UNIT 5
SPECIAL CONCRETE

Light weight concrete - High density concrete - Self compacting concrete - High pressure concrete - No fines concrete - Hot weather concreting, Under water converting - Vacuum concrete - Ferro cement - Polymer concrete, High strength and High performance concrete - Shotcrete process - Geopolymer concrete.

LIGHT WEIGHT CONCRETE

Light weight concrete (foamed concrete) is a versatile material which consists primarily of a cement based mortar mixed with at least 20% of volume air. The material is now being used in an ever increasing number of applications, ranging from one step house casting to low density void fills. Light weight concrete is a special concrete which weighs lighter than conventional concrete. The density of this concrete is considerably low (300 kg/m3 to 1850 kg/m3) when compared to normal concrete (2200kg/m3 to 2600kg/m3).

Three types of LWC

- Light weight aggregate concrete - UK, France & USA
- Aerated concrete - Scandinavian countries
- No – fines concrete is less popular

Lightweight and free flowing, it is a material suitable for a wide range of purposes such as, but not limited to panels and block production, floor and roof screeds, wall casting, complete house casting, sound barrier walls, floating homes, void infill, slope protection, outdoor furniture and many more applications.

Lightweight Concrete

<u>Structural light weight concrete</u>

- Concrete which is light weight and has sufficient compressive strength.
- 28 days compressive strength of more than 17Mpa and 28 days dry density not exceeding 1850 kg/m^3.
- Generally have normal fine aggregates and lighter coarse aggregates.
- Workability is less due to water absorption by the aggregates.
- Drying shrinkage is more and less thermal expansion than normal concrete.
- Is good in sound proofing, sound absorption & thermal insulation.
- Economical when compared to normal weight concrete.
- Has good fire resistance property than conventional concrete.

<u>Case study for LWC</u>

SAND KEY CONDOMINIUMS PHASE II
Clearwater, Florida
U.S.A.

High strength lightweight concrete is increasingly utilized in office buildings and residential buildings in order to achieve long clear spans. In early 2000 the Sand Key Condominiums were constructed in the Sand Key Beach resort area near Tampa, Florida, U.S.A..

Mix design of LWC

- Difficult to decide water – cement ratio, due to variable water absorption by aggregates.
- Generally done by trial mixing.
- Pre – saturation of aggregates is done to avoid excessive absorption of water by aggregates.
- Concrete with saturated aggregates will have higher density, which is bad in freezing & thawing action.
- In rare cases, aggregates are coated with bitumen to overcome the water absorption problem.

NO-FINES CONCRETE

- It is a type of light weight concrete produced by omitting the fine aggregates from conventional concrete.
- This concrete has only cement, coarse aggregate and water.
- Due to absence of fine aggregates, concrete will have large voids, resulting in light weight.
- Even though there is reduction in strength, there is no capillary movement of water, resulting in low permeability and consequently more durable.
- Density of concrete will be less if coarse aggregates are of single size ranging from 10mm to 20mm rather than well grade aggregates.
- No–fines concrete with lighter coarse aggregates; we can get density as low as 640 kg/m^3.
- In this concrete, strength criteria depend on cement content in the concrete than water/ cement ratio.
- Drying shrinkage is comparatively less. But shrinkage takes place rapidly than conventional concrete.
- Thermal conductivity is also comparatively less.
- No – fines concrete has better architectural appearance.

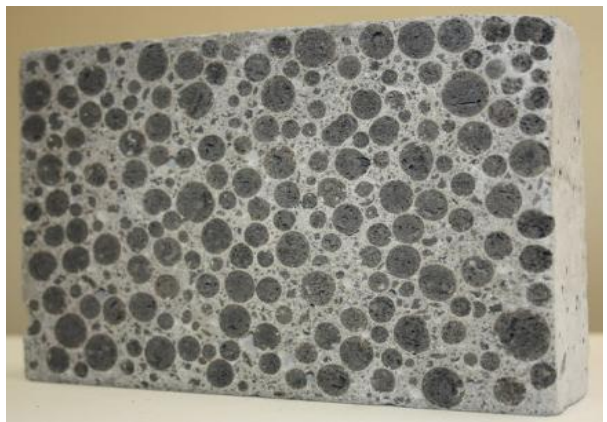
No-fines Concrete

No-fines concrete is usually used for both load bearing and non-load bearing for external walls and partitions. The strength of no-fines concrete increases as the cement content is increased. However, it is sensitive to the water composition. Insufficient water can cause lack of cohesion between the particles and therefore, subsequent loss in strength of the concrete. Likewise too much water can cause cement film to run off the aggregate to form laitance layers, leaving the bulk of the concrete deficient in cement and thus weakens the strength.

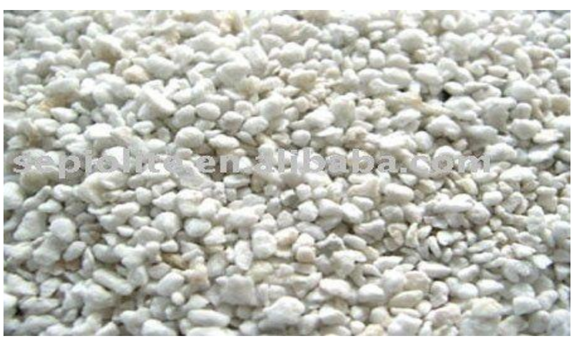
<u>LIGHTWEIGHT AGGREGATE CONCRETE</u>

- Basically two types of light weight aggregates
    - Natural aggregates
    - Artificial aggregates
    - Natural light weight aggregates are less preferred over artificial aggregates.
- Important natural aggregates – Pumice & Scoria
- Artificial aggregates are usually produced by expanding the rocks such as Shale, Slate, Perlite, Vermiculite, etc.,
- Type of aggregates decides the density of concrete.
- Density of concrete as low as 300 kg/m3 can be achieved.
- Compressive strength varies from 0.3Mpa to 40Mpa.

Natural light-weight aggregate	Artificial light-weight aggregate
(a) Pumice	(a) Artificial cinders
(b) Diatomite	(b) Coke breeze
(c) Scoria	(c) Foamed slag
(d) Volcanic cinders	(d) Bloated clay
(e) Sawdust	(e) Expanded shales and slate
(f) Rice husk	(f) Sintered fly ash
	(g) Exfoliated vermiculite
	(h) Expanded perlite
	(i) Thermocole beads.



Lightweight Aggregate Concrete



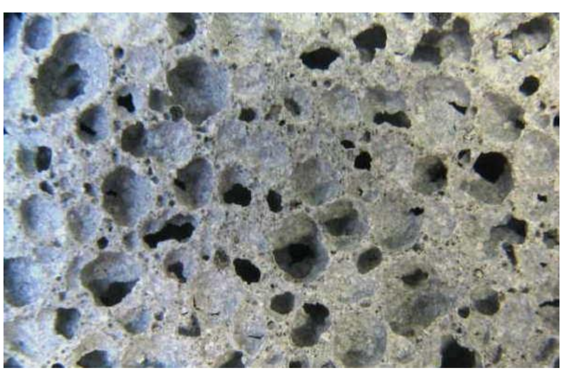
Expanded Perlite ***Exfoliated Vermiculite***

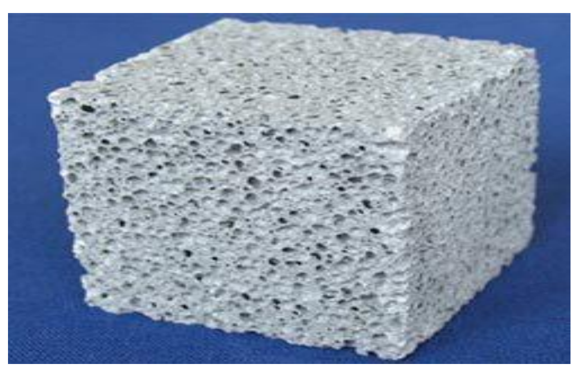
Properties of light weight aggregates

- Pumice and Scoria are volcanic rocks having densities between 500kg/m^3 to 900kg/m^3.
- Natural aggregates have good insulating properties but subjected to high absorption and shrinkage.
- Among artificial aggregates, Perlite & Exfoliated Vermiculite gives lowest possible dense concrete. (Perlite – 30kg/m3 to 240 kg/m3 and Vermiculite 60kg/m3 to 130kg/m3).
- Light weight aggregates have higher apparent specific gravity than conventional aggregates.
- Properties of artificial aggregates are less variable than natural aggregates.
- Light weight aggregates have a tendency to absorb more water than conventional aggregates.
- Semi – light weight concrete with normal fine aggregates and lighter coarse aggregates is better than all light weight aggregates.
- In case of RCC structures, increase the cover by 10mm extra, to avoid corrosion steel.
- Light weight aggregates have harsh surface. Add pozzolanic materials to improve workability.

AERATED/FOAMED CONCRETE

Aerated concrete does not contain coarse aggregate, and can be regarded as an aerated mortar. Typically, aerated concrete is made by introducing air or other gas into a cement slurry and fine sand. In commercial practice, the sand is replaced by pulverized- fuel ash or other siliceous material, and lime maybe used instead of cement. The figure below shows the aerated concrete.





Aerated/Foamed Concrete

- Produced by introducing air into the concrete.
- It is also called cellular concrete having voids between 0.1mm to 1mm size.
- Two ways are there to induce the air in concrete.
    - Gas concrete
    - Foamed concrete
    - Gas concrete is produced by chemical reaction in which gas is produced in the concrete.
- Finely divided aluminum powder is generally used as gas producing agent.
- Its quantity is about 0.2% of weight of cement.
- Aluminum powder reacts with Ca (OH)2 to liberate hydrogen bubbles.

