UNIT 1 CONSTRUCTION TECHNIQUES

2 MARKS

1. **What is 33 grade of cement refer to? Or Discuss the various grades of cement. (April/May 2017,19) (Nov/Dec2016,2017)**

   Grade of cement represents the specific 28 days compressive strength. The following three grades are given along with their compressive strengths

   33 Grade OPC – 33 MPa

   43 Grade OPC – 43 MPa

   53 Grade OPC – 53 MPa

2. List any two durability properties of hardened concrete (April/May 2017,2019)

- Mechanical strength, in particular compressive strength. The strength of normal **concrete** varies between 25 and 40 MPa. ...
- **Durability**. ...
- Porosity and density. ...
- Fire resistance.
- Thermal and acoustic insulation **properties**.
- Impact resistance.

3. State any two physical properties of cement (April/May 2018)

- It has high compressive strength.
- It is free from corrosion and there is no appreciable effect of atmospheric agents on it.

- It hardens with age and the process of hardening continues for a long time after the concrete has attained sufficient strength.

4. List the methods of curing of concrete (April/May 2018)

- Shading of **concrete** work.
- Covering **concrete** surfaces with hessian or gunny bags.
- Sprinkling of water.
- Ponding **method**.
- Membrane **curing**.
- Steam **curing**.

5. **Define hydration of cement (Nov/Dec 2015)**

Cement wen added with water reacts to form a hard mass and the reaction is exothermic in nature. The heat evolved during this reaction is called heat of hydration.

6. What is meant by RMC (Nov/Dec 2015)

Ready-mix concrete, or *RMC* as it's also known, refers to *concrete* that is specifically batched or manufactured for customers' construction projects, and supplied to the customer on site as a single product. It is a mixture of Portland or other cements, water and aggregates: sand, gravel, or crushed stone. Ready-mix concrete is concrete that is manufactured in a batch plant, according to a set engineered mix design. Ready-mix concrete is normally delivered in two ways

7. Mention any four destructive methods of testing concrete (Nov/Dec 2016, 2017)

- Rebound Hammer Test- RH Test.
- Ultrasonic Pulse Velocity- UPV Test.
- Combined Method UPV & RH Test.

- Core Extraction for Compressive Strength Test.
- Ingredient Analysis of Concrete Core.
- Concrete Cover Measurement by Laser Based Instrument

8. State the classification of admixture according to function (Nov/Dec2018)

- air entrainers.
- water reducers.
- set retarders.
- set accelerators.
- superplasticizers.
- specialty admixtures: which include corrosion inhibitors, shrinkage control, alkali-silica reactivity inhibitors, and coloring.

9. What is the right time of curing concrete (Nov/Dec2018)

The Normal final setting time of cement is six to eight hours. In short, the curing should start after minimum six hours (Final setting time of cement) and not less than 24 hours. Thus, when concrete curing has to start is varies and depends on when the surface of the concrete begins to dry.

10. What is meant by passive building (April/May 2019)

Passive house is a voluntary standard for energy efficiency in a building, which reduces the building's ecological footprint. It results in ultra-low energy buildings that require little energy for space heating or cooling

11. Differentiate load bearing structure and framed structure (April/May 2019)

In Load bearing structure the load is transferred from the slab to the wall and then to the foundation, whereas, In Frame structure the load is transferred from slab to the beams

then to the columns and atlast from columns to the foundation. ... Load bearing structures are comparatively less costly than Frame structures.

Sixteen marks

1. **Explain the aspects of high rise building technology (April/May 2019)(Nov/Dec 2019)**

High-Rise Buildings Technology

1. Braced frame structural system

- Braced frames are cantilevered vertical trusses resisting laterals loads primarily diagonal members that together with the girders, form the "web" of the vertical truss, with the columns acting as the "chords".
- Bracing members eliminate bending in beams and columns.

