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BRANCH-CIVIL ENGG.

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Concrete as a construction material.

- what is concrete ?

→ Concrete is the most widely used man malde construction in the world is second only to water as the most utilized substants on the plannet.

→ It is often by mixing cementing material, water & aggregates & some time admixure in requared proportions.

→ The mixture when placed in forms in alloud to cure haredens into a reock - like mass known as concrete.

→ The hardaning is caused by chemical reaction between water & cement & it continuse fore a long time & consequ. ently the concrete grose stronger with age

→ The harden concrete may also be considerd as an artifisial stone in which the voids of laregere particles (corce-aggreigate) are filled by the smallere particles (fine aggregate) & the voids of fine aggregate are fill with cement. In concrete mixed the cementing material & water from a pest called cement water paste which is addition to filling the voids the fine - aggregate & carse aggreigate & bind them together as clacss. their by cementing material,

→ The key to producing a strong, durable & unifrom concrete that is high performance concrete lies in the carefull control of its basic & process component this are the following cement :- portland cement, the most widly used ingreadent in preasent day compreases phases that consits of campound of calcium, silicum, alumion, Iron, & oxigen

aggregate :- This are primoraly nateraally occurreing inert grannual material such as sand, gravel, crushed stone,

water :- The water content & the miniareal & chemical dissolved in it are creusial to achievieg quality concrete.

• chemical admixter :-

These are the inflents other then portland cement & aggrigats that are added to the mixture Immitally before or during mixing reduce the water requirement, acclarated or retared setting specific durcibility character etc.

• supplimentary cementing materaial :-

It is also know as meneral adtivies contribuit to the properties of harden concrete through hydrolic or

-pozzolanic activity.

Ex- Natural pozzolanas, flagash, ground-granulat, blast furenance, slag, silica-fume.

→ concrete has high compressive strength but its tensile strength is very low, in situation where tensile stress are developed the concrete is strengthemed by steel bars short randomly distrubated fibers forming a composiete construction called Rainforced cement concrete (R.C.C) or fiber rainforced concrete. the concrete without rainforcement called plane cement concrete (P.C.C) or concrete.

* Grades of concrete :-

Grade		material (cement : sand : aggregate)
① M_5	—	1 : 5 : 10
② $M_{7.5}$	—	1 : 4 : 8
③ M_{10}	—	1 : 3 : 6
④ M_{15}	—	1 : 2 : 4
⑤ M_{20}	—	1 : 1.5 : 3
⑥ M_{25}	—	1 : 1 : 2

$M_{10} - M_{20}$ = Ordinary concrete

$M_{25} - M_{55}$ = standard concrete

$M_{60} - M_{80}$ = High strength concrete.

→ For M_5 — M is mix design & 5 is characteristic compressive strength after 28 days.

• Advantages of concrete :-

Concrete as a construction material has the following advantages

(1) concrete is economical in the long run as compaire to other engineering materials. Except cement. It can made from localy avalable courese & fiber aggregate.

(2) concrete poseases a high compressive strength, & the corrosive & weathering Effect are minimal when properly prepared its strength is equal to that of a hard natural stone.

(3) the green or newely mixed concrete can be easily handle & molded or frermd in to virtually any shape or size according to specifications

(4) It is strong in compression & has onlimited structural application's in combination with steel reainforcement. concrete & steel have approxmetaly Equal coefficient of expension.

(5) concrete can be cumped & hence it can be laid in difficult positions also.

(6) concrete can even be spread on an field into fine cracks for repair by the buniting process.

(7) It is durable, fire resistance & requires very little maintenance.

- Disadvantages of concrete :-

The following are the dis-advantages of concrete.

(1) concrete has low tensile strength & hence cracks easily. therefore cuncrete is to be reinforced with steel bar or meshes or fiber.

(2) fresh concrete srinks on drying & hardned expand on weating. Provission for construction joint has to be made the ovoide the develpment due to drying srinkes & mousture muments

(3) concrete expand & contracts with the change in temprature hence, expanction joints have to be provided to avoided the formation. the cracks due to thermal mument.

(4) concrete under sustained loading undergose creep reasulting in the reduction of Pree-stress the Pre stress construction

(5) concrete entiraly impravocy to mousture & contents soulable solts which may cause a efflorescence.

(6) concrete is liable to disintegrate by alkali & sulphate attack

2nd chapter

Cement

- Cement – cement is a well known building mate-
  -rial & has occopide on indispensiable,
  place in construction work, there are
  of verite of cement avalable in market
  a mixture cement & sand when mixed
  with water to from a paste is known as
  cement motar, where as the compressite
  product oftend by mixing cement, water
  & on inert matris & sand & greavel or
  crushed stone is known as cement concrete

-> cement motar used in portland cement.
-> potland cement is difined as hydralic cement,
That is a cement that not only harden
by reaecting with water but also foring
a water resistance product.

- OPC – portland cement having adhesive & cholsi
  wich provide bending medium for descrent
  inerendents
  → It is obtained burnign together in a defined
  perpotion. a mixture of naturally occuring
  argillaceos (alumina) & calcareoys
  mater; to a parcial fusion on high
  temprature (1450 c°)

The product obtaind on burening is called as clinker or nodules(3-25 mm) diametere, is called . & ground to the requird finance to produce a matereial known as cement.

→ dureing the greinding of clinker, gipsum or plaster of parice (caso4) is added to adjest the seting time the amount of gypsum is about 3% by weight of clinkere, is also improve the soundness the cement.

compossition of portland cement :-

→ The raw matereial consist mainly lime, silica alumina & iron oxide, depending open the oxide verite of raw materials used in the manufactures in cement the oxide composition of PPC are as fallows :-

oxide	Percentage	Averrage
Lime "cao"	60 - 65	63
Silica "SiO"	17 - 25	20
Alumina 'Al_2O_3'	3.9 - 9	6.3
Iron oxide 'Fe_2O_3'	0.5 - 6	3.3
magnesia 'mgo'	0.5 - 4	2.4
Sulphar treioxide 'SO_3'	1 - 2	1.5
alkalis	0.5 - 1.3	1.0

→ The composition of portland cement basically mainly 4 compound:-

Tricalcium silicate 'C_3S'	$3CaO \cdot SiO_2$ (alite)	25-5
Dicalcium silicate 'C_2S'	$2CaO \cdot SiO_2$ (belite)	20-4
Tricalcium Aluminate (C_3A)	$3CaO\ Al_2O_3$ (aluminate)	5-12
Tetra calcium Alumina Ferrite (C_4AF)	$4CaO \cdot Al_2O_3\ Fe_2O_3$ (Ferrite)	6-12

→ The two silicate mainly C_3S, C_2S, together constitute about 70-80% of the cement ba
C_3S, C_2S give the same product called calcium silicate & calsium hydroxide.

→ C_3S having a faster rate of reaction accompanied by greater hit evolaption devl early strength

→ on the other hand C_2S hydrate & harden solwly & provide much of ultimate streng

→ C_3S & C_2S need aproximately 24 & 21% wat by wate

→ Thus a higher % of C_3S result in rapp hardaning with an early gain in stre at a higher heat of hydration.

→ C_3A in cement is comparately small the n water required fore the hydration of ceme sussta tialy offeted. It provide weak resistance sulphate attack.

Hydreation of cement :-

when the cement comes in contact with water the Hydreaction of cement process both inward or out-wared in the sence that the hydreaction product get deposition on the outere peripheri & the newcleaus & the on hydreated cement inside greate greadually deminished in Volume

→ The reaction proceties solwly fore 2 - 5 hrs before accelerating as the surface skin breaks

→ The crystal of various resulting compounds from an interelucking random three dimensi filling the space origionally occupied by the watere, resulting in stiffining

watere cement ratio :-

A cement of averaye composation requiard about 25% of watere by mash fore chemical reaction

→ The relation between watere to cement ratio strength lessere the watere used highere the strength of concrete sence that much watere,

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gth

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Physical Properties of portland cement

① Finess test:-

-> The fineness of a cement is a measure of the size of particles of cement & espresse in terms of specific surface of cement. it is an important factor in determining the rate of gain of strength.

-> for a given weight of cement the surface area is more for a finer cement then for a coarser cement.

-> The residue of cement should not exid 10% when sieved on a 90μ is sieve

② setting time:-

cement when mixed with water forms paste finally a hard mass is obtained. in this process of setting a stage is reached when the cement paste is sufficiently rigid to with stand a definite amount of pressure to time to reach this stage. is called setting time.

- It is devided in 2 parts, named initial & final setting time.

The time at which the cement paste loses its plasticity is termed as initial setting time. (it should not be 30 min).

The time taken to reach the stage when the paste becomes a hard mass is known as final setting time (it should not be more than 600 min or 10 hr)

) soundness :-

The unsoundness cement is caused by the undesereable expanction of same of its consti- tuetes sometimes after setting.

. The soundness is due to the present of freeline & magnesia in the cement. the free-line hydreates very slowly because it covered by thin film of cement, which prevents direct contract between lime & water.

i) compressive strength :-

) The strength paste generally carrauting tension & comprection. the ability of cement to make concrete in compression is strong therefore this are largely this supersede the motar qube crossing paste & concrete compressive strength.

- cement motar (1:3) having on area of 5000 area preparer & tested in testing machine.

Types of cement

1) By using additivis, changing. the chemical composition of the portland cement varying the percentage of 4 bacic compo through the different raw matercials it to upten several types of cement, Each sum unic carractics for the requar performance a grasual increase in 'C_3S' contant & finess as enable gener properes proper very high strength at Early ages.

Type of cement	oxide composition %				compound compo %		
	CaO	SiO_2	Al_2O_3	Fe_2O_3	C_3S	C_2S	C_3A
ordinary cement	63	20.6	6.3	3.6	40	30	11
Rappid-hardensh	43.5	20.7	5.2	2.9	50	21	9
Low-heat	60	22.5	3.2	4.6	25	45	5
sulfate rresistance	64	24.5	3.7	3.0	40	40	5

Generealy properse of portlant cement

The commonly use portland cement in is branded as 33 grade, 43 grag & 53 gr having 28 days min compressive strength exceeding 33, 43 & 53 mpa respectlebly all the 3 grade of ordinary portland cement the same materia by increasing the tricalcium silicate (C_3S) also by finnere grinder clinkere.

IS10262-1982 has clasify the OPC greade wise freom A to F dureing open the 28 days compressive strength are,

A (32.5 – 37.5) mpa or N/mm^2

B (37.5 – 42.5)

C (42.5 – 47.5)

D (47.5 – 52.5)

E (52.5 – 57.5)

F (57.5 – 62.5)

OPC based cement :-

opc based cement are the following type :—

→ Rappid hardening portland cement
→ low heat portland cement
→ Sulfate-resisting cement
→ masonry cement
→ water proof cement
→ white portland cement
→ colore portland cement

→ Hydrophobic cement

→ Air-entraining cement.

→ Expansive cement

→ Oil-well cement

→ Rappid haredening cement :-

- The cement is similare to OPC but high "C_3S" content & finere greinding. a highere fines of cement poreticles gratter surface area fore action with watere, it gane strength more quickly then OPC.
- It is only about 10% costly of them OPC

→ Low-heat poretland cement

- The cement is less reactive then OPC. & his often by increasing the proporesion of "C_2S" & readucing 'C_3S'. This reaction in the content of more rappidly fibratic compount C_3S & C_3A is a slow devlopment of strength but ultimate strength is same.

- It is used in mass cement construction.

3) sulphate-resistance cement :-

- A portland cement with low C_3A & C_4AF contents is very effective aganest sulfate attack. sulphate such a cement having high silicate content is called sulfate resisting cement

- IS456-2000 limits the total content of C_4AF & C_3A such that they both shall not exit 25%

9) masonry cement :-

- This cement is manufacture by Intimently greinding a mixture of OPC clinker (5-25mm) & gypsum with meanearal additips or inert materials such as lime stone dolomite, carbonated. sladge & air entraining agents in suitable propery generally to a finess greater that of opc.

- masonry cement conforming to the standard requirement can be produce by intergreiding 3 parts of portland cement clinker 5 parts of granulated blost furnac slag

setting time - initial - 90min
final - 24hre

→ white portland cement:-

- The process of manufacturing white cement on the same as opc but the amount of iron oxide which responsible for grayesh collor is limitated to 1%

- This is achived by carefully selection of raw material & often by the use of rifined furnace ail (RFO) or gass fual in place of Pulverized in kiln

• water-proof portland cement:-

→ It is manufacter by adding a water proofing substance to ordinary Portland cement during mixing.

→ The common admixture are calsium stearate aluminium stearate, gypsum treated with tannic acid.

• collor portland cement:-

→ This are basically portland cement to hinch-Pigment added in quantities up to 10% during the process of grinding the cement clinker

Hydrophobic Cement :-

- This type cement is optent by adding watere repaellant film forming substances like acid, boric acid, oleic acid & penta clolophenol. to opc during grinding of cement clinker.

- This cement is usefull for the less having high humidity. poor transportation system & perforce storage for long thime.

Air-enterning cement :-

- This cement manufacters by small quantity of air enterning ajentc like alkali salts of would resins. synthetic deteregent of alkali oryl. sulfate type & calcium ligno sulphate vith OPC

It is added to an extend 0.025 - 0.10% by weat of OPC cement clinker at the time of grinding

Expansive cement :-

cement wich dosn't shink while hardaning & expance slidly time is called expansived cement

This cement is commonly use for grouting ancher golts or grouting machine - function or press stress concreete ducts.

