals. These soft or aggressive water will leach calcium from cement paste or aggregates and washes away aggregate particles that become loosened as a result of leaching of the paste. Most of the problems due to salts arise from the aggressive fluid penetrating into the interior pore space of the concrete.

**(vii) <u>Sulphate attack:</u>**

Sulphates are present in sea water, industrial effluents and some ground water. The sulphate attack is characterized by the appearance of whitish appearance on the surface. Chemical reaction between sulphate and hydration products changes the microstructure and pore size distribution of the cement paste. It forms sulpho aluminates hydrate which has greater volume than that of the original compound. The resultant expansive stress may be great enough to cause deformation.