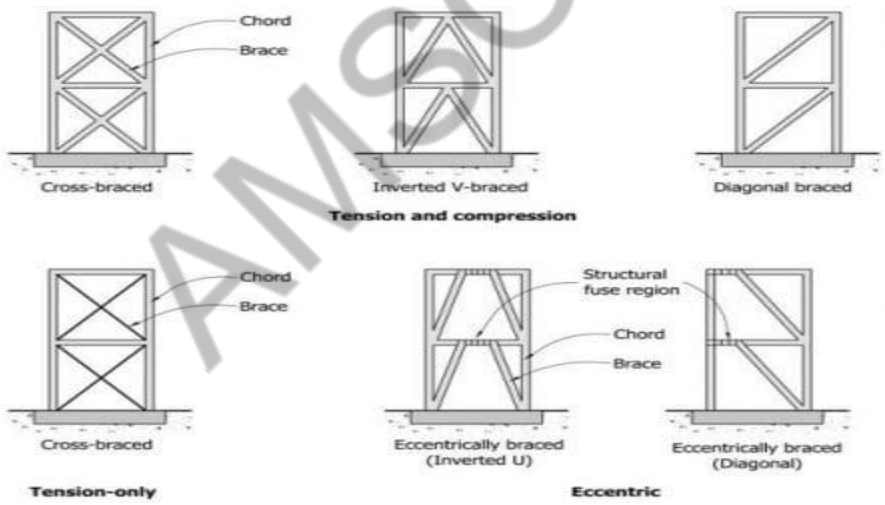


Fig.1:Different bracing types

- It is used in steel construction

- This system is suitable for multistory building in the low to mid height range.
- efficient and economical for enhancing the lateral stiffness and resistance of rigid frame system.
- This system permits the use of slender members in a building.
- An outstanding advantage of braced frame is that, it can be repetitive up the height of the building with obvious economy in design and fabrication.
- However, it might obstruct internal planning and the location of doors and windows. That is why it shall be incorporated internally along with lines of walls and partitions.

Fig.2:Braced frame structure

2. Rigid frame structural system

- In rigid frame structure, beams and columns are constructed monolithically to withstand moments imposed due to loads.
- The lateral stiffness of a rigid frame depends on the bending stiffness of the columns, girders and connections in-plane
- It is suitable for reinforced concrete buildings.

- It may be used in steel construction as well, but the connections will be costly.
- One of the advantages of rigid frames is the likelihood of planning and fitting of windows due to open rectangular arrangement.
- Members of rigid frame system withstand bending moment, shear force, and axial loads.
- 20 to 25 storey buildings can be constructed using rigid frame system.
- Advantages of rigid frame include ease of construction, labors can learn construction skills easily, construct rapidly, and can be designed economically.
- Maximum beam span is 12.2m and larger span beams would suffer lateral deflection.
- A disadvantage is that the self-weight is resisted by the action from rigid frames.
- Finally, Burj Al Khalifa which is the tallest structure in the world is constructed using rigid frame system.

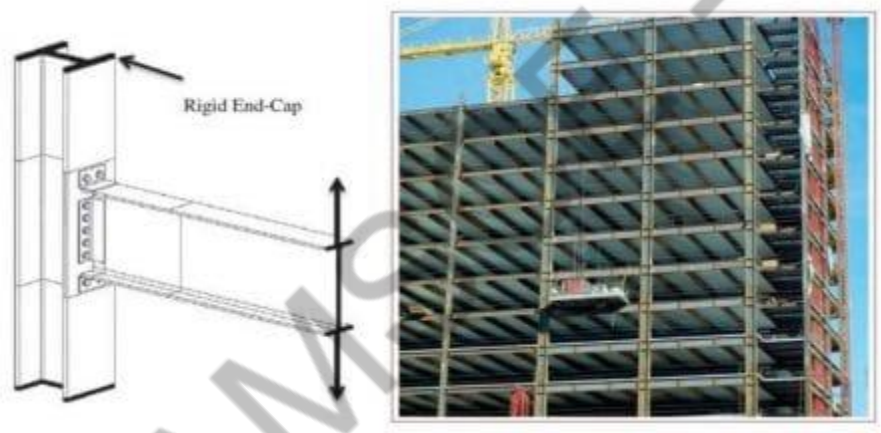


Fig.3:Rigid frame structural system

3. Wall-frame system (dual system)

- It consists of wall and frame that interact horizontally to provide stronger and stiffer system.
- The walls are usually solid (not perforated by openings) and they can be found around the stairwells, elevator shafts, and/or at the perimeter of the building.

- The walls may have a positive effect on the performance of the frames such as by preventing a soft storey collapse.
- Wall-frame system suitable for buildings with storey number ranges from 40-60 storey which is greater than that of shear or rigid frame separately.
- braced frames and steel rigid frames provide similar advantages of horizontal interaction.