• Oil - well cement :-

- The annular space between steel casting & cedemntary of surenation though oil-well has been deat of drill. It shill of by cement slorrry to prevent escape of oil & gas.

- It is used at considerable depth where reveling tempreature mey be high 350°C under pressure up to 150 mpa it resist corrosin condition from sulphor gas

• Very high strength cement :-

The cement of this catagory can be oftend by Inproving Partical dencity & micro-structure of cement paste as follows.

→ removing entrapped air :-
In the conventsiolly mixed cement peste relatedly longere voids of deferrts are usually present due to entrapped air with limit the strength. In one of the systems water soluble Polymer is added as a rheological aid to permit cement to mixed with a very small amount of water & as final processing of strength entrapped air is removed by amlied of pressure of 5 mpa

providing densely packed system :-
opc & ultrafine silica fume are mixed upentona densified system contuning homogeneausly arranged parcticle, A compressive 270 mpa has been optent with silica fume substituted paste

achiving densifection with pressing by this method with warmn pressing i.e appling heat & pressure simoultinolsly to cement paste. resultin prosocity & generation of very homogenios of fine micro structure with small procity.

non- opc cement :-
- High alumina cement
- magnesium phosphate cement

High alumina cement :-
This cement basicaly difforent from opc & concrete made with it has properties different from opc concrete.
HAC is very reactive & produces very high early strength reactive & produces very highry early strength about 80% of ultimate strength is devloped are the age of 24 hours & even at 6-8 hrs. HAC has an innitial seting time of about 4 hours

8 Final setting time 5 hrs

- HAC is exteremly registance to chemical attack & is seatable from under sea water application

- The matercial used from it manufactere are lime stone or chalk. & Bauxite, which are crushed in to lumps not exceeding 100 mm

- The raw matercial with appropate proportion of coke are chaged into farnch which is fired with palverized coal or oil. the fussion take place ~~1600~~ of abow 1600°c

- magnesium - Phosphate cement:-
- It consist of a pre-packed mixture dead burnt magnesite & fine - aggregate
- It sets rappidly & yields durable high strength cement motarc. the dead burnt magnesin is optent by calcening $MgCO_3$ at or above 1500°c & grinding the Product to finess to 300000 - 330000 mm^2/g

Aggregate, water & admixture   ch - 3

Aggregate :-

concrete can be considere to be an arti-
-ficial stone oftend by bynding together the Particles of relatebly inert fine corce material with cement peste aggregate is generally chepper then cement & Impact greater Volume stability & durability in concrete.

- In any concrete useally aggrigate from about 70-75% up the total Volume mass
- Aggrigate imfluance the property the concrete Such as water requirement, cohesiveness & workbility in the concrete in the plastic stronge
- The aggrigate is an inneret fillert material & its physical, thormal & chemical property implunce the performance to grate extent while chossing aggregate fore a perticular concrete. Follo wing requirement should be kept in mind.

-> Economy of mixture

- Strength of the hardenmass
- durability of the structure.

* classification of aggrigate:-

- The classification of aggrigate based un there geological origin, size, shape, unit etc,

* classification according geological origin:-

The aggregate are usally dereived From naturealy mane having naturealy reduce to desigerc size to creossing the sweatablity of localy avalable depent often geological history of the reeason.

· according to schorece of nadureal OR Forrmation the aggregate are classified in two ways.

(1) natureal aggregate
(2) Artifical aggreegate.

(1) Natureal aggreegade:-

This are natureally accoriding aggrigates of tend from natureal deposet sand or greavel. The chepest natureal occurering aggregates & naturreal sand & greavel the most commonly used sorece of natureally

1) Artifical aggrigate :-
This are artificialy mancofactere or Processed aggrcigate : the most widly used artificial corrced aggrcigete arce clean broken bricks . & are called fresh blast furncee slag the artificial fine aggrcigate may be sow dust flyash etc.

2) classification accorcding size :-

The size of aggrcigate used in concrcete rcange. from feu cm or more down to a few μ

The max size of aggrcegate may very but in Each case it is to be so graded that the particles of different size !

Fraction are in ~~co~~ crcorporcated in the max in appocrcate perfraction.

- The particle size destrcubution is called the grading of aggrcegate.

• Accorcding to the size the aggrcegate arce classified 3 types

(1) Fine aggrcegate.

(2) courcse "

(3) All - in "

① Fine aggregate :- The aggregate most of which passes through 4.75 mm is sheave & retained on 75 μ (i.e 0.075 mm) is sheave are trmed as fine aggregate

- material between 0.06 mm & 0.002 mm is classified as silt & smaller particles are called clay.

The soft consist sand, silt & clay in about equal proportion is called loom.

- Fine aggregate helpfull in filling of the voids of corse aggregate the fine aggregate of natural sand or crushed stone sand or crushed gravel sand.

* corase - aggregate :-
The aggregate most of which reatend on The 4.75 mm is sheave & contend only that much of fine material by the specifiction as fromed as corse aggregate

- on crushed gravel or stone may be one of the oftend by the crushing of gravel hared stone.

The graded corse aggregate is described by its normal size 40, 20, 16, 12.5 mm etc

All - in - aggregate :-

some time combine aggregate avalable in natural - comprising differend fraction of fine & coarse aggrigate which are known as all-in - aggregate.

-> It is not generally making high quality concrete | Single size aggregate :-

Aggregate compressing partides volume encensial with a norrow limit size paction are called single size aggregate.

Ex - A 20mm single size aggregate means all aggrigate most of which passes through 20mm is sieve & the measure portion of which is reaten in a 10mm is sieve

· The elongation index of an defind as the % by weight of particles present in it whose greater dimension whose length is greater than 9/5 of their mein dimension

Ex - men size of aggregate = $\frac{16+20}{2}$ = 18mm

Elongated index = 9/5 × 18 = 32.4 mm

* elongated index = 100 × $\frac{\text{weaght of elongated aggregate}}{\text{weaght of complet sample}}$

Flaky Index:-

It is the % by weight of particles having least dimension less than 3/5 of their mean dimension

Ex - mean size of aggregate $= \frac{16+12.5}{2}$

$= \frac{28.5}{2} = 14.25$ mm

Flaky index $3/5 \times 14.25 = 8.55$ mm

* classification of unit weight aggregate:-

• The aggregate can also be clasified according to be normal weight, heavy weight & light weight.

(1) Normal weight aggregate:-

The commonly use aggregate i.e sand & gravel crushed rock such as granite basalt, quartz, sand stone, lime stone etc which have specific gravity between 2.5 & 2.7 produce concrete with unit weight ranges from 23-26 kN/m³

Heavy weaght aggregate :-

* some have weight or high density aggregat such as barytes (s.g - 4.0 - 4.6) ferrophosphate (sg - 5.8 - 6.8), geothite (sg - 3.4 - 3.7) Hematite (sg - 4.9 - 5.3) lmente (s.g - 4.0 - 4.6) limonate (s.g - 3.4 - 4.0), magnetite (4.2 - 52 are use in the manufacture or heavy weigh concrete which is more effective as readiaction shield, concrete having unit - weaght about 31, 30, 35, 38, 40, 47, 857 kn/m

* light weaght aggregate :-

* light weight having unit weight upto 12 kn/m³ are use to manufacture the structural concrete & mesonary block fore reoduction of the self weight of the structure. This aggregate may be natural such as diatomite pumic may be natural are bloated clay aggregate,

Chareactreistic of aggregate:-

Aggregate are the inert material that in mixd in fixed perpporetion with cementing material to produce concrete. these actay filters ore volume increasing components are responsible strength, hardness & durability.

- The plastic stage aggregate influence the property of concrete such as water requirement cohesive ness & workbility of concrete while they inflances strength durability & harden stage.

- The perroperties of aggregate which influence the properties of concrete are particle shape & size of aggregate. specific gravity bulk density, water absorption surface mosture dele terious material strength of aggregate alkali reaction.

- The specific greaity of an definied as the reatio of the mass of the solid in a given volume of sample to the mass of an equal volume of an water at the same temprature

The specific gravity of most aggregate varcious between 2.4 - 2.9

cement — 3.15

granite — 2.80

fine-aggregate — 2.63

gravel — 2.66

Types of specific gravity :-

1) apparent specific gravity.
2) Bulk specific gravity.

1) apparent specific gravity.

The ratio of weight of aggregate to the weaght watere accuping the volume equal to the solid aggregate

2) Bulk specific gravity

The ratio of weight of aggregate to the weaght of water accuping the volume equal to that of solid of aggregate including its is known as "bluck specific" gravity.

Specific gravity = $\frac{\text{mass of oven dry gravity in air}}{\text{mass of saturated surface dry aggregate - mass of saturated surface aggregate in water}}$

apparent specific gravity :- $\frac{C}{C-B}$

water absorbation = $\frac{A-C}{C} \times 100$

loose bulk dencity :- It can be determined by filling the contener with dry aggregate until it over flow from the container now lable the top of container by weaght the aggregate mass.

voids :- It is the empty species between the aggregate particles it is determine be between gross volume of aggregate mass & the volume accupied of the particles along.

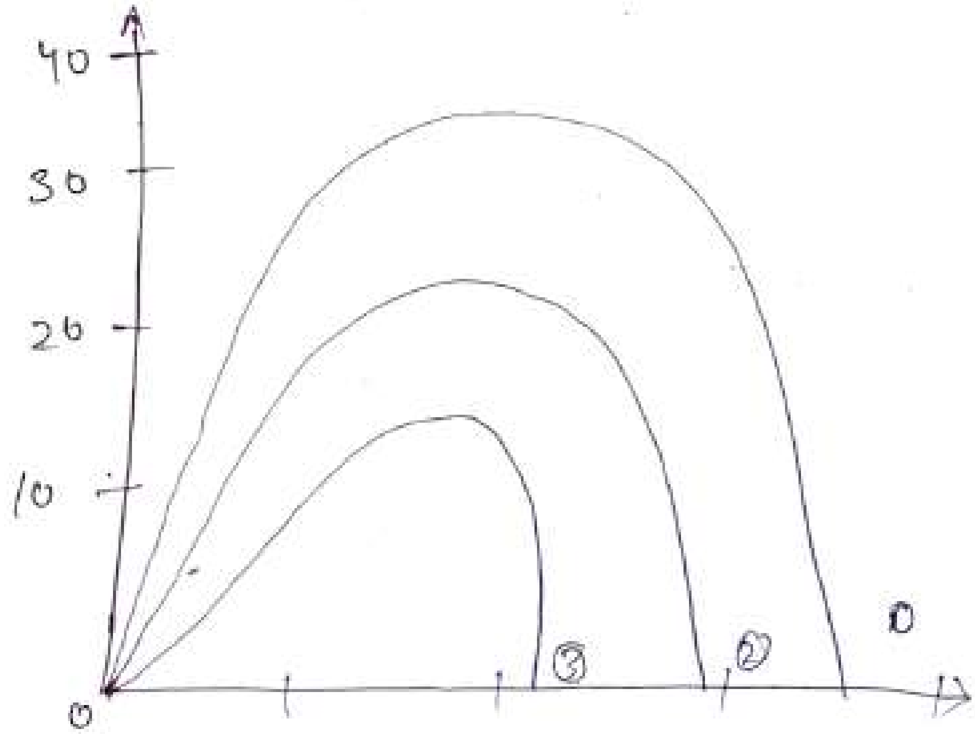
void reatio = $1 - \frac{\text{bulk dencity}}{\text{apparent specific gravity}}$

Bulking of sand:-

The increase in volume of a given mass of fine aggregate caused by the preasent of watere is known as bulking.

The bulking of fine aggregate its cause the particles of watere which the particles of parct the extend of bulking depend on the musture presend in sand

If the sand contenins mustare content up to 12-20% then it arcupose the same volume when it drey ading with mustarie contend with of 5% the sand may bulk up to 20-40% upen the finess sand



① fine sand

② medium sand

③ coarse sand

% bulking $= \frac{h - h_1}{h_1} \times 100$

h = heightu of sand

h_1 = height of water

- concrete is a chemical combined mass which is manufactured from binding materials & inert materials mixed with water

- water is a Important constituent
- It chemicaly reacted with cement
- strength & durability of concrete is control to a large extent by its water cement ratio

- The minim water cement required is 0.30 but the concrete containing water

this properti will be very hard & diff -cult to place but too much water reduces the strength of concrete

- If thoomuch water added to concrete the exes water along with cement quality of mixing watere:-

The watere use fore mixing & curing of concrete should be free from amount of deleterious material the unwanted situation leading to the distress of concrete which is caused due to the mixing curing watere being of inappreoted quality.

- Effects of Impurities of watere on propereties of concrete.