There are ***two methods*** to prepare the aerated concrete. The first method is *to inject the gas into the mixing during its plastic condition by means of a chemical reaction*. The second method, *air is introduced either by mixing-in stable foam or by whipping-in air, using an air-entraining agent*. The *first method* is usually used in precast concrete factories where the precast units are subsequently autoclaved in order to produce concrete with a reasonable high strength and low drying shrinkage. The *second method* is mainly used for in-situ concrete, suitable for insulation roof screeds or pipe lagging. The differences between the types of lightweight concrete are very much related to its aggregate grading used in the mixes.

No-fines Concrete	*Light-weight aggregate concrete*	*Aerated Concrete*	
		Chemical aerating	*Foaming mixture*
(*a*) Gravel	(*a*) Clinker	(*a*) Aluminium powder method	(*a*) Preformed foam
(*b*) Crushed stone	(*b*) Foamed slag	(*b*) Hydrogen peroxide and bleaching powder method	(*b*) Air-entrained foam
(*c*) Coarse clinker	(*c*) Expanded clay		
(*d*) Sintered pulverised fuel ash	(*d*) Expanded shale		
(*e*) Expanded clay or shale	(*e*) Expanded slate		
(*f*) Expanded slate	(*f*) Sintered pulverised fuel ash		
(*g*) Foamed Slag	(*g*) Exfoliated vermiculite		
	(*h*) Expanded perlite		
	(*i*) Pumice		
	(*j*) Organic aggregate		

Advantages and Disadvantages of Lightweight Concrete

Advantages

- Reduces the dead load of the building.
- Easy to handle and hence reduces the cost of transportation and handling.
- Improves the workability.
- Relatively low thermal conductivity
- Comparatively more durable. But less resistant to abrasion.
- Have applications in pre-stressed concrete, high rise buildings & shell roofs.
- Good resistance to freezing & thawing action when compared to conventional concrete.
- Helps in disposal of industrial wastes like fly ash, clinker, slag etc.

Disadvantages

- Very sensitive with water content in the mixtures
- Difficult to place and finish because of the porosity and Angularity of the aggregate.
- In some mixes the cement mortar may separate the aggregate and float towards the surface
- Mixing time is longer than conventional concrete to assure proper mixing

BASIC PRINCIPLES OF LIGHTWEIGHT CONCRETE

The basic principle behind the making of light weight concrete is by inducing the air in concrete.

To achieve the above principle practically, there are 3 different ways.

- By replacing the conventional mineral aggregates by cellular porous aggregates
- By incorporating the air or gas bubbles in concrete (Aerated concrete).
- By omitting the sand from the concrete (No- fines concrete).

TESTING PROGRAM OF LIGHTWEIGHT CONCRETE

In order to study the behavior of lightweight concrete, normal concrete testing was done to determine the material and structural properties of each type of lightweight concrete and how will these properties differ according to a different type of mixture and its composition. Once concrete has hardened it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics. For new concrete this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures.

COMPRESSIVE STRENGTH

Compressive strength is the primary physical property of concrete (others are generally defined from it), and is the one most used in design. It is one of the fundamental properties used for quality control for lightweight concrete. Compressive strength may be defined as the measured maximum resistance of a concrete specimen to axial loading. It is found by measuring the highest compression stress that a test cylinder or cube will support.

There are three type of test that can be use to determine compressive strength; cube, cylinder, or prism test.

WATER ABSORPTION

These properties are particularly important in concrete, as well as being important for durability. It can be used to predict concrete durability to resist corrosion. Absorption capacity is a measure of the porosity of an aggregates; it is also used as a correlation factor in determination of free moisture by oven-drying method. The absorption capacity is determined by finding the weight of surface-dry sample after it has been soaked for 24 hr and again finding the weight after the sample has been dried in an oven; the difference in weight, expressed as a percentage of the dry sample weight, is the absorption capacity. **A**bsorption capacity can be determine using BS absorption test. The test is intended as a durability quality control check and the specified age is 28-32 days.

DENSITY

The density of both fresh and hardened concrete is of interest to the parties involved for numerous reasons including its effect on durability, strength and resistance to permeability. Hardened concrete density is determined either by simple dimensional checks, followed by weighing and calculation or by weight in air/water buoyancy methods.

High Density Concrete (HDC)

High density concrete is also known as Heavy weight concrete. *High density concrete* is mainly used for the purpose of radiation shielding, for counterweights and other uses where high density is required.

<u>Main Components</u>

- Cement
  - Provides limited strength
  - Not that useful in high density concrete
  - Used as binding material
- Water
- Aggregates
- ***Admixtures*** - Water reducing admixture is used. It consists of Lignosulfonic acid, carboxylic acids
    - Use of Water reducing admixture in high density concrete
    - Increase workability
    - Reduces water requirement
    - Reduces cement content requirement
    - High early strength

The high density concrete has a better shielding property, so that it can protect harmful radiations like X-rays, gamma rays, and neutrons. High density aggregates are used to achieve heavy weight concrete.

Some of the high density aggregates are barite, Ferro-phosphorus, limonite, hematite, ilmenite, magnetite, goethite, steel punching, and steel shots. The point to remember is that in order to achieve this type of concrete, high fixed water content is required.

The selection of the above mentioned aggregates mainly depend upon the physical properties like bulk density, specific gravity, availability of materials, and its expenses.

In order to achieve workability, high density the aggregates should be free from dirt, oil or grease stains and other foreign matter. Or else, it will retard the hydration process and the effective bonding of particles. Some of the boron additions like colemanite, borocalcite are used in the preparation of concrete to improve the shielding properties. These additions may affect the setting time of concrete so; trial mixes should be made and tested depending upon the suitability.

Applications of HDC

- High density radiation shielding
- Precast blocks
- Mass concrete projects
- High density concrete applications columns
- Gravity seawall, coastal protection & breakwater structures
- Bridge counterweights
- Ballast for ocean vessels
- Off shore platforms noise and vibration dampening

Advantages

- High neutron and gamma ray attenuation
- Good mechanical properties
- Relatively low initial and maintenance cost
- Easy to construct

Disadvantages

- Space
- Weight

Proportioning, mixing and placing of High Density Concrete

- The mix proportions for these high density concrete is same as that of normal concrete.
- Conventional method of mixing and placing is used in high density concrete. The most important thing is to prevent overloading the mixer especially when heavy weight aggregates such as steels are used. Batch sizes should be reduced to 40 to 50% of the allowable mixer capacity. Also avoid excess mixing because it will result in workability and bleeding of concrete.
- Preplaced aggregate methods can be adopted when placing heavy weight concrete. In this method the aggregates are placed in forms, the appropriate grout made of cement, sand and water is pumped over the placed aggregates, so that they can fill the voids in between the aggregates. This method prevents the segregation of coarse aggregates also reduces drying shrinkage and helps us to achieve concrete of uniform density and composition.
- Puddling method can also be adopted. In this method, the mortar is placed in forms of 2″ thick and the coarse aggregates are placed over it and vibrated internally. Care should be taken that, the coarse aggregates are distributed evenly.
- Pumping of heavy weight concrete can be adopted only the height is limited. The heavy weight concrete cannot be pumped to larger distances because of their greater densities.
- They are mainly used in the construction of radiation shields (medical or nuclear). Offshore, heavyweight concrete is used for ballasting for pipelines and similar structures
- The ideal property of normal and high density concrete are high modulus of elasticity , low thermal expansion , and creep deformation
- Because of high density of concrete there will be tendency for segregation. To avoid this pre placed aggregate method of concreting is adopted.
- High Modulus of Elasticity, Low thermal Expansion, Low elasticity and creep deformation are ideal properties.
- The high density. Concrete is used in construction of radiation shields. They are effective and economic construction material for permanent shielding purpose.
- Most of the aggregate specific gravity is more than 3.5

SELF-COMPACTING CONCRETE (SCC)

By the early 1990's, Japan has developed and used SCC. Self compacted concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of formwork under its self weight. Thus SCC eliminates the vibration for the compaction of concrete without affecting its engineering properties. As of the year 2000, SCC used for prefabricated products (precast members) and ready mixed concrete (cast-in-situ) in JAPAN, USA and later on INDIA etc.

Development of SCC

- In 1983, the problem of the durability of the concrete structures was a major topic of interest in Japan.
- The creation of durable concrete structures requires adequate compaction by skilled workers.
- Solution for the achievement of durable concrete structures independent of the quality construction work is the use of SCC.
- The necessity of this type of concrete was proposed by Okamura in 1986.
- Studies to develop SCC have been carried out by Ozawa and Melawi at the University of Tokyo.
- Present-day SCC can be classified as an advanced construction material.

Constituents of SCC

With regard to its composition, SCC consists of the same components as conventionally vibrated concrete, which are

- Cement
- Aggregates
- Water
- Chemical Admixtures i.e. super plasticizers and Viscosity Modifying Agents
- Mineral Admixtures i.e., fly ash, Silica Fume etc.