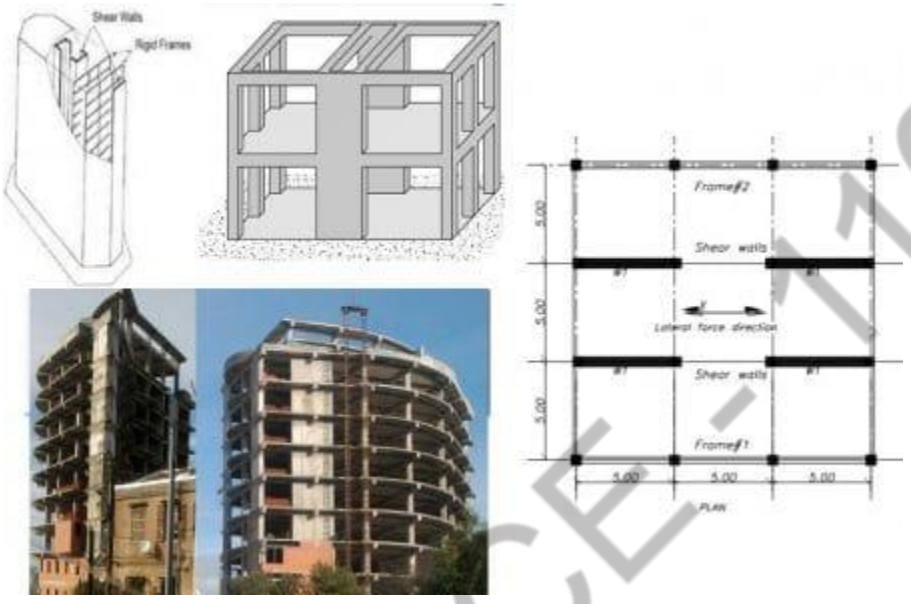


Fig.4: wall frame system

4. Shear wall system

- It is a continuous vertical wall constructed from reinforced concrete or masonry wall.
- Shear walls withstand both gravity and lateral loads, and it acts as narrow deep cantilever beam.
- Commonly, constructed as a core of buildings
- It is highly suitable for bracing tall buildings either reinforced concrete or steel structure. This because shear walls have substantial in plane stiffness and strength.
- Shear wall system is appropriate for hotel and residential buildings where the floor-by floor repetitive planning allows the walls to be vertically continuous.

- It may serve as excellent acoustic and fire insulators between rooms and apartments.
- shear wall structural system can be economical up to 35 stories building structure.
- Shear walls need not to be symmetrical in plan, but symmetry is preferred in order to avoid torsional effects.

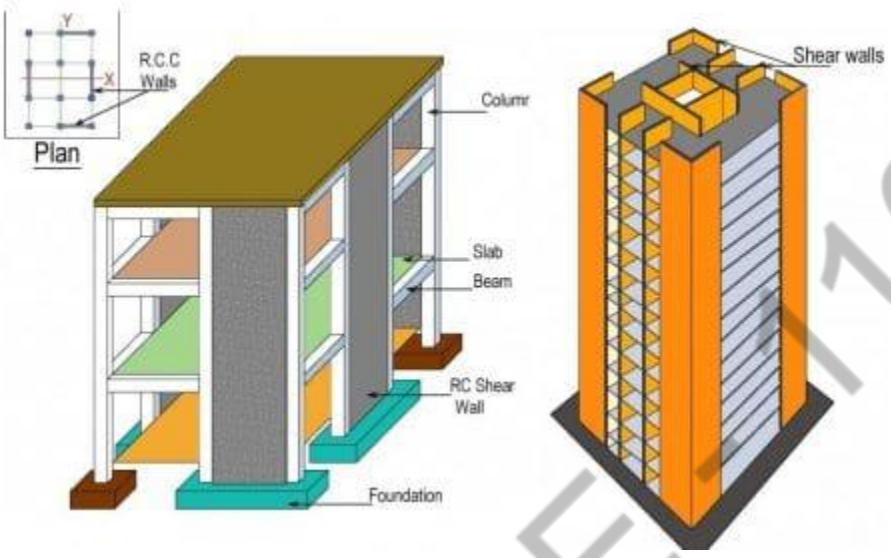


Fig.5: shear walls system

5. Core and outrigger structural system

- Outrigger are rigid horizontal structures designed to improve building overturning stiffness and strength by connecting the core or spine to closely spaced outer columns
- The central core contains shear walls or braced frames.
- Outrigger systems functions by tying together two structural systems (core system and a perimeter system), and render the building to behave nearly as composite cantilever.
- The outriggers are in form of walls in reinforced concrete building and trusses in steel structures.
- Multilevel outrigger systems can provide up to five times the moment resistance of a single outrigger system.