-> The strength & durability of concrete is reduce due to the % of impurities of mixing watere

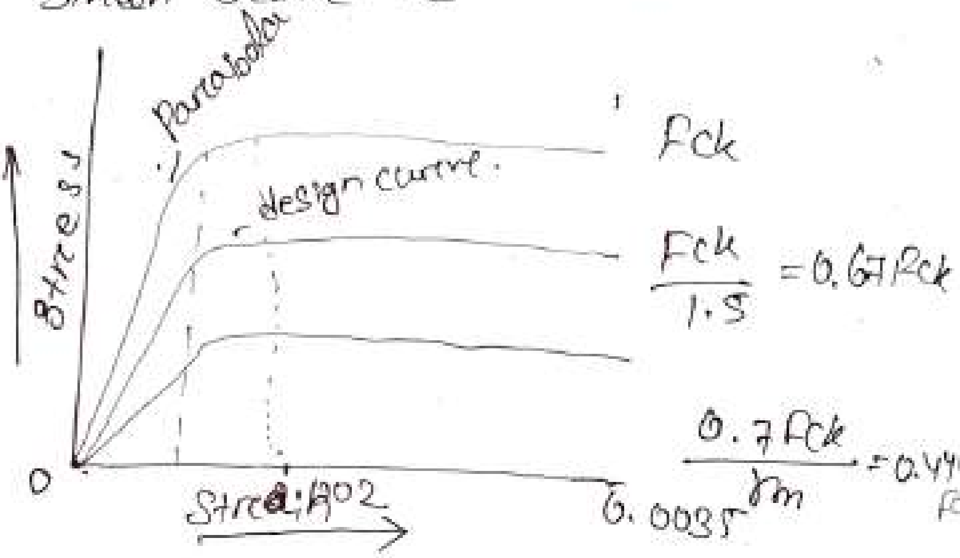
-> The effects are mainly espressed in terms of difference in the setting of the poretland cement

-> A difference in 28 days compressive strength of to 10% of control test generally considere to be satisfactory measured the quality of mixing watere.

-> Desolved reeduces compressive strength by 10-30% of that of tend using portable watere, watere contening longere quality of cloride contening longere quantity

Stress-Strain characteristic of concrete

- The relaction is fairly liner in the initialy stages but subsequently becomes non liner reaching a maximum value & then a decening portion is often before concrete finaly fails. The curve is usualy oftend by a testing a cylinder with a hight lateral dimension ratio of at list to under uniform rate of strain, if a uniform rate of stress adopted, ~~in to a~~ between not be possible to optent disible portion of stress & strain beare the maximum stress

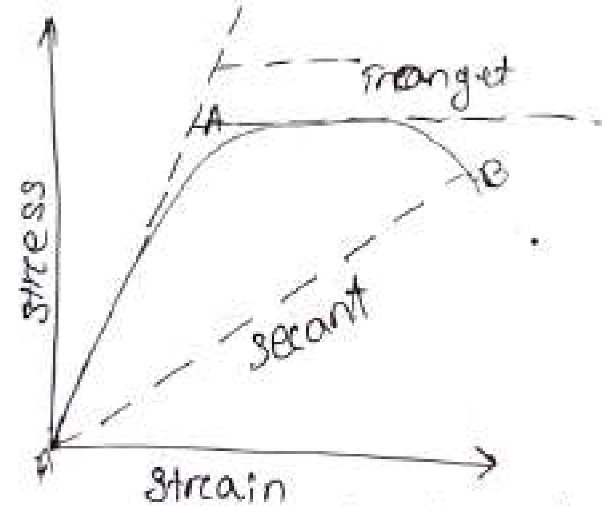


Concrete is not strictly elastic in the sence that if it is unloded after being stress to 0.446 fck or 0.5 fck or less a permanent set is noticed. The magnetude permanet sed graduary decreases it more cycle of loading & unloading, (0.446 fck) & the stress-strain comes to become a straight line, the creep deformation of concrete also varyes linerely with the substence stress orc 0.446 fck ≃ 0.5 fck

• Modulous of elastoity

• The young modulous is defined as stress to strain. The stress-strain behivere of an elastic mater is a straight light up to the elastic limit.

• concrete is not an elastic materecial, the stress-strain behievere concrete is a straig line of its ultimate strength. If a trangent to the initial point is drewn the slope of line is called initial tranged modulous of concrete stress-strain behievere as concrete is not a straight line the modulus is little importatant.



Suppose at any othere point a trangent is drewn & the slope is find out, this is known as tranged modolous. the value of this modoles measure the increment stress cabe. Fore an increment small value of stress, the strain calculate using this modolus the will not give the of strail.

uptain a satisfactory stress solution for the design a straight line drrown form the origin to the point on the stress strain called at which the deforemation are to be calculated the slope of this known as second modulus & is of a practiceble value! the term elastic modulus of elasticity of second modulus only.

Shrinkage:-

The dimension stability of a construction material to refers to is dimenson change over a long pereiod in time. If the change is so small that it will cause not only cause any structural preoblems. For concrete during shrinkage & creep are to fenomena additonal to the deforemation due to loads which compormise its dimensonal stability.

- It is the contraction suffered by concrete even in the assies of load.
- The two types of shrinkage strains are (1) plastic (2) Drying class

- Plastic shrinkage:-

The hydraction of cement caugese in reduction in the volume of the system of cement. water to an Extent 7% of the volume of dry cement. this contraction is plastic strain & is due to loss of water by evaporation surface of concrete, perticularly under hot climent & high wind. this can reesulting surface cracking.

• Draying shrinkage:-

• The shrinkage takes place after the concr has set & harden is called drying shrinkag & it takes place in the 1st few months.

• withdral of water from concrete stored in un saturated air causes drying shrinkage.

• A part of this shrinkage is recovered on immersion of concrete in water. It is turned as mustare movement.

• The shrinkage is affacted by water cement ratio, cement content, ambient humidity. Type of aggregate, size & shape of specimen, Type of cement, admixture, other factors.

* Permeability of concrete :-

when exes water in concrete avaporate it leaves voids the concrete element creating capillaries which are directly related to the concrete porosity & permability. The volume of mustare pass through depends on its peremabil Peremability is governed by porosity, which in turn is a direct consict on the water-cement ratio on the concrete mix by propere selection of ingredents & mix proporetioning & following the good construction porctles

almost impervious concrete can be obtain.

The well packed aggregate has reduce the amount of field water & cement paste.

Durability of concrete :-

A dureable concrete is one that performs satisfactory under anticipated exposure. working condition durible its services the material & mix proporti-tion is used should be such as mentanance intigr & if applicable to protect envotted material from corrosion. even the concrete is durable material required a little of no mentanance in normal envirement but when subjected to highly aggresive ore postile envirement. It has been found to deteriote resulting in premeture feloure of structure ore reach a state require costly require. One of the main charactristic inflence the dureabilite the concrete each its peremabilite to the increase of water, oxyden, carebon dyoxide, sulphate & other deleterious substances.

Sulphate attack :-

Sulphate are generally found in ground water & subsoil. Sea water also content large water of sulfate. Sulfate can be natural accureing ore could be as ~~subs~~ consequese of industrial waste disposal. calsium, sodium, magnisuim & ammonium sulphates are haremfull to concrete as they can lead to increase in the concrete volume & consequent & cracking.

- Calsium sulfate react with, calcium aluminate present in cement hydract froming & expensive ettreingite.

Sodium sulfate react with calsium hydreoside forems, expensive & present of aluminate & majn in turem lid to the fromation of littrenecte

* cloreide attacks:-

when considering durabilite of concrete ch attack element enemy, it responsable of lisy 80% of the felowere of concrete structure,

In the presence of oxigen & water cloreide the attack corerose the steel reducing the strength of structureals dreastically.

- cloreide-ion is formes on the element chloreine gains & electron ore when a compound such as hydreagen cloreide is deserved in water.
- correson take plase as the cloreide ions meat with the steel & the surraunding passive material to preoduce a chemical process, which forem hydreoclorcic acid.
- Two main sourse ~~are~~ of cloreide ions are from the cloreide mix component & from the surreounding enveremment.

* Acid attack on concrete:-

Concreete structure used for storeing liquids, Some of which are harmfull of concrete.

- In industreial plant concrete flors concrete come incontact liquids which damage the flore.
- In damp condition SO_2 & CO_2 & othere acid fumes Present in atmospeare affect concrete by dissolv & removing part of the set cement.

Efflorrences:-

The water leaking through crack or fulty joint or through the area of compacted, porrous concrete. dissolves some of the readly soilable soilable calcium hydractio & other solids & after evaporation lease calcium carbonate as white deposite or surface.

This deposite surface of concrete from the leaching on calcium hydraction & subsicuent carbonation & evaporation are termed as efflorrences.

—x—

concrete mix design

Introduction :-

- Concrete mix design involves a process of Prepration in which a mix of ingredients c-eat the requared & durability for the con structure.

→ Concrete of differend quality can be often using its constituents mainly cement, water, fine-aggregate, coarse aggregate & minireal additives. in differend proportion. The ingredients varing characteristic can be used to produce concrete of acatable quality. The common method of expresing the proportion of the material in a concrete mix in the form of parts in the ratio of cement, the fine & coarse aggregate being taken as unit.
→ The proteretion should indicate it by volume or mass.

→ water cement ratio is generaly expresed by mass

- Data are input requared for mix design :-
for the mix design of concrete following data is requared.

(i) characteristic (traget) compressive strength are 28 days.
(ii) Degree of workbility (selection of water cement ratio)

(iii) Estimation of entrapped aire.

(iv) Selection of waterecement & fine to total aggregate ratio,

(v) calculation of cement content.

(vi) calcalation of aggregate content.

charastreistic compressive strength of 28 days.

→ The traget mean compressive strength (ft), at 28 days each $f_t = f_c + K \times S$

where f_t = traget means strength of 28 days
f_c = characterestic strength of 28 days
K = statistical coefficent known as tolerance factor ore risk factore = 1.65
S = Standared deviation fore the initial value of mix design, 'S' may be taken adopted from the table

Grage of concrete	asume standared deviation (S N/mm²)	Remark
m10	3.5	These values related to the site control as below.
m15	3.5	(i) propere storage
m20	4.0	(ii) weitch batching of all material
m25	4.0	(iii) control addition of water
m30	5.0	(iv) regulare chealing of all materical
m35	5.0	(v) Pereiodical checking of
m40	5.0	workbility & strength.
m45	5.0	
m50	5.0	

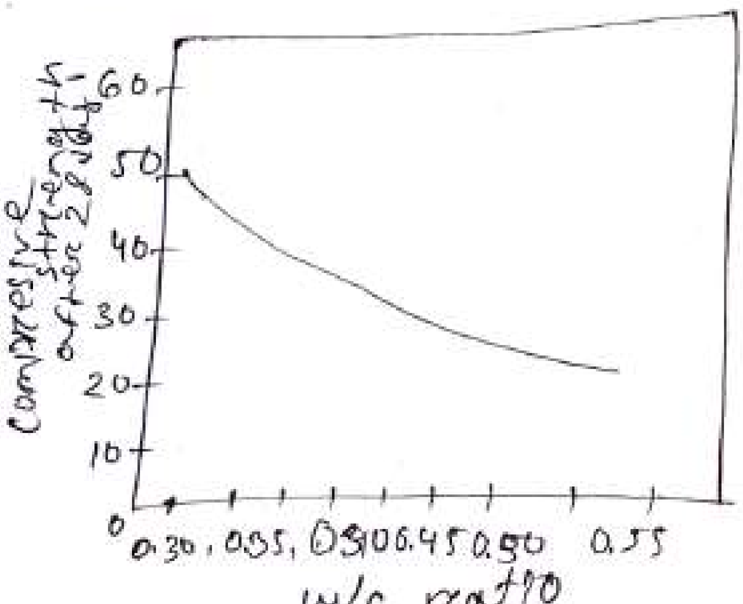
$$ft = fc + 1.65 \times S$$ — (ii)

Ex - for M_{10} = $10 + 1.65 \times 3.5$

(iii) Selection of water cement ratio:-

even when the water cement ratio is fi the compressive strength of concrete is influence by cement, aggregate, maxm siz aggregate, surface testure.

→ The sites degereable to estables relation between strength & free water cement, fore the material to be used & site condi



i) Estimate of Entrapped aire :-

The aire content is estimated fore the norenal aggregate used.

Approximate amound of entreapped aire

maxm size of aggregate (mm)	Entreapped aire as % of volume of concrete
10	3.0
20	2.0
40	1.0

selection to water content & fine to total aggregate reatio:-

→ Fore medium strength concrete i.e m_{35} grade concrete & high concrete i.e higher then m_{35} concrete.

→ The watere content & % of sand in total aggregate by absolate volume basis can be determine.

→ The following condition are followed (i) creushed coarse aggregate (ii) fine aggregate consisting of neturcal sand confarems to greading of zone '2'

→ corkbility coreosponding to 30mm (compression factore equal to 0.80)

- Calculation the cement content :-

→ The cement content per unite volume concrete may be calculated from water cement ratio & the quantity of water per unite volume concrete as cement by mass equal to water content / water cement ratio. (IS-456-2000 P- 20)

SL. NO.	Exposure	Plain concrete: Minimum cement content kg/m³	Maximum free-water cement ratio	minimum grade of concrete	Reinforced concrete: minimum cement content kg/m³	maximum free-water cement ratio	minimum grade of concrete
1	mild	220	0.60	—	300	0.55	m20
2	moderate	240	0.60	m15	300	0.50	m25
3	Severe	250	0.50	m20	320	0.45	m30
4	very severe	260	0.45	m20	340	0.45	m35
5	Extreme	280	0.40	m25	360	0.40	m40

• calculation for ~~free~~ aggregate content:—

→ Aggregate content calculated may be relation

$$V = \left(w + C/S_c + 1/p \times Fa/S_{Fa}\right) \times 1/1000$$

Coarse aggregate $= C_a = \frac{1-p}{p \times} \times Fa \times \frac{S_{ca}}{S_{Fa}}$

where V = absolute volume of fresh concrete. which is equal to volume in concrete in m^3 – the volume of entrapped air.

w = mass of water (kg/m^3 of concrete)

C = " " cement kg/m^3 of concrete)

S_c = specific gravity of cement

p = ratio of fine aggregate to total aggregate by absolute volume

Fa = total mass of fine-aggregate in kg/m^3 in concrete

Ca = total mass of coarse aggregate in kg/m³ for concrete.