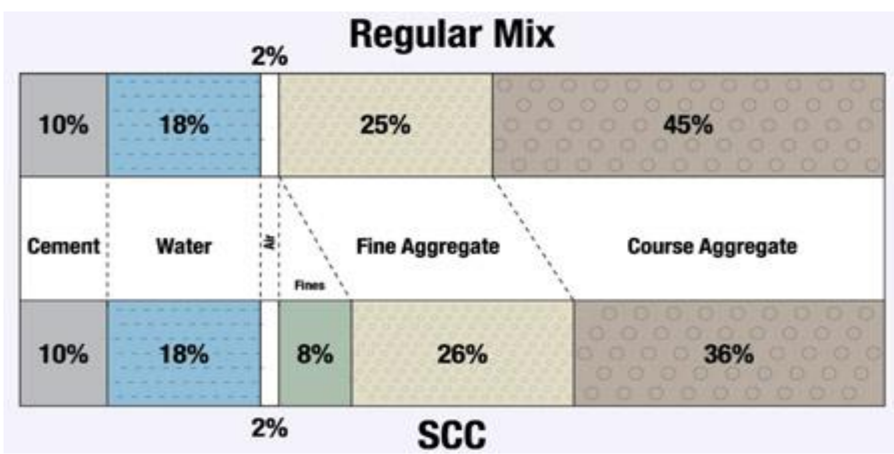
Typical mix proportion values

Constituent	**Typical range by volume(liter/m^3)**
Powder	160-240
Water	150-210
Coarse aggregate	270-360
water to powder ratio	0.80-1.10
Fine aggregate	48-55% of total aggregate weight

Properties of SCC

- **Filling ability (excellent deformability) -** flows easily at suitable speed into formwork
- **Passing ability (ability to pass reinforcement without blocking) -**passes through reinforcements without blocking
- **High resistance to segregation-** the distribution of aggregate particles remains homogeneous in both vertical and horizontal directions
    - Static segregation due to gravity, vertical direction
    - Dynamic segregation due to flow, horizontal direction

Comparison between Conventional Concrete and SCC

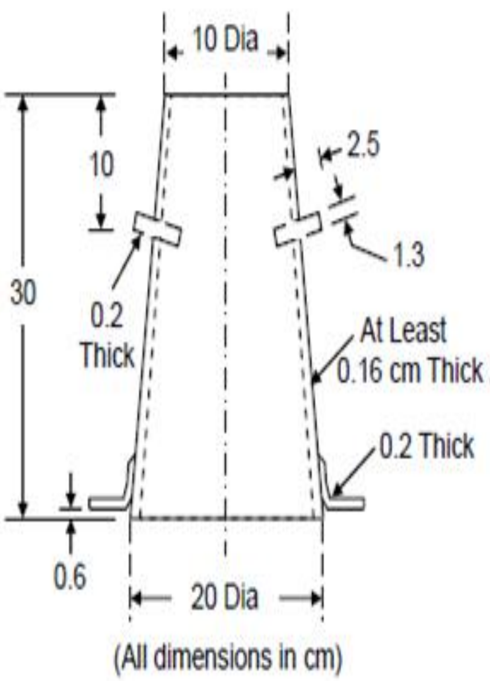


__Measurement of SCC flow properties in fresh state__

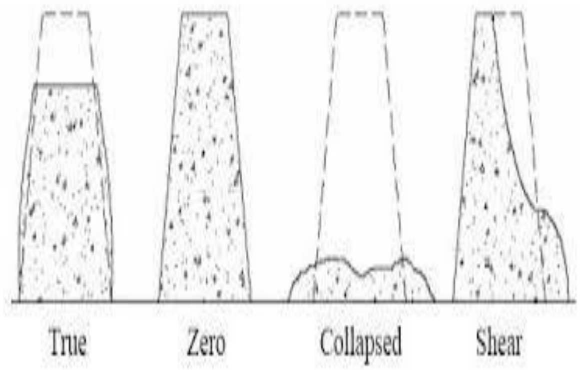
1. **SLUMP FLOW & T_{50} TEST**
2. **L-BOX TEST**
3. **V-FUNNEL TEST AND V-FUNNEL TEST AT $T_{5MINUTES}$**

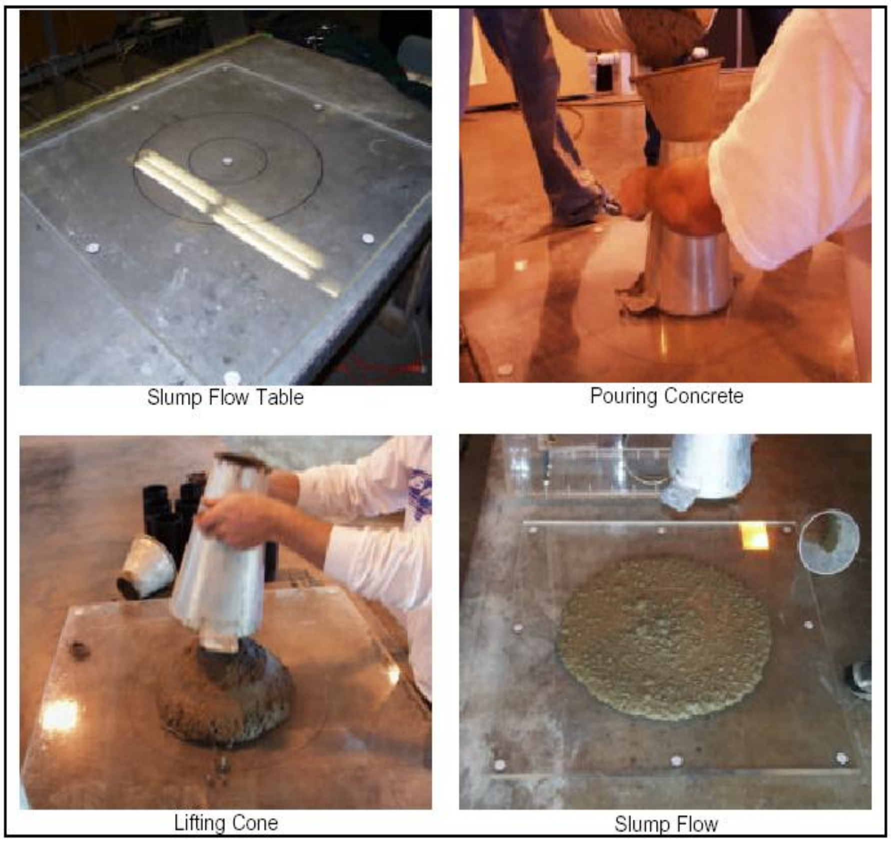
__Slump Flow & T_{50} test__

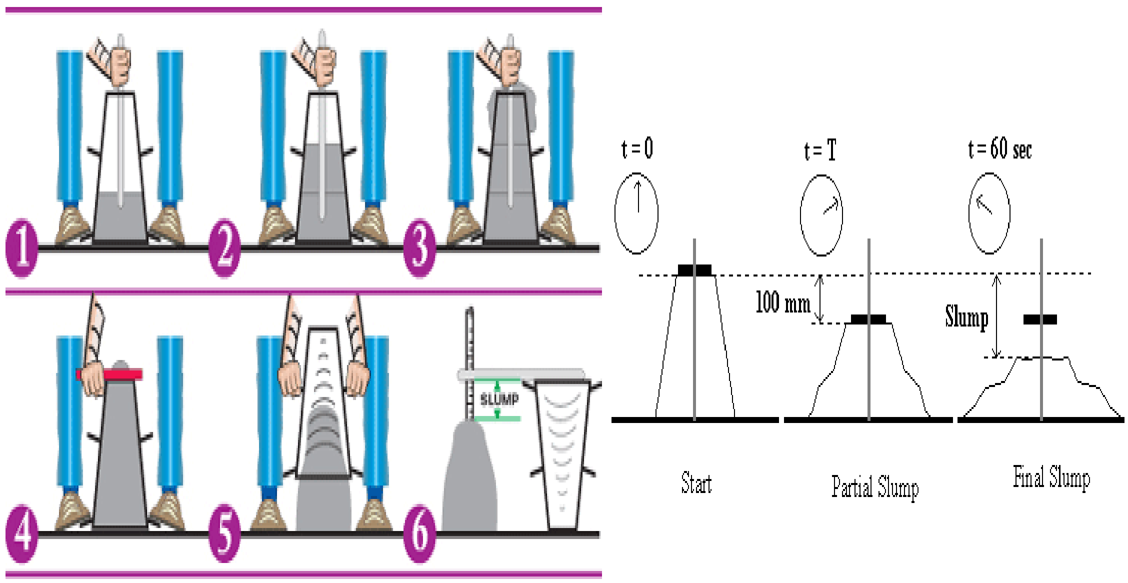
- Slump flow test is used to find the filling ability of the SCC.
- The SCC sample is poured in to the slump cone then the slump flow diameter is measured.
- The flow time is measured & that is known as T_{50} slump time.
- The higher the slump flow value, the greater its ability to fill formwork under its own weight.