Sfa & Sca = specific gravity of fine aggregate & coarse aggregate respetly.

- Actual quantity for the mix:-

The mix properetion calculate by the above noted method are based on the absunction that aggregates & saturated surface dry.

- calculated mix should be chacked by trail batch for each treail. the mix should be sufficent to prepare at list 3, 150 mm cubes & workbility any chance is requard to be done.

Nominal mix concrete :-

The wide use of concrete of construction material has led to the use of mixes of fixed properetion which ensure, adiquate strength. this mixes are known as nominal mixes.

→ Nominal mix concrete use for concrete of greade m_{20} or lower. this mixes called standard mixes are by defination conserebative but are usefull as of the self set of properetion that allow the designed concrete to be produce to minimum prepare work. for ordinary concrete from which quite on demanting performance is expected the nominal or standard are used.

DESIGN MIX CONCRETE :-

The concrete making materials being essentially variable result in the production of mix of variable quality. In such a situation, for high performance concrete, the most rational approach of mix proportioning is to select proportions with specific materials in wind which possess more or less unique characteristics, this will ensure the concrete with the appropriate properties to be produce, most economically.

→ Other factors like workability, durability, compaction, equipment available, curing methods adopted, etc. also influence the choice of the mix proportions. the mix proportion so arrived at is called the "designed mix"

→ The method doesnot guarantee the correct mix for the desired strength, thereby necessitating the use of trial mixes.

→ In the process of mix propotioning, a number of subjective desisions are required on which hinge the important ramifications for the concrete. the designed mix serves only as guid

Basic considerations for concrete mix design

The concrete mix design is a process of selecting suitable ingredients for concrete & determining their proportions which would produce, as economically as possible, a concrete that satisfies the job requirements, i.e. concrete having a certain minimum compressive strength, workability & durability. the proportioning of the ingredients of concrete s an important phase of concrete technology as it ensures quality & economy.

The proportioning of concrete mixes is accomplished by the use of certain empirical relations afford a reasonably accurate guide to select the best combination of the ingredients so as to achieve the desired properties. The design of plastic concrete of medium strength can be based on the following assumptions.

i) The compressive strength of concrete is governed by its water - cement ratio

ii) For the given aggregate characteristics, the workability of concrete is governed by its water content.

For high-strength or high-performance concrete mixes of low workability, considerable interaction occurs between the two criteria & the validity of such assumptions may become limited.

There are various factors which affect the properties of concrete, e.g. the quality & quantity of cement, water & aggregates, techniques used for batching, mixing, placing, compaction & curing, etc.

MIX - DESIGN PROCEDURE :- (IS 10262 - 2009)

Concrete mix proportioning - Guidelines has followed the format of ACI mix proportioning method; the European nations do not have common concrete mix design method because it considers mix design a part of concrete.

Production,

1.) Determination of basic characteristics of available fine & coarse aggregates:-

The properties required are :-

(a) The maximum nominal size of coarse aggregate
(b) The gradings fine & coarse aggregate.
(c) The gradings zone of the fine aggregate.
(d) The unit weight, specific gravities, & absorption capacities of both the coarse & fine aggregate.

* If necessary, two or more different size coarse aggregate fractions may be combined so that the overall grading of coarse aggregate conforms to table-2 of IS-383 for the particular nominal maximum size of aggregate.

2.) Selection of free-water-cement ratio:-

(a) The mean target strength "ft" is determined from the specified characteristic compressive strength at 28-days "fck" & the level of quality control using the equation.

$$f_t = f_{ck} + k \cdot S$$

$$f_t = f_{ck} + 1.65S$$

where 'S' is the standard deviation & 'k' is the statistical coefficient depending upon the accepted proportion of low result

$k = 1.65$ (from IS 456-2000)

The standard deviation which represents the degree of control to be estimated statistically from the variations in results of test conducted on trial mixes in the field or laboratory. It shall be based on at least 30 test strength samples.

Group No.	Grade of concrete	Assumed standard deviation, mpa	Quality control
1	M_{10}, M_{15}	3.5	The values correspond to the site control having proper storage of cement, weigh batching of all materials; controlled addition of water, regular checking of all materials aggregate grading & moisture content, & periodical checking of workability & strength where is deviation from the above, values given in the above Table shall be increased by "1.0 mpa"
2	M_{20}, M_{25}	4.0	
3	M_{30}, M_{35}, M_{40}, M_{45}, M_{50}, M_{55}	5.0	
From IS-456-2000 pg-23, Table-8			

b) The free water-cement ratio for the mean target strength obtained in the step(a) is selected from the figure representing the relationship between the characteristic compressive strength & free w/c ratio established, for the materials to be used in the job.

c) The free w/c ratio so chosen is checked against the limiting the maximum w/c ratio for the requirement of durability given in the table, the lower of the two values in adopted.

*minimum cement content & maximum water cement ratio of concrete with normal-weight aggregate of 20 mm nominal maximum size subjected to different exposures (Adapted from IS-456-2000 Pg-20, table)

* Adjustments to minimum cement contents for aggregates other then 20mm nominal maximum size.

Sl. No.	Nominal maximum size, mm	Adjustments to minimum cement contents, kg/m^3
1	10	+40
2	20	0
3	40	-30

3) Selection of free water content :-

The water content per unit volume of concrete (for aggregate in saturated surface dry condition) is selected from the table for the standard conditions of type of aggregate & workability.

maximum water content for nominal maximum size of agg.

SL. NO	Nominal maximum size of agg., 'mm'	max. water content, kg	validity or reference conditions
1	10	208	applicable to angular crushed coarse agg.
2	20	186	water content corresponding to saturated surface dry aggregate.
3	40	165	applicable to slump range of 25 to 50mm.

Adjustments in the water content for the change in type of agg. & workability.

Change in conditions stipulated above	Adjustment required in water content
i) shape of aggregate.	
1) sub-angular aggregate.	-10 kg
2) Gravel with same crushed particles.	-20 kg
3) Rounded gravel.	-25 kg
ii) workability	
1) For each additional 25 mm slump alternatively,	+3 %
2) Required water content may be established by trial.	
3) use of chemical admixtures conforming to IS 9103	water reducing admixtures & superplasticizer usually decrease water content by 5 to 10 % & 20 % & above respectively at appropriate dosages

Selection of cement content :-

a) The minimum cement content & supplementary cementitious material content per unit volume of concrete calculated by dividing the free water content arrived after adjustments in the step (3) by the free w/c ratio obtained in the step 2(b).

b) The cementitious material contain so obtained is compared with minimum value based on the requirements of the durability. & greater of the two values adopted.

5) Estimation of volume proportion of coarse agg. in total aggregate:-

The volume proportion (p) of coarse agg. of given nominal maximum size is estimated from the table for the reference water-cement ratio of 0.5 & grading zone of fine aggregate used; it is adjusted suitably for the selected water-cement ratio.

• Proportion of coarse aggregate to total agg. for ~~proportion of coarse aggregate~~ different zone of fine agg. (IS-10262-2009)

Sl. No.	Nominal maximum size of agg. (mm)	Volume fraction of coarse agg to total agg (p) for different zones of fine agg.			
		Zone IV	III	II	I
1	10	0.50	0.48	0.46	0.44
2	20	0.66	0.64	0.62	0.60
3	40	0.75	0.73	0.71	0.69

6) Computation of total absolute volume of aggregate:-

The total absolute volume of coarse & fine agg. (saturated surface dry condition) is computed by subtracting the sum of absolute volumes of cementitious materials & water already determined in steps 2 & 3, the chemical admixture & entrained air, from unit volume of concrete.

Thus, total absolute volume of agg. 'va' (m^3) is given by

$$V_a = 1.0 - \left[V - \frac{C}{S_c \times 1000} + \frac{W}{1000}\right]$$

where, W, C, V & S_c are the mass of water (kg), mass of cement (kg), air content (m^3) per & the specific gravity of cement, respectively

7) Determination of absolute volumes of fine & coarse agg. :-

The volume of agg. obtained in step 6 is divided into coarse & fine aggregate fractions by volume in accordance with coarse agg. proportion "p" already determined in step 5. The absolute volumes of coarse agg. (V_{ca}) & fine agg (V_{fa}) per unit volume of concrete are determined as

$V_{ca} = p.V_a$ & $V_{fa} = (1-p)V_a$

where, (p) Represents the ratio of coarse agg. in the total absolute volume of agg.

Therefore, contents of fine & coarse agg by mass are,

$C_{fa} = (S_{fa} \times 1000) V_{fa}$ &

$C_{ca} = (S_{ca} \times 1000) V_{ca}$

where, S_{fa} & S_{ca} are the specific gravity of saturated surface dry fine & coarse agg. respectively, in kg/liter.

Thus the concrete mix proportions for the first trial mix by mass (kg) are :-

Cement : water: fine agg. : coarse agg.

$c : w : V_{fa} \cdot S_{fa}(1000) : V_{ca} \cdot S_{fa}(1000)$

The above, concrete mix proporetions can b expressed by volume (m^3) as where. are the bulk densities respectively.

Cement water fineagg. coarse agg.

$$\frac{C}{\gamma_c} : \frac{w}{1000} : \frac{V_{fa} \cdot S_{fa}(1000)}{\gamma_{fa}} : \frac{V_{ca} \cdot S_{ca}(1000)}{\gamma_{ca}}$$

where, γ_c, γ_{fa} & γ_{ca} are the bulk densities (kg/m^3) of cement, fine & coarse agg. resp

8) Adjustmentss for agg. moisture & determ -ion of final proportions:-

Since agg. are batched on actual weight basis, the amount of mixing watere to b added is adjusted to take into account th absorption & the current moisture con -tent to generate equivalent of saturated surface drey condition of the agg.

9.) Preparation of trial batches & testing:

(a) The concrete mix proportions for the first trail mix or treial mix no.1 are determine & the workbility of the trail mix is measure in the terems of slump, the mix is carefully oserved for freedom from segregation & bleeding & its finishing properties. If the slump of trial mix is different from the stipulated value. the water &/or admixture content is suitably adjusted to obtain the correct slump

i) The mix proportions are recalculated keeping the free w/c ratio at the pre-selected volume; this compromises trial mix No. 2. In addition two more trial mix no. 3 & no. 4 are formulated with the water content same as trial mix no. 2 & varying the free-cement ratio by ± 10% of the preselected value.

j) The fresh concrete of each trial batch obtained above is tested for unit weight, yield & air content & three 150 mm cubes are cast. the wet cubes are tested after 28-days moist curing & checked for the strength

o) Final mix proportions:-

- The total mix nos 2-4 are analyzed for relavent information, including the relationship between compressive strength & w/c ratio. the w/c ratio required for the mean target strength using the relationship is computed. the mix proportions for the changed w/c ratio are recalculated keeping water content at the same level as that determined in trial mix no.2
- For field trials, produce the concrete by actual concrete production method to be used in the field.
- maximum cement content (IS-1343-1980) = 450 kg/m3

R Swain
02/06/2022.

PRODUCTION OF CONCRETE

The design of a satisfactory mix proportion is by itself no guarantee of having achieved the objective of quality concrete work. The batching, mixing, transportation, placing, compaction, finishing & curing are very complimentary operations to obtain desered good quality concrete.

→ Good quality concrete is a homogeneous mixture of water, cement, aggregates & other admixtures

→ The aim of quality control is to ensure the production of concrete of uniform strength in such a way that there is a continuous supply of concrete delivered to the place of deposition each batch of which a nearly like the other batches as possible.

→ The production of concrete of uniform quality involves the following five definable phases:

1) Batching ore measurement of materials.
2) mixing of concrete.
3) Transportation.
4) placing, compaction & finishing of concrete.
5) curing.

BATCHING OF MATERIALS :-

A proper & accurate measurement of all the materials used in the production of concrete is essential to ensure uniformity of proportion ~~of concrete is~~ & aggregate grading in uniformity successive batches.

→ For most of the large & important jobs the batching of materials is usually done by weighing.

→ The factors affecting the choice of proper batching system are:

(i) Size of job
(ii) Required production rate.
(iii) Required standards of batching Performance.

The batching equipment falls in to three general categories, namely, manual, semi-automatic, & fully automatic systems.

1) manual Batching :-

In this short of batching all operations of weighing & batching of concrete ingredients are done manually. manual batching is acceptable for small jobs having low batching rates.

2.) Semi-automatic :-

This batching is one in which the aggregate bin gates for changing batches are opened by manually operated switches gates are closed automatically when the designated weight of material has been delivered. The system contents interlocks which prevent batcher charging & discharging occurring simultaneously.

3) Automatic Batching :-

It is one in which all scales for the materials are electrically activated by a single switch & complete autographic records are made of the weight of each material in each batch. ... The batching cycle when preset weighing tolerances are exceeded.

→ The batching plant generally comprises two, three, four or six compartment bins of several capacities together with a supporting system. Below the bins are provided the weight batchers discharging over the conveyor belts.

→ For most of the small jobs, volume batching is adopted. i.e. the amount of each solid ingredient is measured by loose volume using measuring boxes, wheel barrows, etc.

MIXING OF CONCRETE MATERIALS:-

The object of mixing is to coat the surface of all aggregates particles with cement paste & to blend all the ingredients of concrete into a uniform mass. The mixing action of concrete thus involves two operations:-

i) A general blending of different particle sizes of the ingredients to be uniformly distributed throughout the concrete mass. &

(ii) A vigorous rubbing action of cement paste on to the surface of the inert aggregate particles.

→ Concrete mixing is normally done by mechanical means called mixer, but sometimes the mixing of concrete is done by hand, machine mixing is more efficient & economical compared to hand mixing.

> In the mixing process, the cement paste is formed first with simultaneous absorption of water in the agg. In second stage, the cement paste coats the aggregate particles.

> The classification of the mixers is based on the technique of ~~agg.~~ discharging the mixed concrete as follows :-

1) Tilting type mixer
2) Non-tilting type
3) Pan or stirring mixer.

The size of a mixer is designated by a number representing its nominal mix batch capacity in liters, i.e the total volume of mixed concrete in liters which can be obtained from the mixer per batch

mixing time :-

It is the time required to produce uniform concrete. The mixing time is reckoned from the time when all the solid materials have been put in the mixer, & it is usual to specify that all water has to be added not later than after one quarter of mixing time. the ~~size~~ time varies with the type of mixer & depends on its size, It is not the mixing time but the number of revolutions of the mixer that are to be considered, because there is an optimum speed of rotation for the mixture. In high-speed pan mixers, the mixing time can be 35 sec, when light weight aggregate is used, the mixing time should not be less than five minutes, sometimes divided into 2 mint.

making the agg: with water followed by there minutes with cement added.

→ The minimum mixing times for the mixers are

Capacity of mixer, "m³"	mixing time, minutes
0.8	1.00
1.5	1.25
2.3	1.50
3.1	1.75
3.8	2.00
4.6	2.25
7.6	3.25

Hand mixing :-

There may be occasions when the concrete has to be mixed by hand, & because in this case uniformity is more difficult to achieve Should be spread in a uniform layer on a hard clean & non-porous base; cement is then spread over the aggregate & the dry materials are mixed by turning over from one end of the heap to another & cutting with a shovel until the mix appears uniform. Turning three Times is usually required

Transportation of concrete :-

concrete from the mixer should be transported to the point where it has to be placed as rapidly as possible by a method which prevents seggregation or less of ingredients The concrete has to be placed before setting has commenced.

→ The specification peremit a miximum of two hours between the introduction of mixing water to the cement & agg. & the discharege, If the concrete is transported in a truck mixer or agitator.

→ In the absence of an agatitor, this figure is reduced to one hour only All these however presume that the tempreature of concrete, when deposited, is not less than 5°c or more than 32°C

→ The requirements to be fulfilled during trans-portation are:-

1) No segregation or separation of materials in the concrete.
2) Concrete delivered at the point of planing should be uniform & of proper consistency.

The prevention of segregation is the most important consideration in handling & transporting concrete

→ Segregation can be prevented by ensuring that the direction of fall during the dumping or dropping of concrete is vertical.

The principal methods of transportating concrete from the mixer are the following -

1) Barrows
   (i) wheel barrows & handcarts
   (ii) power barrows or powered buggies or dumpers.
2) Tippers & lorries
3) Truck mixers & agitator lorries

4) Dump buckets
5) The monorail system or trolley or rails most commonly used method of transport concrete by the hand pans passing from hand is slow, wasteful & expensive.

* Pumped concrete :-
Pumping of concrete through steel pipelines is one of the successful method of transportating concrete. pumped concrete has largely been used in construction of multistorey buildings, tunnels & bridges.

→ The pump capacity can range from 15 m³/h to 150 m³/h. The normal distance to which the concrete can be pumped is about 400m horizontally, & 80m vertically.

Placing of concrete :-
The methods used in placing concrete in its final possition have an important effect on its homogenity, density & behavior in service. the same care which has been used to secure homogenity in mixing & the avoidance of segregation in transporting must be exercised to preserve homogenity in placing.
To secure good concrete it is necessary to make certain preparations before placing. The forms be examined for correct alignment & adequate rigidity to withstand the weight of concrete impact loads during construction ~~without of concrete, impact load during construction~~.

the weight of concrete, impact loads during without undue deformation. The form must also be checked for tightness to avoid any loss of mortar which may result in honeycombing. Before placing the concrete, the inside of the forms are cleaned & treated with a release agent to facilitate their removal when concrete is set.

The concrete should be placed in its final position rapidly so that it is not too stiff to work. where fresh concrete is required to be placed on a previously placed & hardened concrete,

In placing the high quality concrete in highway or runway pavement construction, the concrete pavers are extensively used.

* Effect of Delay in placing :-

It is not generally recognized that there is a gain in compressive strength with delay in placing provided the concrete can still be adequately compacted. the limits imposed by the latter requirement varies with the type of mix. only a short delay can be allowed for a dry mix in hot weather. a delay of several hours is possible with very wet mix in cold weather.

→ The delay between mixing & final placing of concrete is limited to between half an hour & one hour

During the manufacture of concrete a considerable quantity of air is entrapped and during its transportation there is a possibility of partial segregation taking place. If the entrapped air is not removed & the segregation of coarse agg. not corrected, concrete may be porous, non-homogenous & of reduced strength. the process of removal to from a homogenous dense mass is termed as compaction.

→ The density, strength & durability of concrete depend upon the quality of this compaction.

→ The internal friction between the particles forming the concrete, between concrete & reinforcement, & between concrete & form-work, makes it difficult to spread the concrete in the forms. The compaction helps to overcome the frictional forces.

→ Friction can also be reduced by adding more water than can combine with cement.

→ Compaction methods :-
The compaction of the concrete can be achieved in four ways :-

(i) hand rodding (ii) mechanical vibrations
(iii) centrifugation or spinning &
(iv) high pressure & shock.

(i) Hand Rodding :-
Rodding is the process of ramming the concrete manually with a heavy float faced tool in an efforet to work it around the

reinforcement, the embedded fixtures & corners of the form work.

→ The rodding action is effective for a depth of Concrete equal to five times the maximum size of agg. & hence the depth of each layer has to be restricted to this value.

(ii) mechanical vibrations:-

vibration is the commonly used method of compaction of concrete, which reduces the internal friction between the different particles & thus consolidates the concrete into a dense, & compact mass. the oscillations are in the form of simple harmonic motion. the mechanical vibrations can be imparted by means of vibrators which are operated with the help of an electric motor or diesel or pneumatic pressure.

-Curing periods:-

To develop design strength, the concrete has to be cured up to 28 days. As the rate of hydration, & hence the rate of development of strength, reduces with time. It is not worthwhile to cure for the full period of 28 days

IS:456-2000 stipulates a minimum of seven-day moist-curing, while IS:7861 (P-1) - 1975 stipulates a minimum of 10 days under hot weather conditions. High early strength cements can be cured for half the periods suggested for OPC. For pozzolana or blast furnace-slag cements, the curing period should be increased. There are many opinions on the length of curing

Period. Periods varying from 13 to 30 days are specified for highway pavements.

1. The method which replenish partly the loss of water by interposing a source of water, or prevent the evaporation, viz.

(a) ponding of water over the concrete surface after it has set this is the most common method of curing the concrete slab or pavements & consists of storing the water to a depth of 50mm on the surface by con-structing small puddle clay bunds all around

(b) covering the concrete with wet straw or damp earth in this method. The damp earth or sand in layers of 50mm height are spread over the surface of concrete pavements. the material is kept moist by periodical sprinkling of water.

(c) Covering the concrete with wet burlap the concrete is covered with burlap placing & the material is kept continuously moist for the curing period. The covering material can be used a number of times & therefore tends to be economical.

(d) sprinkling water:-

This is a useful method for curing vertical or inclined surfaces of concrete wherein the earlier methods cannot be adopted. the method is not very effective as it is difficult to ensure that all parts of concrete is moist all the time. The spraying can be done in fine streams through nozzles fixed to a pipe spaced at set intervals.

2. The methods preventing or minimizing the loss of water by interposing an impermeable medium between the concrete & the surrounding environment are as follows.

(a) covering the surface with waterproof paper
waterproof paper prevents loss of water in concrete & protects the surface from damage. the method is satisfactory for concrete slabs & pavements. A good quality paper can be often reduce. the paper is usefull made of two sheets struck together by rubber latex composition. plastic sheeting is a comparatively recent innovation as a protective cover for curing concrete.

(b) Leaving the shuttering or formwork on the thick watertight formwork also prevents the loss of moisture in concrete & helps in curing the sides & the base of the concrete.

(c) membrane curing of the concrete the process of applying a membrane forming compound on concrete surface is termed membrane curing. often, the term membrane is used not to refer to liquid memberanes but also to a solid sheeting use to cover the concrete surface. The curing membrane serves as a physical barrier to prevent loss of moisture for the concrete to be cured.

Following are the different sealing compounds used: (i) Bituminous & asphaltic emulsion or cutbacks

(ii) Rubber latex emulsions

(iii) Emulsions of resins, varnishes, waxes, drying oils & water-repellant substances.

(iv) Emulsions of paraffin or boiled linseed oil in water with stabilizer.

(d) chemical curing It is accomplished by spray. The sodium silicate solution. About 500g of sodium silicate mixed with water can overt $1m^2$ of surface. forms a hard & insoluble calcium silicate. It actually acts as a case hardener & curing agent

3. methods involving the application of artificial heat while the concrete is maintained in a moist condition are used in planning curing where the curing of concrete is accelerated by raising its temperature. the accelerated process of curing has many advantages in the manufacture of precast concrete products since; (i) The molds can be reused within a shorter time (ii) due to reduced storage space in the factory is reduced.

The Temperature can be raised in practice by
(a) placing the concrete in steam.
(b) placing " " in hot water
(c) passing an electric current through the concrete

Steam curing :-
For concrete mixes with water-cement ratio ranging from 0.3 to 0.7, the increased rate of strength development can be achieved by resorting to steam curing. the mixes with low w/c ratio respond more favourably to steam curing than mixes with higher w/c ratio

In steam curing, the heating of the concrete products is caused by steam either at low pressure or high pressure

The method ensures even heating of products all over, even if the space between the stacked precast concrete products is very small.

Formwork :-

Though formwork generally forms a part of concrete construction practice, but as it influences the performance of hardened concrete appreciable, its salient features are described in brief in the following sections. The formwork or shuttering may be defined as molds of timber or some other material into which the freshly mixed concrete is poured at the site & which hold the concrete till it set. the formwork includes the total system of support of freshly placed concrete i.e from lining & sheathing plus all necessary supporting members, bracings, hardware & fasteners.

concrete construction practices directly affect formwork. It is more than simply making from the right site. A good formwork should be strong. Stiff, smooth & leakproof

Requirements of formwork:-

Quality :- The formwork is designed & built accurately so that the desired shape, size position & finish of cast concrete is obtained, & thus

1. all lines in the formwork should be true & surface be plane so that the cost of finishing the surface of concrete on removal of shuttering is the least, &

2. The Foremwork should be [illegible]

Safety :- The Foremwork is built substantially so that it is strong enough to support the dead and live loads during construction without collapse ore dangere to workmen or the structure.

Economy :-

The foremwork should be built efficiently, save time & money fore the contractore & ownere alike. Aftere the concrete has set the foremwork should be easily strippable without so that it can be used repeatedly.

Types of foremwork :-

The matereial used in the foremwork largely depends upon the availability & cost

Timbere foremwork :-

Timbere used fore foremwork should be cheap, easily available & easy to work manually & on machines. A good timbere fore foremwork should be light fore easy handling & lifting stiff fore not giving excessive deflections, usually free from knots, knot holes, bad flaws, etc.

Plywood foremwork :-

plywood sheets bounds with synthetic resin adhesive are being widely used nowadays. Thickness of ply varies from 3-18 mm. sizes less then 6mm thick are used fore lining the timber foremwork to get neat & smooth surface smooth finished.

The common size of are 1200×1200 to 3000×3000 mm. The main advantages is that large panal surfaces are avalable.

Steel foremworek :-

Steel foremworeks are commonly employed fore big projects where the forems are to be repeatedly used. the steel forems can be easily fabricated & not to required many adjustments as the units are standardized. They give smooth surface needing very little finishing.

Stripping of forem :-

The removale of forems aftere the concrete has set is teremed stripping of forems. the stripping ore streiking of forems should proceed in a defined ordere. the foremworek should be so designed & constructed as to allow them to be stripped in the desired ordere. The period up to which the forems may be kept in place before they are stripped is called stripping time. The factores affecting the stripping time are the position of the forems, the loads coming on the elements immediately aftere stripping, tempreature of the atmosphere, the subsequent loads coming on the element, etc, using ordinary portland cement with tempreatures above 20°c, the stripping times normally required.

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02/06/2022

V. Good.

Inspection & Quality ...

* Quality control of concrete As per IS: 456

→ Concrete is generally produced in batches at the site with the locally available materials of variable characteristic. It is therefore, likely to very from one batch to another. the magnitude of this variation depends upon several factors, such as variation in the quality of constituent materials, variation in mix proportions due to batching process; variation in the quality of batching & mixing equipment available; the quality of overall workmanship & supervision at the site.

→ concrete undergoes a number of operations such as transportation, placing, compacting & curing. During this operations, considerable variations occur partly due to quality of plant available & partly due to differences in the efficiency of techniques used. under such a situation concrete is generally referred to as being of good, fair or poor quality

→ concrete has mainly to serve the dual needs of safety (under ultimate loads) & serviceability (under working loads) including durability.

→ Therefore the aim of quality control is to reduce the variations & produce uniform material providing the characteristics desirable for the job envisaged.