TMi


True
Zero
Collapsed
Shear


Slump Flow Table
Pouring Concrete
Lifting Cone
Slump Flow

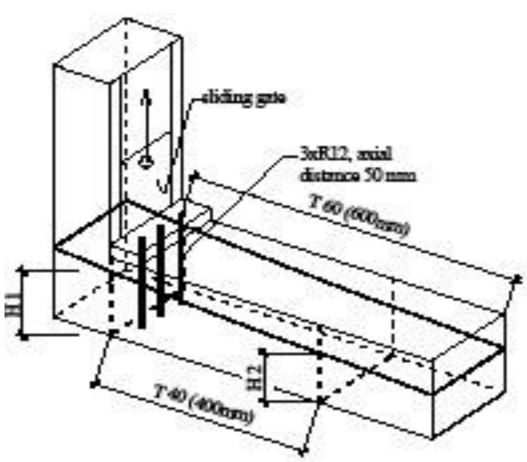


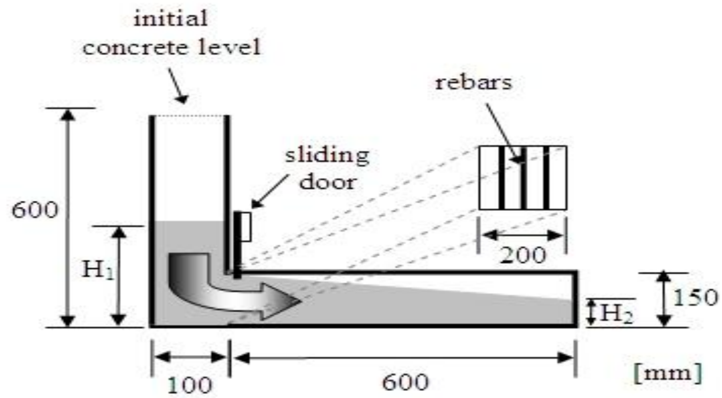
Slump Flow test apparatus

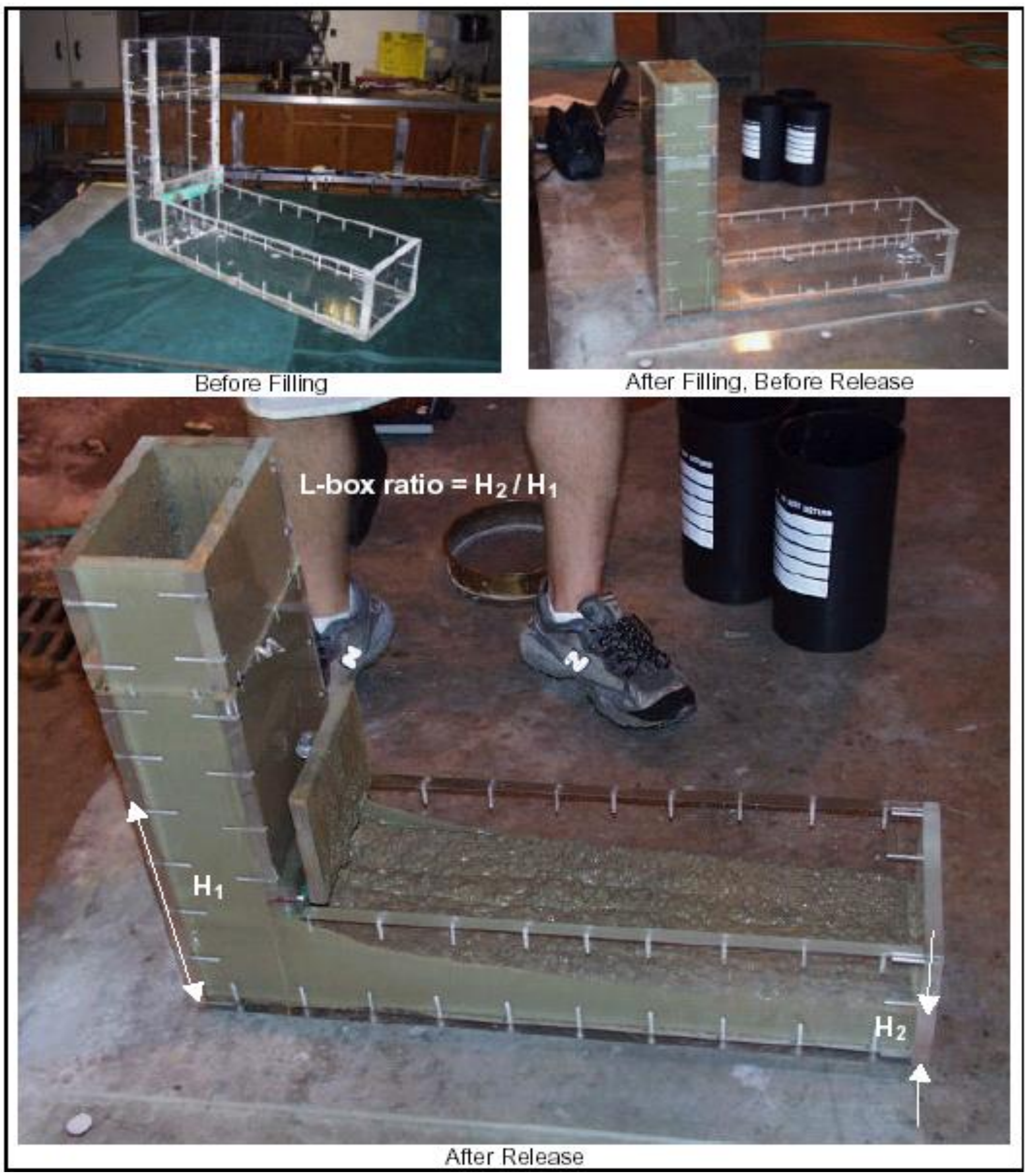
L-BOX TEST

- The L-Box test is used to find the passing ability of SCC.
- The SCC sample is poured in to the L-Box apparatus, now the plate is removed to allow flow.
- The L-box ratio is calculated as H_2/ H_1.

  - According to EFNARC, when the ratio of h_2 to h_1 is larger than 0.8, self compacting concrete has good passing ability.



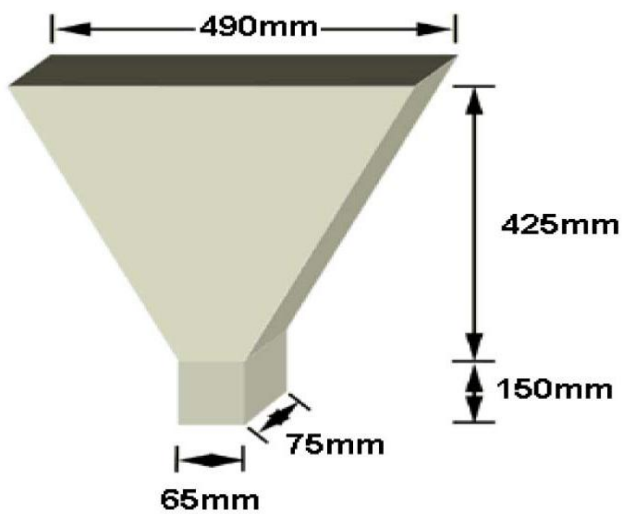

initial
concrete level
rebars
sliding
door
600
H_1
200
150
H_2
100
600
[mm]


Before Filling
After Filling, Before Release
L-box ratio = H_2 / H_1
H_1
H_2
After Release

V-FUNNEL TEST AND V-FUNNEL TEST AT $T_{5\ MINUTES}$

- The V-Funnel test is used to find the Segregation Resistance of SCC.
- The SCC sample is poured in to the V-Funnel apparatus, now it's allowed to flow by its weight.
- The emptying time of V-Funnel is noted.

This test measured the ease of flow of the concrete, shorter flow times indicate greater flow ability. After 5 minutes of setting, segregation of concrete will show a less continuous flow with an increase in flow time.



Test Results on Fresh Concrete and Acceptance Criteria for SCC									
S. No	**Method**	**Unit**	**Water/Cement Ratio**					**EFNARC Specification**	**Remarks**
			0.23	**0.24**	**0.25**	**0.26**	**0.27**		
1	Slump Flow Test	mm	655	660	665	680	700	SF1: 550-650 SF2: 660-750 SF3: 760-850	SF2
2	T500	sec	3.94	3.88	3.82	3.32	2.50	VS1: T500 ≤ 2 VS2: T500 > 2	VS2
3	V-Funnel	sec	8.50	8.35	8.10	7.95	6.8	VF1: ≤ 8 VF2: 9-25	VF2
4	T_5min	sec	11.8	10.9	10.6	10.23	9.9		
5	L-Box	h2/h1	0.95	0.95	0.96	0.975	0.9	PA1> 0.8 (2 rebars) PA2> 0.8 (3 rebars)	PA2
6	U-Box	mm	9	7	6	5	4	0-30	OK

ADVANTAGES OF SCC

- Elimination of problems associated with vibration.
- Faster construction
- Improves working conditions and productivity in construction industry.
- Greater freedom in design.
- Less noise from vibrators and reduced danger from hand-arm vibration syndrome (HAVS).
- Ease of placement results in cost savings through reduced equipment and labor requirement.
- Improves the quality, durability, and reliability of concrete structures due to better compaction and homogeneity of concrete.
- Reduced wear and tear on forms from vibration.
- Reduced permeability.

DISADVANTAGES OF SCC

- More precise measurement and monitoring of the constituent materials.
- Requires more trial batches at laboratory as well as at ready-mixed concrete plants.
- Costlier than conventional concrete based on concrete material cost (exception to placement cost).
- Lack of globally accepted test standards and mix designs
- More stringent requirements on the selection of materials

NO FINES CONCRETE

No-Fines Concrete is a method of producing light concrete by omitting the fines from conventional concrete. No-fines concrete as the term implies, is a kind of concrete from which the fine aggregate fraction has been omitted. This concrete is made up of only coarse aggregate, cement and water. Very often only single sized coarse aggregate, of size passing through 20 mm retained on 10 mm is used. No-fines concrete is becoming popular because of some of the advantages it possesses over the conventional concrete.

The single sized aggregates make a good no-fines concrete, which in addition to having large voids and hence light in weight, also offers architecturally attractive look.