→ quality control is thus conformity to the specifications, no more no less. The most practical method of effective quality control is to check what is done in totality to conform to the specifications. An owner will have no right to expect anything more than what is in the specifications. The builder, knows that anything less than what is in the specification will not be acceptable to the owner.

* FACTORS CAUSING VARIATIONS IN THE QUALITY OF CONCRETE

The main factors causing variation in concrete quality are as follows :-

1. Personnel :-

The basic requirement for the success of any quality control plan is the availability of experienced, knowledgeable & trained personnel at all levels. The designer & the specification - writer should have the knowledge of construction operations as well. The site engineer should be able to comprehend the specification stipulations.

Infact, quality must be a discipline imbibed in the mind and there should be strong motivation to do every thing right in the first time.

2. material, equipment & workmanship :-

For uniform quality of concrete, the ingredients (particularly the cement) should be preferably be used from a single source. when ingredients from diffe-rent sources are used, the strength & other characteristics of the materials are likely to change, & therefore they should only be used after proper evaluation & testing. the cement should be tested initally once every two months. Set cement with hard lumps is to be rejected.

→ Grading, maximum size, shape, & moisture content of the agg. are the major source of variability.

→ The eggregate should be free from impurities & deleterious materials.

→ The water used for mixing concrete should be free from silt, organic matter, alkali, & suspended impurities.

→ The equipment used for batching, mixing & vibrating should be of the right capaci

→ The green concrete should be handled, transported & placed in such a manner that it doesnot get segregated the time interval between mixing & placing the concrete should be reduced to the minimu possible.

* mixing, Transportation, placing & Curing Requirements of concrete As Per IS 456:

→ mixing:-
concrete shall be mixed in a mechanical mixer. The mixer should comply with IS 1791 & IS 12119. The mixers shall be fitted with water measuring devices. the mixers shall be continued until their is a uniform distribution of the material & the mass is uniform in colour & consistency. If there is segregation after unloading from the mixer, the concrete should be remixed.

→ The mixing time shall be atleast 2 min.

→ For other types of more efficient. mixers, manufacturers recommendations shall be followed; for hydrophobic cement it may be decided by the engineer-in-charge.

→ workability should be checked at frequent intervals.

→ Dosages of retarders, Plasticisers & Superplasticisers shall be restricted to 0.5, 1.0 & 2.0 Percent respectively by weight of cementitious materials & unless a higher value is agreed upon between the manufacturer, & the constructor based on performance test.

Transporting & Handling:

After mixing, concrete shall be transported to the formwork as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients or ingress of foreign matter or water & maintaining the required workability.

During hot or cold weather, concrete shall be transported in deep containers. Other suitable methods to reduce the loss of water by evaporation in hot weather & heat loss in cold weather may also be adopted.

Placing :-

The concrete shall be deposited as nearly as practicable in its final position to avoid rehandling. The concrete shall be placed & compacted before initial setting of concrete commences & should not be subsequently disturbed. Method of placing should be taken to avoid displacement of reinforcement or movement of formwork. As a general guidance, the maximum permissible free fall of concrete may be taken as 1.5 m compaction :-

concrete should be thoroughly compacted and fully worked around the reinforcement around embedded fixtures & into corners of the formwork.

Concrete shall be compacted using mechanical vibrators complying with IS:2505, IS:2506, IS:2514 & IS:4656. over vibration & under vibration of concrete are harmful & should be avoided. vibration of very wet mixes should also be avoided.

whenever vibration has to be applied externally the design of formwork & the disposition of vibrators should receive special construction to ensure efficient compaction & to avoid surface blemishes.

INSPECTION AND TESTING OF STRUCTURES

1. Inspection :-

To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records workmanship & construction

Tests should be made on reinforcement & the constituent materials of concrete in accordance with the relevant standards. where applicable, use should be made of suitable quality assurance schemes.

care should be taken to see that :

(a) design & detail are capable of being executed to a suitable standard, with due allowance for dimensional tolerances;

(b) There are clear instructions on inspection standards;

(c) There are clear instructions on permissible deviations;

(d) elements critical to workmanship, structural performance, durability & appearance are identified &

(e) there is a system to verify that the quality is satisfactory in individual parts of the structure, especially the critical ones.

*2. Immediately after stripping the formwork all concrete shall be carefully inspected and any defective work or small defects either removed or made good before concrete has thoroughly hardened.

Testing :-

In case of doubt regarding the grade of concrete used either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete &/or load test may be carried out.

Core Test :-

1. The points from which cores are to be taken & the number of core required shall be at the discretion of the engineer-in-charge & shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the grade of concrete specified for the corresponding age & no individual core has a strength less than 75%.

Load Tests for Flexural member :-

Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete.

The structure should be subjected to a load equal to full dead load of the structure plus 1.25 times the imposed load for a period of 24h & then the imposed load shall be removed.

> Note:- Dead load includes self weight of the structural member plus weight of finished & walls or partitions, if any, as considered in the design.

The deflection due to imposed load only shall be recorded. If within 24 h of removal of the imposed load, the structure does not recover at least 75% of the deflection under superimposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 80%, the structure shall be deemed to be unacceptable.

If the maximum deflection in mm, shown during 24h under load is less than $40l^2/D$ where 'l' is the effective span in m; & D the overall depth of the section in mm. It is not necessary for the recovery to be measured.

* Members Other Than Flexural members:-

members other than flexural members should be preferably investigated by anal

* Non-destructive Tests :-

Non-destructive tests are used to obtain estimation of the properties of concrete in the structure. The methods adopted include ultrasonic pulse velocity & rebound hammer, probe penetration, pullout & maturity. Non-destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength & the physical quality measured by the non-destructive tests.

Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.

DURABILITY OF CONCRETE :-

A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The materials & mix proportions specified & used should be such as to maintain its integrity & if applicable, to protect embedded metal from corrosion.

One of the main characteristic influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate & other potentially deleterious substances. Impermeability is governed by the constituents & workmanship used in making the concrete.

A suitably low permeability is achieved by having an adequate cement content, sufficiently low free water/cement ratio, by ensuring complete compaction of the concrete, & adequate curing.

The factors influencing durability include:

a) The environment;

b) The cover to embedded steel;

c) The type & quality of constituent materials;

d) The cement content & w/c ratio of the concrete.

e) workmanship, to obtain full compaction & efficient curing; &

f) the shape & size of the member.

The degree of exposure anticipated for the concrete during its service life together with other relevant factors relating to mix composition, workmanship, design & detailing should be considered. The concrete mix to provide adequate durability under these conditions should be chosen taking account of the accuracy of current testing regimes for control & compliance as described in HS standard.

* Requirements for Durability :-

1. Shape & size of member :-

The shape or design details of exposed structures should be such as to promote good drainage of water care should also be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to avoid the harmful effects of early loss of moisture. member profiles & their intersection with other members shall be designed & detailing.

General environment:-

The general environment to which the concrete will be exposed during its working life is classified into five levels of severity. that its mild, moderate, severe, very severe & extreme.

Table 3 Environmental Exposure conditions (clauses 8.2.2.1 & 35.3.2)

Sl. No.	Environment	Exposure conditions
1	mild	concrete surfaces protected against weather ore aggressive conditions, except those situated in coastal area
2	moderate	concrete surfaces sheltered from severe rain ore freezing whilst wet concrete exposed to condensation & rain concrete continously underwater concrete in contant ore buried under non aggressive soil/ground water. concrete surfaces sheltered from saturated salt air in coastal area
3	severe	concrete surface exposed to severe rain alternate wetting & drying ore occasional freezing whilst wet ore severe condition.
4	very severe	concrete surfaces exposed to sea water spray. corrosive fumes ore severe freezing conditions whilst wet, concrete in contact with ore buried under aggressive sub soil ground water
5	Extreme	surface of members in tidal zone members in direct contact with liquid/ solid aggressive chemicals.

2. Abrasive :-

specialist literatures may be referred to for durability requirements of concrete surfaces exposed to abrasive action, for example, in case of machinery & metal tyr...

3. Freezing & thawing :-

where freezing & thawing actions under we... conditions exist, enhanced durability can b... obtained by the use of suitable air entraining admixtures. when concrete low... then grade M50 is used under these conditions. the mean total air content by volume of the fresh concrete at the tim... of delivery into the construction should be:

Nominal maximum size Aggregate (mm)	Entrained Air %
20	5 ± 1
40	4 ± 1

Since air entrainment reduces the strength, suitable adjustments may be made in the mix design for achieving required strength.

4. Exposure to sulphate attack:-

Table 4 gives recommendations for the type cement maximum free w/c ratio & minimum cement content, which are required at different sulphate concentrations in near -neutral ground water having pH of 6...

For the very high sulphate concentrations conditions, some form of lining such as polyethylene or polychloroprene sheet; or surface coating based on asphalt, chlorinated rubber, epoxy; or polyurethane materials should also be used to prevent access by the sulphate solution.

* Requirement of concrete cover :-
The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete.

4. Concrete mix proportions :-
The free w/c ratio is an important factor in governing the durability of concrete & should always be the lowest value. The minimum cement content & maximum w/c ratio apply to 20 mm nominal maximum size aggregate.

maximum cement content :-
cement content not including fly ash & ground granulated blast furnace slag in excess of 450 kg/m³ should not be used unless special consideration has been given in design to the increased risk of cracking due to drying shrinkage in thin sections, or to early thermal cracking & to the increased risk of damage due to alkali silica reactions.

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SPECIAL CONCRETE Ch - 9

* Introduction to ready mix concrete :-

A concrete whose constituents are weight bat at a Central batching plant, mixed either a the plant itself or in truck mixers, & then transported to the construction site & delivere in a condition ready to use, is termed ready mixed concrete (RMC)

→ The technique is useful in congested sites at diverse work places & saves the consu from the botheration of Procurement, st & handling of concrete materials.

→ Ready mix concrete are produced under factory conditions & Permits a close con of all operations of manufacture & transpo of fresh concrete.

→ The concrete quality & quantity or volum required for the particular application specified by the consumer.

→ RMC is ordered & supplied by volume (or in a freshly mixed & unhardened state. wh ordering concrete 5 to 10 % more concre than estimated from a volumetric calculati is ordered. this will account for the was or spillage, over-excavation, spreading forms some lose of entrained air, settle of wet mixture, & change in volume, d concrete volume is one to two % less th that of fresh concrete.

High - Performance concrete :-

High performance concrete (HPC) is concrete that has been designed to be more durable that if necessary, stronger than conventional concrete, necessary.

→ HPC mixtures are composed of essentially the same materials as conventional concrete mixtures but the proportions are designed, or engineered to provide the strength & durability needed for the structural & environmental requirements of the project

→ - High strength concrete is defined as having a specified compressive strength of 55 mPa or greater, as it represent a strength lable at which special care is required for :- Production & testing of the concrete & at which special structural design requirements may be needed.

* Silica - fume concrete :-

Note:- Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys.

→ Silica fume is a very reactive pozzolana. Concrete containing silica fume can have very high strength & can be very durable.

→ Silica fume is avaliable from suppliers of concrete admixtures & when specified, is simply added during concrete production. Placing, finishing & curing silica fume concrete require special attention on the part of concrete contractor.

→ It is composed of [illegible] silica fume, fine aggregate, coarse agg. & water.

→ Fresh & hardened properties of silica-fume concrete is superior to conventional concrete.

→ It require higher water content than conventional concrete.

→ The possibility of bleeding & segregation is low

→ It has high plastic shrinkage.

→ It enhances the properties of fresh & hardened concrete, high durability, high early compressive strength.

→ It is added to up to 15% by weight of cement, although the normal proportion is 7% to 10%

* Short - crete concrete or Guniting :-

→ Short - crete is mortar or very fine concrete deposited by jetting it with high velocity on to a prepared on different countries.

→ It offers advantageous over conventional concrete in a variety of new construction & repair works.

→ Shotcrete is more economical than conventional concrete because of less formwork requirement, required only a small portable plant for manufacture & placement

– It is off two types :-
- dry mix process.
- wet mix process.

→ Guniting also known as a dry process shotcrete, uses air pressure to convey dry matereial from machine through hose to nozzle where water is added. the technique of depositing very thin layers of mortars. in each pass of the nozzle that available with the shotcrete. is termed guniting.

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Deterioration of concrete & its Prevention

2

* Introduction:-

It is the action or process of becoming impaired or inferior in quality, functioning or co[ndition].

→ Though concrete is quite strong mechanically, it is highere susceptible to chemical attack & thus concrete structures get damaged & even fail unless some measures are adopted to counterac deterioration of concrete & thereby increasing the durability of the concrete structure.

* Type of deterioration:-

Deterioration of concrete is caused not only be acids in the form of water solutions or acidic gases which form acids on dissolving in water, but by salt solution & even by alkalies.

→ Deterioration of concrete due to corrosion caused by the various aggressive chemicals can be classified into three categories

1. Decomposition of concrete:-

In this form the decomposition of concrete is caused by action of liquids which are able to dissolve the ingredients of hardened cement. water percolating through the mass of concrete can greatly speed up decomposition by increasing the ionic strength of solution. A common example of this type of destruction in the leaching action

2. chemical reaction :-

In the forem of destruction a chemical inter-action between hardened cement constituents & a solution takes place. the easily soluble reaction products are removed from the internal structure of concrete by diffusion or percolation. this happens when concrete is attacked by a solution of acids & certain salts.