The fine aggregate is not added in this concrete so that there are voids left in the coarse aggregate. The coarse aggregate may be any of the usual type or the light weight aggregate. The coarse aggregate used should be finer than 20 mm size and not more than 10% should pass the 10 mm sieve. The usual proportion of cement to aggregate is 1:10 in case of heavy aggregate and 1:6 in case of light aggregate. The amount of water should be just sufficient to give a coating of cement paste on all particles. Too little water may leave loose aggregate inside the concrete and too much of water may cause the cement paste to flow and segregate. It is better to wet the aggregate before adding cement and water. The concrete should then be mixed thoroughly till all the particles are coated. Properly prepared concrete will not segregate during placing. It does not need any water tight forms also. It should be rammed but only rodded to remove large cavities. This concrete cannot be easily cut away afterwards and all fixtures etc. should be placed in the green state. It has no resistance t penetration of water and suitable rendering may be applied on its external surface.

Properties of no fines concrete

- It does not segregate
- The density varies with the grading of aggregates
- Water cement ratio of this concrete varies from 0.38 to 0.52
- Its strength increases with time
- There is very little cohesiveness, necessitating longer duration of form work removal.
- Shrinkage of this concrete is lower than normal concrete and its thermal expansion is about 0.6 to 0.8 of normal concrete.

Limitations of no fines concrete

- It disintegrates rapidly
- It is unsuitable for foundations and in places continuously in touch with moisture, because of its high absorption quality.
- It is also not suitable for reinforced concrete.

Mix-proportion of No-Fines Concrete

No-fines concrete is generally made with the aggregate/cement ratio from 6 : 1 to 10 :1. Aggregates used are normally of size passing through 20 mm and retained on 10 mm. Unlike the conventional concrete, in which strength is primarily controlled by the water/cement ratio, the strength of no-fines concrete, is dependent on the water/cement ratio, aggregate cement ratio and unit weight of concrete.

The water/cement ratio for satisfactory consistency will vary between a narrow range of 0.38 and 0.52. Water/cement ratio must be chosen with care. If too low a water/cement ratio is adopted, the paste will be so dry that aggregates do not get properly smeared with paste which results in insufficient adhesion between the particles. On the other hand, if the water/cement ratio is too high, the paste flows to the bottom of the concrete, particularly when vibrated and fills up the voids between the aggregates at the bottom and makes that portion dense. This condition also reduces the adhesion between aggregate and aggregate owing to the paste becoming very thin.

No standard method is available, like slump test or compacting factor test for measuring the consistency of no-fines concrete. Perhaps a good, experienced visual examination and trial and error method may be the best guide for deciding optimum water/cement ratio.

No-fines concrete, when conventional aggregates are used, may show a density of about 1600 to 1900 kg/m3, but when no-fines concrete is made by using light weight aggregate, the density may come to about 360 kg/m3. No-fines concrete does not pose any serious problem for compaction. The use of mechanical compaction or vibratory methods is not required. Simple rodding is sufficient for full compaction.

No-fines concrete does not give much side thrust to the formwork as the particles are having point to point contact and concrete does not flow. Therefore, the side of the formworks can be removed in a time interval shorter than for conventional concrete. However, formwork may be required to be kept for a longer time, when used as a structural member, as the strength of concrete is comparatively less. The compressive strength of no-fines concrete varies between 1.4 MPa to about 14 MPa. Table 12.5 shows the compressive strength of no-fines concrete.

The bond strength of no-fines concrete is very low and, therefore, reinforcement is not used in conjunction with no-fines concrete. However, if reinforcement is required to be used in no-fines concrete, it is advisable to smear the reinforcement with cement paste to improve the bond and also to protect it from rusting.

HOT AND COLD WEATHER CONCRETING

It is generally well recognized that when concrete has to be mixed and placed in either very hot or very cold weather, it is necessary to take precautions to ensure that the concrete is not damaged or adversely affected by the ambient weather conditions. At temperatures below freezing, for example, freshly placed concrete may be damaged by the formation of ice within its pore structure. In very hot weather the concrete may stiffen prematurely, preventing it from being compacted and finished properly, or the temperature of the concrete may rise to the point where thermal cracking occurs as it cools. It is perhaps not so well recognized, however, that even at moderate air temperatures, strong dry winds can cause concrete to dry out prematurely and to crack.

There are a few fixed rules on what constitutes hot or cold weather in respect of concreting operations. NZS 3109 Concrete Construction discusses the range 5°C to 30°C and AS 1379 The Specification and Manufacture of Concrete to be within the range of 5°C to 35°C at the point of delivery. Precautions will always be necessary when ambient air temperatures lie outside this range.

Concreting in Hot Weather

The effects of high temperatures can be summarized as follows:

- Shorter setting times and early stiffening
- Increased rates of hardening
- Possible 28 day strength loss
- Increased tendency for plastic shrinkage
- Difficulties in placing and finishing
- Danger of cold joints - a cold joint is formed when plastic concrete is placed against concrete that has set and commenced hardening

They may well be necessary, however, at air temperatures within this range, at less than 10°C or more than 30°C, say. At the lower temperatures, the concrete, whilst in no danger of freezing, may take an excessively long time to gain its specified strength. At the higher temperatures, particularly if accompanied by hot dry winds, plastic cracking and premature stiffening of the concrete may take place.

Precautions for hot-weather concreting should be initiated when the ambient temperature is expected to exceed 30 to 35°C. These precautions may consist of one or more of the following practices:

- Dampening forms, reinforcement and sub-base
- Erecting wind breaks and sunshades to protect exposed concrete surfaces
- Cooling concrete ingredients
- (During transport of wet concrete) cooling containers, pipelines, chutes, etc
- Completing the transporting, placing and finishing of concrete as rapidly as is practicable
- Informed usage of set-retarding admixtures (to counter premature stiffening of the fresh mix)
- Immediately following the initial finishing operation, spraying a fine film of aliphatic alcohol over the exposed concrete
- Surface - to limit evaporation and help control plastic shrinkage cracking (this should be repeated as necessary during
- Any subsequent operations up to final finishing)
- Immediate curing after final finishing is complete
- Moist curing to control concrete temperature
- Restricting placing to night time when ambient temperatures are generally lower.

Concreting in Cold Weather

The prime effects of low temperature on freshly placed concrete are:

- A decrease in the rate at which the concrete sets and gains strength, with a resultant increase in the time taken to finish the concrete;
- (at temperatures below freezing) physical damage to the concrete in the form of surface scaling or bursting, and the cessation of hydration.

Precautions which may be taken to protect the concrete in cold weather may consist of one or more of the following practices:

- Providing heaters, insulating materials, and enclosures if sub-zero temperatures are expected
- Using high-early-strength cement
- Heating the raw materials (the temperature of the concrete when it is placed in the forms should be above 5°C)
- Not placing concrete on frozen ground
- Ensuring means of maintaining suitable curing temperatures when using Type GP (general purpose Portland) cement
- the temperature of the concrete should be maintained at 20°C or above for 3 days
- Insulating the concrete (a thick insulating blanket is often sufficient protection for pavements)

Controlling the effects of hot and cold weather Controlling the effects of hot and cold weather		
Aspect	**In Hot Weather**	**In Cold Weather**
Preplanning	Preplan carefully to avoid delays at all stages. Have standby equipment and manpower for all stages. Pay particular attention to speed of application, effectiveness and duration of curing arrangements. Schedule nighttime placement if possible.	Preplan carefully to ensure adequate equipment and manpower available especially if there is a likelihood of temperatures below 0°C.
Concrete	Use water reducing retarding admixtures in the concrete.	Reduce the setting time of the concrete by (in order of effectiveness):

	Reduce the temperature of the concrete by (in order of effectiveness): ➢ Reducing temperature of aggregates ➢ Using liquid nitrogen injections in the mixed concrete ➢ Reducing temperature of mixing water ➢ Using cement with lower heat of hydration ➢ Reducing temperature of cement	➢ heating mixing water (maximum 70°C) ➢ using (chloride-free) accelerating admixture ➢ using higher cement content ➢ using high-early-strength cement
Batching, mixing and transporting	Shade batching, storage and handling equipment or at least paing with reflective paint. Discharge transit mixer trucks as soon as possible.	
Placing and Compacting	Shade reinforcement, formwork and subgrades if possible and spray with water. Ensure that slabs have minimum 'fronts' to which concrete is added. Place concrete in walls and deep beams in shallow layers. Use burlap covers if there is any delay between load deliveries.	Thaw frozen subgrades and heat frozen forms (particularly steel) before placing concrete. Warm, insulate or enclose handling and placing equipment. Avoid delays in handling and placing.

Finishing and Curing	Use sunshades and windbreaks to lengthen finishing time (or, if hot/dry winds present, to control plastic shrinkage cracking). For flatwork, use aliphatic alcohol after initial screeding if hot/dry winds present. Use revibration to correct plastic shrinkage cracking. Use water curing as the preferred method for at least 24 hours.	Maintain concrete temperature until safe strength reached by means of form insulation, insulated covers or heated enclosures. Delay striking of formwork for as long as possible. Avoid thermal shocks and temperature variations within a member. This includes not using cold water for curing, and removing protective measures gradually.

VACUUM CONCRETE

The concrete from which water is extracted by a vacuum process before the hardening takes place is known as vacuum concrete. Vacuum concrete is the effective technique used to overcome this contradiction of opposite requirements of workability and high strength. With this technique both these are possible at the same time.