3. crystallization :-

This forem of destruction involves accumulation, crystallization. & polymerization of reaction products which increase the volume of solid phase within the pore structure of the concrete.

Alkali-Silica Reaction :-

Alkali silica reaction (ASR) takes place when free lime in concrete interacts with reactive silica % in many types of agg. The reaction forms a gel that absorbs moisture & expands & creates tensile stresses that can creach concrete.

Leaching :-

The type of deterioration may be caused by the dissolution of the ingredients of hardened cement by the aqueous solution i.e by the leaching process. since calcium hydroxide is a readily soluble ingredient of hardened cement, the destruction of concrete by the laching action also called lime leaching it is greatly dependent upon the permeability of the concrete

5. chemical Interaction :-

① Deterioration may be caused by the chemical reaction between the hardened cement constituents of concrete & the chemicals of a solution the reaction products formed may be either water soluble & may get removed from the internal structure of concrete by a diffusion process, or the reaction products if insoluble in water may get deposited on the surface of concrete as an amorphous mass having no binding properties with the result that it can be easily washed out from the concrete surface.

6. crystallization :-

concrete may get deteriorated by the accumulation or crystallization of salts in its process. which leads to the development of internal stresses & formation of cracks. These salts in the pores of concrete may be either formed as a result of chemical reaction between the corrosive media & the constituents of hardened cement or may be brought from out side by the penetration of salt solution & released there on the evaporation of water.

Alkaline solutions of low concentration are less harmful to concrete. however, the concrete gets deteriorated on exposure to concentrated solutions of alkalies. as they combine with atmospheric carbon dioxide producing crystallizable carbonates

Prevention of concrete ① Detereioration

A dureable structureal concrete requires the satisfaction of two criteria, namely that of a suitable binding agent of adequate chemical resistance & that of thorough compaction to a high density. Thus, the making of a densere concrete having the least porosity is a most effective means of reducing the deterioration of concrete. A quantitative information regarding the effects of the range of parameters like water-cement ratio, cement content, curing conditions together with effects of cement admixtures & replacement on the corrosion of concrete helps determine the durability of concrete empirically. The effects of these parameters are described below. Thus from the considerations of permeability the w/c ratio is usuallay limited to 0.45 - 0.55 except in mild environment. In the concrete for marine environment or in sea water application a minimum cement content of 350 kg/m³ or more required. & nominal maximum size of agg. used. i.e crushed rock & rounded river gravel of 20 mm nominal size have approximately 27 ~~35~~ 22 % of agg. voids. A cement concrete of 400 kg/m³ & w/c ratio of 0.45 will produce paste volume of 30 % which is sufficient to over-fill the voids of crushed rock. The concrete in sea water or exposed directly should be at least of M20 grade in case of plain concrete & M25 in case of reainforced concrete. The use of slag or pozzolana cement is advantageous under such conditions. The ordinary portland cement having C_3A content less then 5 % has got the maximum resistance against sulfatic environment. the supersulfated cement supposed to provide an acceptable durability against acidic envoirment. when concrete is dense with a w/c ratio of 0.40 or less.

Durability of concrete can also be increased by impregnating the pores of concrete with a suitable polymer.

As the destructive processes in concrete are complex. a cleare understanding of the destructive mechanism may help the selection of an appropriate technique to protect or improve the resistance of structural concrete to the aggressive agents.

* Corrosion of Reinforcement :-

concrete normally provides a high degree of protection against corrosion to embedded steel reinforcement this is because concrete inherently provides a highly alkaline environment for the steel which protects & passivates the steel against corrosion in addition, concrete of low-w/c ratio & will cured has a permeability which minimizes & of corrosion inducing agents like oxygen, chloride ion, carbon dioxide & H_2O sometimes. the first evidence of distress is the brown staining of concrete around steel permeating by cracking. sometime concrete cracking occurs because the corrosion product of steel, an iron oxide or rust has a volume twice as much as that of metallic iron from which it is formed

Effects of corrosion & prevention :-

In most case, the corrosion rate is extremely slow & the normal life span of a structure is not largely affected. However if the external & nominal may taken place an increased rate & create serious problem.

The distress due to corrosive action may be in the form of deep pitting & a severe loss of cross section of the reinforcement, this is particularly serious if the reinforcement is subjected to high stress as in the case of structures carrying heavy loads. A combination of high stress & intense corrosion will produce stress concentrations that may result in rupture of the reinforcement. the corrosion of embedded steel can be minimized by using the following recommendations:-

1. For the reinforced - concrete members totally immersed in sea water, the cover should be increased by 40 mm beyond that specied for normal condition. However, for the members periodically immersed in the sea water, this increase in cover should be raised to 50 mm. In the case of high-strength concrete of Grade M25 or above, the additional thickness of cover specified above may be reduced to half.

2. The additional cover thickness ranging from 15 - 50mm beyond the values for normal condition may be provided when the surface of the concrete members are exposed to the action of harmful chemical, salty atmosphere, acid vapors, sulfurous smoke etc. However, the total cover is limited to 75 mm.

3. To reduce the corrosion of reinforcement the chloride ions in the concrete should be limited to its threshold or critical value IS:456-2000 has prescribed the limit of total amount of chloride in concrete, that total amount of chloride ions in concrete should be limited to 0.6%

4. In the case of an excessively aggressive environment or where for practical reason it is not possible to meet the requirements of cover & quality of concrete recommended above, special protection system should be considered corrosion inhibitors may be added to concrete to prevent the corrosion of embedded steel.

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.1) Repaire technology fore concrete structures

Hough concrete is a reledtivly durable building materrial. It may suffere damage ore distress during its surrvice life due to number of reason.

Because of the varrying conditions undere which it is produced at varryes location, the quality of concrete suffers occasionally eithere during production ore suarvices condition resuldance , distress.

Some times the distress in a structure is brought about by poore construction practice, errore in designing & deteling & construction overe loads.

the othere causes may be drying shreinkage, thoremal stress, weathering, chemical reaction & corerroson & reinforcement.

Symptom, causes & prevention & remedy of defects during construction.

Symptom	Cause	Prevention	Remedy
Cracks in horizontal surface, as concrete stiffens or very soon thereafter.	Plastic shrinkage: rapid drying of surface.	Shelter during placing, cover as early as possible. use air entrainment.	Seal by brushing in cement or low-viscosity polymer.
Cracks form above ties, reinforcement, etc, or at arrisses. especially in deep lifts.	Plastic settlement: concrete continues to settle after starting to stiffen.	change mix design. use air entrainment	Recompact upper part of concrete while still plastic. Seal cracks after concrete has hardened.
Cracks in thick sections occurring as concrete cools.	Restrained thermal contraction.	minimize restraint to contraction. Delay cooling until concrete has gained strength	Seal cracks
Blowholes in form faces of concrete.	Air or water trapped against formwork: Inadequate compaction unsuitable mix design. unsuitable	Improve vibration. change mix design. use appropriate release agent, use absorbent formwork	Fill with polymer modified fine mortar.

voids in concrete.	release agent. Honeycombing: In-adequate compaction. Grout loss	Improve compaction. Reduce maximum size of agg. Prevent leakage of grout.	Cut out & make good. Inject resin
Erosion of vertical surfaces, in vertical streaky pattern.	Scouring: water moving upwards against form face.	change mix design, to make more cohesive or reduce water content.	Rub in polymer-modified fine mortar.
color variations.	variations in mix propo-rtions, curing conditions materials, characteristics of form face, vibration release agent. Leakage of water from formwork	Ensure uniformity of all relevant factors Prevent leakage from formwork.	Apply surface coating.
powdery formed surface.	Surface retardation, caused by sugars in certain timbers.	change form material. seal surface of form-work ~~surface~~ Apply lime wash to form face before first few uses.	Generally none required.
Rust strains.	pyrites in aggrigates. Rain streaking from unprotected steel. rubbish in formework. Ends of wire ties turned out	Avoid contaminated aggregates. protect exposed steel clean forms thoroughly. turn ends of ties inwards.	clean with dilute acid or sodium citrate / sodium dithionite. Apply surface coating.

Plucked surface.	Insufficient release agent. Careless removal of formwork.	more care in application of release agent & removal of formwork	Rub in fine mortar, or patch as for spalled concrete.
Lack of cover to reinforcement.	Reinforcement moved during placing of concrete. or badly fixed. inadequate tolerances in detailing.	Provide better support for reinforcement. more accurate steel. fixing. Greater tolerances in detailing.	Apply polymer modified cement & sand rendering. Apply protective coating

Cracking of concrete Due to Different Reasons :-

→ cracking is the most common indication of the distress in a concrete structure. crack may represent the total extent of the damage, or they may point to problems of greater magnitude.

→ cracking of concrete structures can never be totally eliminated, but the practitioner should be aware of the causes evaluation techniques. & the methods of repair.

→ The cracks in a structure are broadly classified in two categories :- superficial cracks & structural cracks. the structural cracks may be active & dormant. A crack where a movement is observed to continue. is termed active whereas the crack where no movement occurs is termed dormant or static.

→ Some of common causes are :-

(1) cracking of plastic concrete
(2) Cracking of Hardened concrete
(3) Thermal cracking
(4) cracking due to chemical reactions.
(5) cracking due to weathering.
(6) cracking due to corrosion of reinforcement
(7) cracking due to poor construction practices
(8) cracking due to construction overloads.
(9) Cracks due to externally applied loads.

1. Cracking of plastic concrete :-

when the exposed surfaces of freshly placi
concrete are subjected to a very rapid
of moisture caused by low humidity, wi
& /or high temprature, the surface
shrinks. Due to restraint provided,
concrete below the drying surface l
tensile stresses develop in the weak, sti
plastic concrete, resulting in shallow c
that are usually short, discontinuous run
in all directions & very seldom extend
the free edge.

In the presence of reinforcement their
pattern may be modified. Plastic shrin
usually occurs prior to final finishing
curing starts. The cracks are often fai
wide at the surface. They range from fe
centimeters to many meters in floors o
slabs or other elements with large surf
areas. Plastic shrinkage cracks may
the full depth of elevated thin structura
elements. Plastic shrinkage cracks can
controlled by reducing the relative volum
change between the surface & the int
concrete by preventing a rapid moistur
loss due to hot weather & dry winds. Th
can be accomplished by using fog nozzl
saturate the air above the surface & us
plastic sheeting to cover the surfac
-tween the final finishing operatio

Cracking of Hardened Concrete :-

The moisture-induced volume changes are characteristic of concrete. A loss of moisture from cement paste results in a volume shrinkage by as much as one percent, whereas the internal restraint provided by the agg. reduces the magnitude of this volume change to above 0.05%, on the other hand an increase in moisture in the concrete tends to increase its volume. If these volume changes are restrained, the tensile stress develops when the tensile strength of concrete is exceeded, it will crack. The surface crazing appears in the form of a series of shallow, closely spaced fine cracks.

3. Thermal Cracking :-

The temperature difference within a concrete structure result in differential volume change when the tensile strain due to differential volume change exceeds the tensile strain capacity of concrete, it will crack, the temperature differentials associated with the hydration of cement affect the mass concrete such as in large columns, piers, footings dams, etc, whereas the temperature differentials due to changes in the ambient temperature can affect any structure.

4. Cracking due to chemical reactions :-

The most important constituent of concrete is cement in alkaline, so it will react with acidic compounds in presence of moisture and in consequence the matrix will become weak & its constituents may be leached. The concrete may crack as a result of expansive reactions between aggregate containing active silica & alkalies derived from cement hydration, admixture or external sources, the alkali silica reaction results in the formation of swelling gel which tends to draw water from other portions of concrete. this causes local expansion & accompanying tensile stresses. control measures include proper selection of aggregate, use of low-alkali & use of pozzolana.

5. Cracking due to weathering :-

The environmental factors that can cause cracks include (i) freezing & thawing, (ii) wetting & drying and (iii) heating & cooling. Except in tropical regions, the damage from freezing & thawing is the most common weather related physical deterioration. in the agg. particles saturated above the critical degree of saturation, the expansion of absorbed water during freezing may crack the surrounding cement paste and/or damage the aggregate itself. The control measures include the use of the lowest practical w/c ratio & total water content, durable aggregate & adequate air-entrainment. Adequate curing prior to exposure to freezing conditions is also important. other weathering processes that may cause cracking in concrete are alternate wetting & drying, & heating & cooling.

Cracking due to corrosion of Reinforcement :-

It is the most frequent cause of damage to reinforced concrete structures. this aspect ~~of the~~ cracking problem has been discussed in ~~detail~~ in chapter ~~15~~. However, the salient featur are outlined for ready reference. The corrosion of steel produces iron oxides & hydroxides, which have a volume much greater than the volume of the original matallic iron. This increase in volume causes high radial bursting stresses around reinforcing bars & results in local radial cracks. These splitting cracks may propagate along the bar resulting in the formation of longitudinal cracks parallel to the bar or spalling of concrete.

Cracking due to poor construction practices:-

poor construction practices, such as adding water to concrete to improve workability lack of curing inadequate form support, inadequate compaction & arbitrary placement of construction joints, can result in cracking in concrete structure. Adding water to improve workbility has the effect of reducing strength increasing settlement & ultimate drying shrinkag The early termination of curing will allow for increased shrinkage at the time when the concrete has low strength.

but also the durability of the structure.
Lack of support for forms or inadequate compaction can result in the settlement cracking of concrete.