In this technique, the excess water after placement and compaction of concrete is sucked out with the help of vacuum pumps. This technique is effectively used in industrial floors, parking lots and deck slabs of bridges etc. The magnitude of applied vacuum is usually about 0.08 MPa and the water content is reduced by up to 20-25%. The reduction is effective up to a depth of about 100 to 150 mm only.

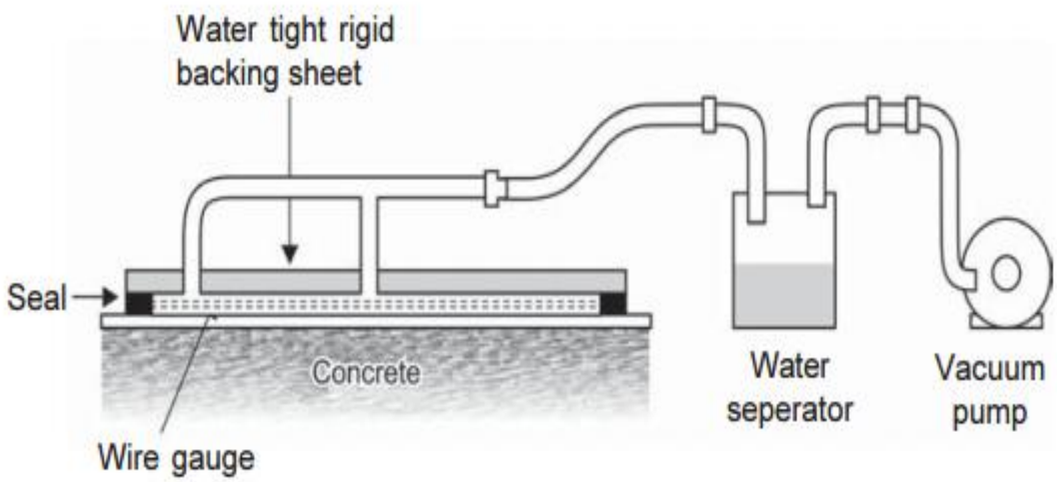
The type of concrete having relatively high slump in order to achieve consolidation is usually useful in case of thin slabs and walls. This is achieved by withdrawing considerable amount of water and air near the surface by use of vacuum mats connected to a vacuum pump.

Technique and Equipments for Vacuum Concrete

The main aim of the technique is to extract extra water from concrete surface using **vacuum dewatering**. As a result of dewatering, there is a marked reduction in effective water-cement ratio and the performance of concrete improves drastically. The improvement is more on the surface where it is required the most.

Mainly, **four components are required in vacuum dewatering of concrete**, which are given below:

1. Vacuum pump
2. Water separator
3. Filtering pad
4. Screed board vibrator

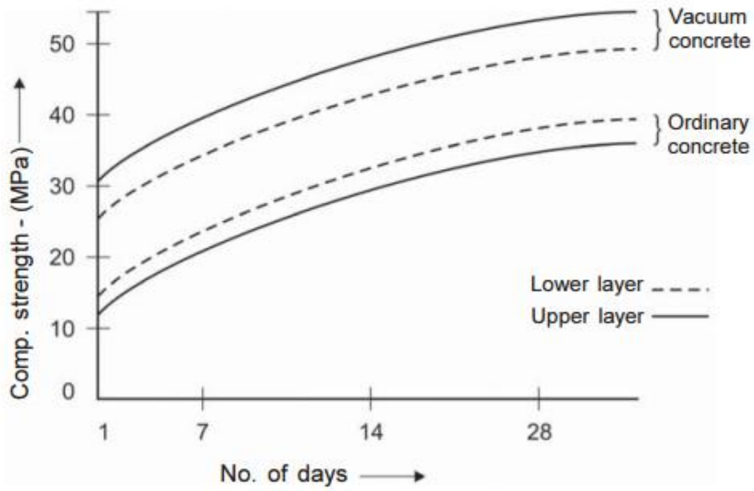


Vacuum pump is a small but strong pump of 5 to 10 HP. Water is extracted by vacuum and stored in the water separator. The mats are placed over fine filter pads, which prevent the removal of cement with water. Proper control on the magnitude of the water removed is equal to the contraction in total volume of concrete. About 3% reduction in concrete layer depth takes place. Filtering pad consists of rigid backing sheet, expanded metal, wire gauge or muslin cloth sheet. A rubber seal is also fitted around the filtering pad as shown in figure. Filtering pad should have minimum dimension of 90cm x 60cm.

Advantages of vacuum concreting

- Due to dewatering through vacuum, both workability and high strength are achieved simultaneously.
- Reduction in water-cement ratio may increase the compressive strength by 10 to 50% and lowers the permeability.

- It enhances the wear resistance of concrete surface.
- The surface obtained after vacuum dewatering is plain and smooth due to reduced shrinkage.
- The formwork can be removed early and surface can be put to use early.



The advantages of dewatering are more prominent on the top layer as compared to bottom layer as shown in figure above. The effect beyond a depth of 150mm is negligible.

FERRO CEMENT

Ferro-cement is a relatively new construction material consists of wire meshes and cement mortar. It was developed by P.L.Nervi, an Italian architect in 1940. Ferro cement is widely used due to the low self weight, lack of skilled workers, no need of framework etc. Quality of ferro-cement works are assured because the components are manufactured on machinery set up and execution time at work site is less. Maintenance cost of ferro-cement is low. Ferro-cement construction has come into widespread use only in the last two decades.


Ferro Cement is

- Highly versatile form of reinforced concrete.
- It's a type of thin reinforced concrete construction, in which large amount of small diameter wire meshes uniformly throughout the cross section.
- Mesh may be metal or suitable material.
- Instead of concrete Portland cement mortar is used.
- Strength depends on two factors quality of sand/cement mortar mix and quantity of reinforcing materials used.

Constituent Materials

- Cement
- Fine Aggregate
- Water
- Admixture
- Mortar Mix
- Reinforcing mesh
- Skeletal Steel
- Coating

Advantages of Ferro-Cement

- Basic raw materials are readily available in most countries.
- Fabricated into any desired shape.
- Low labor skill required.

- Ease of construction, low weight and long lifetime.
- Low construction material cost.
- Better resistance against earthquake.

Disadvantages of Ferro-Cement

- Structures made of it can be punctured by collision with pointed objects.
- Corrosion of the reinforcing materials due to the incomplete coverage of metal by mortar.
- It is difficult to fasten to Ferro-cement with bolts, screws, welding and nail etc.
- Large no of labors required.
- Cost of semi-skilled and unskilled labors is high.
- Tying rods and mesh together is especially tedious and time consuming.

Process of Ferro-cement Construction

- Fabricating the skeletal framing system.
- Applying rods and meshes.
- Plastering.
- Curing

Applications of Ferro-cements

- Housing
- Marine
- Agricultural
- Rural Energy
- Anticorrosive Membrane Treatment.
- Miscellaneous.

Cost Effectiveness of Ferro-Cement Structures

- The type of economic system.
- Type of applications.
- Relative cost of labor.
- Capital and local tradition of construction procedure.
- Doesn’t need heavy plant or machinery.
- Low cost of construction materials.

Recent Applications

- Residential and Public Buildings.

- Industrial Structures.
- Agricultural structures.
- Transportation Structures.

POLYMER CONCRETE

Polymer concrete is conventional concrete made with ordinary Portland cement wet cured, and impregnated with a liquid/gaseous monomer (methyl methacrylate) and polymerized by gamma radiation or chemically initiated means i.e. by using thermal catalytic method (adding 3% by weight benzoyl peroxide) to the monomer as a catalyst. The impregnation is aided by drying the concrete at a higher temperature by evacuations and soaking in the monomer under pressure.

Advantages of polymer concrete

The polymerized products due to very low voids content and quantity of polymer have

- High compressive strength and impact strength
- High resistance to freezing and thawing
- High resistance to abrasion and chemical attack
- Reduced permeability

Applications of polymer concrete

- Polymer concrete is useful in large number of application such as:
- Marine works
- Prefabricated structural elements
- Prestressed concrete
- Nuclear power plants
- Sewage works and desalination plants
- Waterproofing of structures and numerous industrial applications

In spite of the above numerous advantages of use the polymer concrete is very expensive and should be used only when utmost necessary. Many times polymerization of surface layer of concrete is found adequate.

HIGH PERFORMANCE CONCRETE

High performance concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete. This concrete contains one or more of cementious materials such as fly ash, Silica fume or ground granulated blast furnace slag and usually a super plasticizer. The use of some mineral and chemical admixtures like Silica fume and Super plasticizer enhance the strength, durability and workability qualities to a very high extent.

- Any concrete which satisfies certain criteria proposed to overcome limitations of conventional concrete may be called as high performance concrete.
- It may include concrete which provides either substantially improved resistance to environmental influences or substantially increased structural capacity while maintaining adequate durability.

The proportioning (mix design) of High Performance concrete consists of three interrelated steps

1. **Selection of suitable ingredients** – cement, supplementary cementing materials (SCM), aggregates, water and chemical admixtures.
2. **Determination of relative quantities of these materials** in order to produce, as economically as possible, a concrete that has the rheological properties, strength and durability.
3. **Careful quality control** of every phase of the concrete making process.

Composition of HPC

The most common **composition of high performance concrete** as supplementing Cementitious materials or **mineral admixtures** are

1. Silica Fume

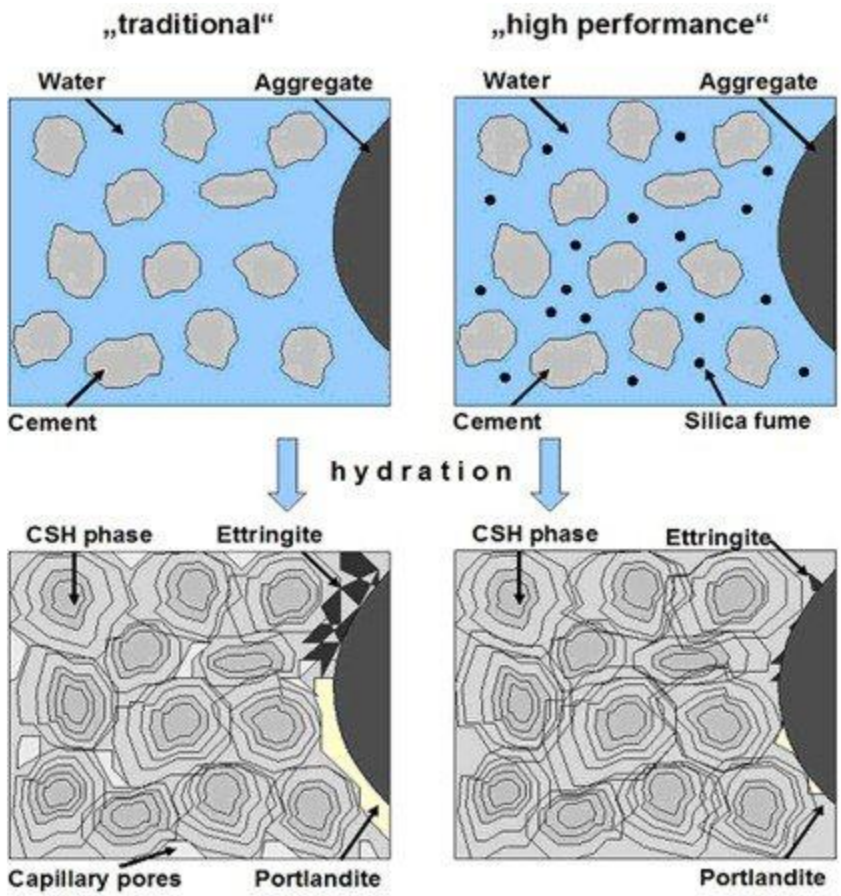
2. Fly Ash

3. GGBFS (Ground granulated blast furnace slag)

1. Silica Fume in HPC - Silica fume is a waste by-product of the production of silicon and silicon alloys. Silica fume is available in different forms, of which the most commonly used now is in a densified form. In developed countries it is already available readily blended with cement. It is possible to make high strength concrete without silica fume, at compressive strength of upto 98 Mpa. Beyond that strength level however, silica fume becomes essential. With silica fume it is easier to make HPC for strengths between 63-98 Mpa.

2. Fly Ash in HPC - Fly Ash of course, been used extensively in concrete for many years. Fly ash is unfortunately much more variable than silica fumes in both their physical and chemical characteristics. Most fly ashes will result in strengths of not more than 70 Mpa. Therefore for higher strengths, silica fume must be used in conjunction with fly ash. For high strength concrete, fly ash is used at dosage rates of about 15 % of cement content.

3. Ground granulated blast furnace slag (GGBFS) in HPC - Slags are suitable for use in high strength concrete at dosage rates between 15-30 %. However, for very high strengths, in excess of 98Mpa, it is necessary to use the slag in conjunction with silica fumes.



Key Features of High Performance Concrete (HPC)

- Compressive strength > 80 MPa ,even upto 800 MPa
- Water-binder ratio =0.25-0.35 ,therefore very little free water
- Reduced flocculation of cement grains
- Wide range of grain sizes
- Densified cement paste
- No bleeding – homogeneous mix
- Less capillary porosity
- Discontinuous pores
- Stronger transition zone at the interface between cement paste and aggregate
- Low free lime content
- Endogenous shrinkage
- Powerful confinement of aggregates
- Little micro-cracking until about 65-70% of fck
- Smooth fracture surface

Concrete may be regarded as high performance for several reasons

- High strength
- High workability
- High durability
- Also improve visual appearance

Properties

- Ease of placement
- Compaction without segregation
- Early age strength
- Long term mechanical properties
- Permeability
- Density
- Toughness
- Volume stability
- Long life in severe environments

Benefits

- HPC become a crucial element of the viability of tall buildings in the region
- High strength to reduce the size of sections
- High durability makes it much important
- It enhance visual effect
- It can bear severe environments

Limitations

- Concrete can be damaged at very high temperature.
- High Performance Concrete has to be manufactured much more carefully than normal concrete.
- An extended quality control is required
- In concrete plant and at delivery site, additional tests are required. This increases the cost
- Some special constituents are required which may not be available in the ready mix concrete plants.

HIGH STRENGTH CONCRETE

High strength of concrete is achieved by reducing porosity, in-homogeneity, and micro-cracks in the hydrated cement paste and the transition zone. Consequently, there is a reduction of the thickness of the interfacial transition zone in high-strength concrete. The densification of the interfacial transition zone allows for efficient load transfer between the cement mortar and the coarse aggregate, contributing to the strength of the concrete. For very high-strength concrete where the matrix is extremely dense, a weak aggregate may become the weak link in concrete strength.

Materials for High-Strength Concrete

Cement

Cement composition and fineness play an important role in achieving high strength of concrete. It is also required that the cement is compatible with chemical admixtures to obtain the high-strength. Experience has shown that low-C3A cements generally produce concrete with improved rheology.

Aggregate

Selection of right aggregates plays an important role for the design of high-strength concrete mix. The low-water to cement ratio used in high-strength concrete makes the concrete denser and the aggregate may become the weak link in the development of the mechanical strength. Extreme care is necessary, therefore, in the selection of aggregate to be used in very high-strength concrete.

The particle size distribution of the fine aggregates plays an important role in the high strength concrete. The particle size distribution of fine aggregate that meets the ASTM specifications is adequate for high-strength concrete mixtures.

Aitcin recommends using fine aggregates with higher fineness modulus (around 3.0). His reasoning is as follows:

- High-strength concrete mixtures already have large amounts of small particles of cement and pozzolana, therefore fine particles of aggregate will not improve the workability of the mix;
- The use of coarser fine aggregates requires less water to obtain the same workability; and
- During the mixing process, the coarser fine aggregates will generate higher shearing stresses that can help prevent flocculation of the cement paste.

Guidelines for the selection of materials

- For the higher target compressive strength of concrete, the maximum size of concrete selected should be small, so that the concrete can become more dense and compact and less void ratio.
- Up to 70 MPa compressive strength can be produced with a good coarse aggregate of a maximum size ranging from 20 to 28 mm.
- To produce 100 MPa compressive strength aggregate with a maximum size of 10 to 20 mm should be used.
- To date, concretes with compressive strengths of over 125 MPa have been produced, with 10 to 14 mm maximum size coarse aggregate.
- Using supplementary cementitious materials, such as blast-furnace slag, fly ash and natural pozzolans, not only reduces the production cost of concrete, but also addresses the slump loss problem.

- The optimum substitution level is often determined by the loss in 12- or 24-hour strength that is considered acceptable, given climatic conditions or the minimum strength required.
- While silica fume is usually not really necessary for compressive strengths under 70 MPa, most concrete mixtures contain it when higher strengths are specified.

Differences between Normal Strength Concrete and High Strength Concrete

- Micro-cracks are developed in the normal strength concrete when its compressive strength reaches 40% of the strength. The cracks interconnect when the stress reaches 80-90% of the strength.
- For High Strength Concrete, Iravani and MacGregor reported linearity of the stress-strain diagram at 65 to 70, 75 to 80 and above 85% of the peak load for concrete with compressive strengths of 65, 95, and 105 MPa.
- The fracture surface in NSC is rough. The fracture develops along the transition zone between the matrix and aggregates. Fewer aggregate particles are broken. The fracture surface in HSC is smooth. The cracks move without discontinuities between the matrix and aggregates.

SHOTCRETE PROCESS

The concrete in which mortar or concrete is pneumatically projected at high velocity on the backup surface is known as Shotcrete or gunite. It is also known as spray concrete as the force of jet impacting on the surface compacts it so as to make itself supporting. This type of concrete has no special properties as compared to normal concrete placed under similar conditions.

<u>Methods of using Shotcrete</u>

Shotcrete may be applied to surfaces using a ***dry or wet mix method***.

The ***wet mix concrete method*** consists of Portland cement and aggregate premixed with water before the pump pushes the mixture though the hose. Additional compressed air is added at the nozzle to increase the velocity of the mixture.

In the ***dry mix process***, compressed air propels a premixed blend of Portland cement and damp aggregate through the hose to the nozzle. In the nozzle, water is added from a separate hose and completely mixed with the dry mixture just as both streams are being projected onto the prepared surface.

Generally, the Shotcrete gun nozzle is held at a right angle two- to six-feet from the surface. In most cases, Shotcrete can be deposited in the required thickness in a single application. For some vertical and overhead applications and for some smooth finishes, Shotcrete must be applied in one- to two-inch thick layers. Once Shotcrete is placed, it can be finished in a variety of methods, including natural finish, broom finish, various rough trowel finishes, and smooth steel trowel finish. After finishing, the concrete must be cured for a period of at least seven days.

Advantages of Shotcrete

- Shotcrete concrete layers are very strong.
- These types of concrete do not need construction or expansion joints.
- It can be evenly applied on uneven surfaces and can be applied from a distance.