8. Cracking due to construction overloads:
The loads induced during construction can be far more severe than those experienced in service. unfortunately, these conditions may occur at the early ages when the concrete is most susceptible to damage & often result in permanent cracks.
A common error occurs when the precast members are not properly supported during transportation & erection. the use of arb. or convenient lifting points. may cause severe damage. A big element lowered too quickly & stopped suddenly carries significant momentum which is translated into an impact load that may be several times the dead weight of the element.

9. Cracking due to Errors in Design & Detailing:
The design & detailing errors that may result in unacceptable cracking include use of poorly detailed re-entrant corners in walls. Precast members & slabs; Improper selection &/or detailing of reinforcement, restraint of members subjected to volume changes caused by variation in temperature & moisture. lack of adequate contraction joints. & improper design

of foundations resulting in differential settlement within the structure. Re-entrant corners provide a location for stress concentration & therefore, are prime locations for initial cracks, as in the case of window & door openings in concrete walls & dapped beams. Additional anchored diagonal reinforcement is required to keep invitable cracks narrow & prevent from propagating further.

Cracks due to Externally Applied Loads :-

Load induced tensile stresses may result in cracks in concrete elements. A design procedure specifying the use of reinforcing steel, not only to carry tensile forces, but also be obtain both an adequate crack distribution & a reasonable limit on crack width is recommended. Flexural & tensile crack widths can be expected to increase with time for members subjected.

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*Repair of cracks :-

Once the cracked structure has been evaluated & the causes of cracking established, a suitable repair procedure may be selected which takes these causes into account. the methods of crack repair including the characteristics of cracks that may be repaired with each procedure & the types of structure that have been repaired are described in the following sections. the repair of concrete structures is carried out in the following stages.

1. Pretreatment of surface & reinforcem
i.e removal of damaged concrete. This
process is termed as the preparation
surface for repairs.
2. Application of repair material.

Preparation of Surface :-

Prior to the execution of any repair, one
the essential requirements common to
repair techniques is that all deteriorati
or damaged concrete. should be remove
This can be accomplished by using tools & ac
The type of which depends to a large deg
on the size, depth, & extent of repair. For
Smaller Jobs, the removal of concrete c
accomplished by hand tools whereas for la
repairs. the surface can be prepared by
light & medium weight air hammers fit
with spade shaped bits. care should be tak
to avoid any damage to the unaffected
For cracks & other narrow defects, sawtle
bits can be used to obtain sharp edges &
under cuts. the preparation of a surface
repair involves the following steps:

1. Complete removal of unsound material e
2. Undercutting along with the formation of
edges
3. Removal of the cracks from the surface
4. Formation of a well-defined cavity geom
with rounded inside corners.
5. Providing rough but uniform surface for

The surface so prepared should be clean, dry, free of laitance & strong. A clean surface means that there should be no foreign matter such as dirt, loose particles, grease or oil, paints resins, etc. on the surface. Oil, grease & animal fat may be removed by chemical cleaning i.e scrubbing the surface with detergents, caustic soda solution or trisodium phosphate. A vigorous scrubbing action with a stiff broom should be carried out during the washing procedure. The laitance which can be detected by the presence of fine powder on surface, when it is scrapped with knife blade be removed by acid etching. In case of application of overlays, waterproofing or protective barriers, the surface should be uniform.

Repair Techniques :-

The repair of cracked or damaged structures is discussed under two distinct categories, namely, ordinary or conventional procedures & special procedures using the latest techniques & newer materials such as polymers, epoxy resins, etc.

Ordinary procedures :-

Superficial or fine cracks are generally removed by treating the surface with whitewash soft distempers, silicate cement paints, etc.

· Preparation of surface :-

The cracked & deteriorated areas are cut or chipped out to the solid concrete. Application of a sound patch to an unsound surface is meaningless because patch will eventually come out. Any

Attempt surface is ... cause will eventually come out

to short cuts over surface preparation False economy. The area to be chipped out be delineated with a saw cut to a depth about 5mm in order to provide neat edges. The edges should be cut out as straight as possible and right angled to the surface with corners rounded within the hole. The thickness of edges should not be less 25mm to prevent them from breaking under load. The unsound concrete is removed by percussive tools. All the loose material be cleaned & the surface should preferably washed off before actual patching work started.

2. Selection of materials:-

The repair system should be so selected the mechanical properties of the repair material are similar to those of the structure being repaired. Cement-based repairs can fire resistance while resins soften at low temperature.

3. Application of material :-

The methods generally used for filling the material are: (a) drypacking, (b) concrete replacement (c) mortar replacement (d) grouting (e) large volume prepacking concrete (f) shotcreting or guniting.

Drypacking :- The method consists of hand placing of low water content mortar on the prepared surface followed by tamping or ramming of mortar into place, producing an intimate contact between the mortar & the existing concrete. Because of the low water cement ratio of the paste, there is little shrinkage. & the mortar provides a durable, strong & watertight patch.

The repair material usually consists of cement sand mortar in proportions of about 1:2.5 or 1:3 using medium or coarse concreting sand. To minimize the shrinkage in place, the mortar should stand for 30 min after mixing mixing & then remixed prior to use. The repair material should be filled properly in compacted layers of about 10mm thick & each layer should normally be applied as soon as the preceding one is strong enough to support it, the preceding layer should be scratched before placing the succeeding layer to secure a good bond or key. Each before placing the succeeding layer to secure a good bond or key. Each layer is compacted over its entire surface by using a hardwood stick of about 200 - 300 mm length up to 25 mm dia with hammer. The last overflowing layer is struck flush with the surface. There need be no time delays between layers, in case of delay between layers a fresh bonding coat should be applied when work is resumed. The mortar may be finished by laying the flat side of hardwood piece against it and striking it several time with a hammer.

(b) concrete replacement :- In general this method is used for large & deep patches those encountered in the repair of old deteriorated portions of concrete structures ~~when concretes~~ when concrete is to be placed to a minimum depth about 150 mm. the general application this method are in the repair of walls, piers, parapets, kerbs & for resurfacing wall & r... channels. The method is particularly suitable where the holes extend throughout the concrete section or where the surface of hole is at least 0.09 m² with a depth of 100 mm for plain concrete. or 0.045 m² a depth a little more reinforcing steel in case of reinforced concrete. As in case of other types of repaires defective concrete is removed so that the sound surface are exposed & reinforcement cleaned.

(c) mortar replacement :-

The method is suitable for the cavities which are too wide for drypack or too shallow for concrete replacement. Generally it used for shallow depressions no deeper than that of the side of the reinforcing bar nearest to the surface. For replacement of deteriorated concrete, this method is suitable for minor restorations. The mortar replacement can be done by hand or can applied pneumatically by using a small pressure gun

i) Grouting :-

The wide & deep cracks may be repaired by filling them with portland cement grout. The grout mixtures may contain cement & water or cement, sand & water. depending upon the width of the crack. However, the water-cement ratio should be kept as low as practicable to maximize strength & minimize shrinkage. water-reducing admixtures may also be used to improve the properties of the grout. the procedure consists of cleaning the concrete along the crack; providing built-up grout ports at intervals, sealing the crack between the ports with a cement paint or sealant. etc.

Shotcreting or guniting :-

It is mortar or concrete conveyed through pressure hose & applied pneumatically at high velocity onto a surface. this material has found wide applications on vertical, horizontal or overhead surfaces.

The objective of this of repair may be to replace concrete that has been lost or removed, & to increase effective cover to the steel reinforcement to protect the structure against future damage by adding additional concrete. In the preparation of surface to be repaired, All the affected concrete must be cut back to unaffected material.

Curing of the sprayed concrete is even more important than that of conventional cast concrete because thinner section may make water loss easier & more serious. The curing method may include a fine water spray, wetted hessian & curing compound.

4. curing of repaire work :-

The curing of patch material requires more care than that required for a con Structure. There is a tendency of old conc absorbing. moisture from the replacement material.

(a) Horizontal repaired surface can be by ponding or by placing wet gunny

(b) The vertical or inclined repaired sur may be cured using damp hessian or burlap pads.

(c) where the above two methods are applicable. membrane curing can be used Initial curing with water followed by me curing is very effective.

(d) Deliquescent salts which hasten curing keeping the patch moist may also be u

Polymer- based Repairs :-

The polymer concrete includes composit prepared by one of the following methods.

Polymere Impregrated concrete (PIC) :-

This is a portland cement concrete impreg -ated by a monomer system which is subse polymerized by radiation or heat & the of a catalyst.

Polymer cement concrete (PCC) :-

This is a concrete in which the monomer is added during the mixing of portland cement water & aggregate. followed by polymerization or curing of the replaced material after its placement.

Polymer Concrete (PC) :-

This is a composite material obtained by adding a polymer or its precursor to the agg. & polymerizing or curing the materia after its placement.

The concrete polymer materials provide hig strength & improved durability under aggres conditions as compared to conventional concret P/C has proved to be the most sucessful concre polymer material for construction Liquid & gaseous monomers can fully penetrate concre by external pressure & can be polymerize

The polymer systems commonly used are th following:

- methyl-methacrylate (MMA)
- MMA + 10% trimetholpropane trimethacrylat (TMPTA)
- styrene and polyester styrene
- methanol
- vinyl monomer.

The sulfur impregnated concrete using commerc-ially available (99.9%) pure sulfur a practical & inexpensive substitute of polymer cement concretes may be ob by substituting at least 30% of epox for cement in ordinary portland cemen mixes. The addition of fly ash to the e cement mixes is favorable for strength. The polymer-based crack repair can affected as described in the follow sections.

1. Polymer impregnation :-

The technique consists of flooding the dried cracked concrete surface wi monomer which is then polymerized Thus filling & structurally repairing crack. A monomer system is a liquid consists of small organic molecules of combining to form a solid plastic monomer systems used for impregnatio a catalyst or an initiator & the basic They also contain a cross linking agent. heated the monomers join together or becoming a tough, strong & durable plas greatly enhances a number of concrete p

2. Drilling & plugging :-

The method is onl method is only app for the cracks running in reasonably lines & accessible at one ent. It consists drilling a hole down the length of crac grouting it to form a key. A hole 50 – 60 mm in dia should be drilled, centered on & following the crack as its full length & provide sufficient repair material to structurally take the loads exerted on the key. the drilled hole is then cleaned & filled with grout. are problems concerning watertightness.

Common Types of Repairs :-

1. Sealing of Cracks :-

The crack or joint sealers are very important in concrete structures as every concrete structure has cracks or joints. The crack sealers should ensure the structural integrity & serviceability. In addition they provide protection from the ingress of harmful liquids & gases.

The method consists of enlarging the crack along its length on the exposed surface & sealing it with a suitable joint sealant. omission of routing may effect the permanency of repair.

The routing operation consists of cutting a groove at the surface that is sufficiently large to receive the sealant, using a concrete saw or hand tool. A minimum surface width of routing of 6 mm is desirable, as repairing the narrower grooves is difficult

2. Flexible Sealing :-

For repairing an active crack. It is to provide for its continuing movement way to achieve this is to rout chase the crack along its length. the prepared crack is filled with a suitable field flexible sealant with strain capacity being at least as large as the one to be accommodated. A wide crack spreads over a greater width so that the resulting strain is compatible with sealant to be. the sealant must adhere to the sides chase but debonded from bottom so that movement in the crack spreads over the width of the chase.

3 Providing Additional Steel :-

The cracked reinforced elements can successfully repaired using epoxy injection & reinforcing bars. the technique consists sealing the crack, drilling holes of 20mm at 45° to the element surface & cross the crack plane at approximately 90° Re bars are placed in to the drilled holes the holes & the crack plane is filled with epoxy pumped under low pressure varying from 0.35 to 0.55 mpa. Typically, 12 or 16mm dia bars extending at least 500mm each side of the crack are used. the reinforcing bars can be spaced to suit the needs of the repair & design criteria the epoxy bonds the bar to the sides

f the hole, fill the crack plane & brings
he cracked concrete surface back to the
monolithic form.

n elastic exterior crack sealant is required
or a sucessful repair. Gel-type epoxy crack
sealants are useful. the sealant should be
applied in a uniform layer approximatly
.5 -2.5 mm thick & shall span the crack
by least 20mm on each side.

Stitching of cracks:-

The stitching procedure consists of drilling
oles on both sides of the crack, cleaning the
oles & anchoring the legs of the stitching
dogs that span the crack, with either a non
hrink grout or an epoxy resin. based bondin
ystem the stitching dogs should be variable
length & orientation or both & should be
located that the tension transmitted across
he crack is not applied to a single plane
within the section but spread ove an area.
e spacing of stitching dogs should be reduced
at the end of cracks.

Repair by Jacketing:-

Jacketing is a process of fastening a
rable material e.g. fiber glass over the
isting concrete & filling the gap with a
rout that the provides the needed performan
aracteristics. the jacketing thus restores
r increases the section of an existing
ember by encasement in a new concrete

The technique is applicable for protecting the member against further deteriorating as well as for strengthening.

6. Autogenous Heeling :-

The natural process of crack repair known as autogenous heeling has a practical application in closing doremant cracks a moist environment. Such a case may found in ass concrete structures. Heeling occure through the carbonation of calcium hydroxide in cement paste by carbon dioxide, which is present in surrounding aire & water. calcium carbonate & calcium carbonate & calcium hydroxide crystals precipitate, accumulate & grow within the cracks. the crystals interlace & twine. producing a mechanical bonding effect which is supplemented by a chemical bond between adjacent crystals, & between the crystals & the surface of the paste & aggregate. As a result, some of the tensile strength of the concrete is restored across the cracked section, & the crack may become sealed.

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