Limitation of Shotcrete

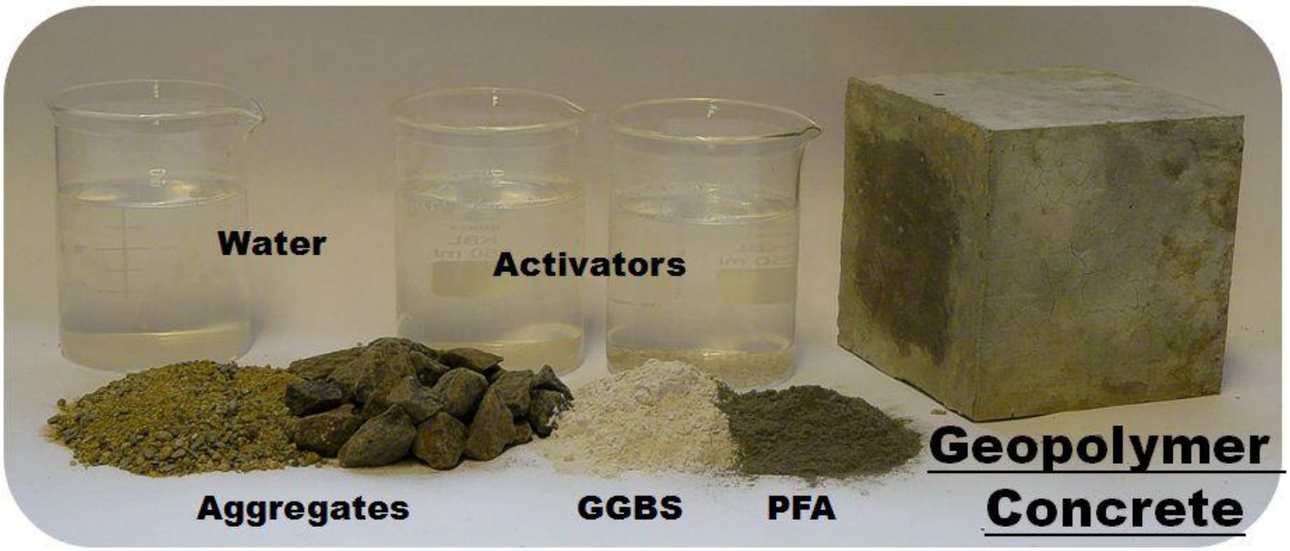
- It has high cost. Its lining is less durable than ordinary concrete lining of the same thickness.

Where to use Shotcrete

- Thin and lightly reinforced sections likes curtain walls etc.
- Shell or folded roofs.
- Lining of tunnels, canals etc, protective covering for soft dock
- Stabilizing rock slopes
- Encasing steel
- Repair of old building and disintegrated leaking lining etc.

GEOPLOYMER CONCRETE

Geopolymer cement is made from aluminium and silicon, instead of calcium and silicon. The sources of aluminium in nature are not present as carbonates and therefore, when made active for use as cement, do not release vast quantities of CO_2. The most readily available raw materials containing aluminium and silicon are fly ash and slag – these are the materials that Zeobond uses to create its low carbon emission binder.



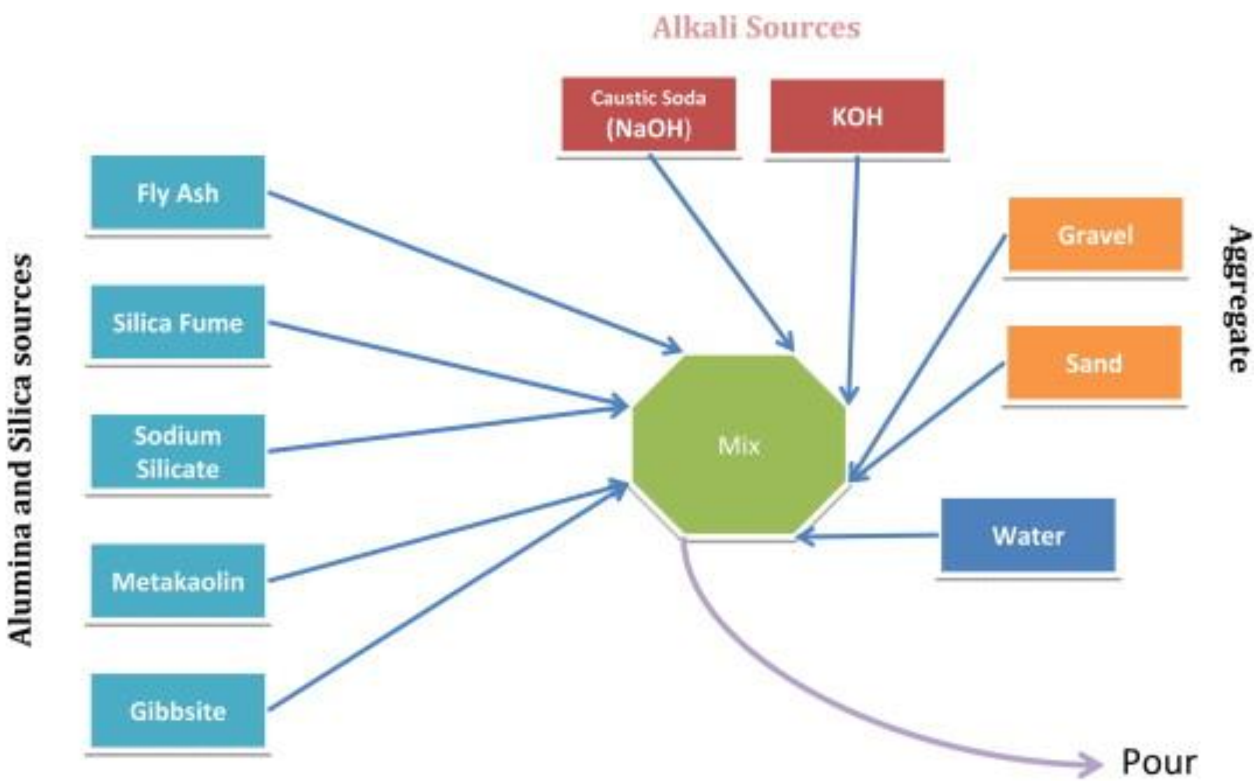
The main process difference between OPC and geopolymer cement is that OPC relies on a high-energy manufacturing process that imparts high potential energy to the material via calcination. This means the activated material will react readily with a low energy material such as water. On the other hand, geopolymer cement uses very low energy materials, like fly ashes, slags and other industrial wastes and a small amount of high chemical energy materials (alkali hydroxides) to bring about reaction only at the surfaces of particles to act as glue.

The properties of geopolymer cement, when used to make concrete, have been repeatedly and independently shown to be equivalent to other cements in terms of the structural qualities of the resulting concrete.

Composition of Geopolymer Cement Concrete Mixes

- Fly ash – PFA – Pulverized Fuel Ash
- GGBS – Ground Granulated Blast furnace Slag
- Fine aggregates and Coarse aggregates

- Catalytic liquid system (CLS) - It is an alkaline activator solution (AAS) for GPCC. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of AAS is to activate the geopolymeric source materials (containing Si and Al) such as fly ash and GGBS.



<u>Advantages of Geopolymer Concrete</u>

It is a newer product that is making traditional concrete look not so spectacular. Here are some of the top advantages of geopolymer concrete.

1. **High Strength** – it has a high compressive strength that showed higher compressive strength than that of ordinary concrete. It also has rapid strength gain and cures very quickly, making it an excellent option for quick builds.

   Geopolymer concrete has high tensile strength. It is less brittle than <u>Portland concrete</u> and can withstand more movement. It is not completely earthquake proof, but does withstand the earth moving better than traditional concrete.

2. **Very Low Creep and Shrinkage** – shrinkage can cause severe and even dangerous cracks in the concrete from the drying and heating of the concrete or even the evaporation

of water from the concrete. Geopolymer concrete does not hydrate; it is not as permeable and will not experience significant shrinkage.

The creep of geopolymer concrete is very low. When speaking of creep in concrete terms it means the tendency of the concrete to become permanently deformed due to the constant forces being applied against it.

3. **Resistant to Heat and Cold** – It has the ability to stay stable even at temperatures of more than 2200 degrees Fahrenheit. Excessive heat can reduce the stability of concrete causing it to spall or have layers break off. Geopolymer concrete does not experience spalling unless it reaches over 2200 degrees Fahrenheit.

   As for cold temperatures, it is resistant to freezing. The pores are very small but water can still enter cured concrete. When temperatures dip to below freezing that water freezes and then expands this will cause cracks to form. Geopolymer concrete will not freeze.
4. **Chemical Resistance** – it has a very strong chemical resistance. Acids, toxic waste and salt water will not have an effect on geopolymer concrete. Corrosion is not likely to occur with this concrete as it is with traditional Portland concrete.

Disadvantages of Geopolymer Concrete

While geopolymer concrete appears to be the super concrete to take the place of traditional Portland concrete, there are some disadvantages such as:

1. **Difficult to Create** – geopolymer concrete requires special handling needs and is extremely difficult to create. It requires the use of chemicals, such as sodium hydroxide, that can be harmful to humans.
2. **Pre-Mix Only** – geopolymer concrete is sold only as a pre-cast or pre-mix material due to the dangers associated with creating it.
3. **Geopolymerization Process is Sensitive** – this field of study has been proven inconclusive and extremely volatile. Uniformity is lacking.

While the idea of geopolymer concrete seems ideal and could be the best thing to come along since Portland concrete, there are still too many unstable issues that can cause major hiccups in the mixing and application process of the concrete.