- Practically, Outrigger systems used for buildings up to 70 stories. Nonetheless, it can be used for higher buildings.
- Not only does the outrigger system decline building deformations resulting from the overturning moments but also greater efficiency is achieved in resisting forces.

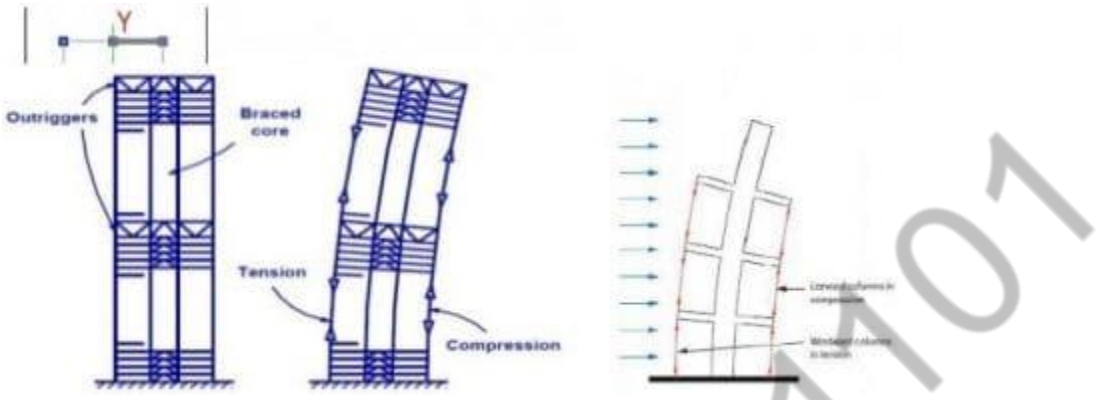


Fig.6: Outtrigger structure system

6. Infilled frame structural system

- Infilled frame structure system consists of beam and column framework that some of the bays infilled with masonry, reinforced concrete, or block walls.
- Infill walls can be part-height or completely fill the frame.
- The walls may or may not be connected to the formwork.
- Great in plan stiffness and strength of the walls prevent bending of beams and columns under horizontal loads. As a result, frame structural performance will be improved.
- During an earthquake, diagonal compression struts form in the infills so the structure behaves more like a Braced Frame rather than a Moment Frame.
- It can build up to 30 storey buildings.

Fig.7: Infilled frame structure system

7. Flat plate and flat slab structural system

- This system consists of slabs (flat or plate) connected to columns (without the use of beams).
- flat plate is a two-way reinforced concrete framing system utilizing a slab of uniform thickness, the simplest of structural shapes.
- The flat slab is a two-way reinforced structural system that includes either drop panels or column capitals at columns to resist heavier loads and thus permit longer spans.
- Lateral resistance depends on the flexural stiffness of the components and their connections, with the slab corresponding to the girder of the rigid frame.
- Suitable for building up to 25 stories.

Fig.8: Flat slab and flat plate structure system

8. Tube structural system

- This system consists of exterior columns and beams that create rigid frame, and interior part of the system which is simple frame designed to support gravity loads.
- The building behaves like equivalent hollow tube.
- It is substantially economic and need half of material required for the construction of ordinary framed buildings.
- Lateral loads are resisted by various connections, rigid or semi-rigid, supplemented where necessary by bracing and truss elements.
- It is used for the construction of buildings up to 60 storeys.
- Types of tube structure system include framed tube system (fig.9), trussed tube system (fig.10), bundled tube system (fig.11), and tube in tube system (fig.12).
- Trussed tube system is formed when external bracing added to make a structure stiffer. This structure type suitable for building up to 100 storeys.
- Bundled tube system consists of connected tubes and it withstand massive loads.
- A tube-in-tube system (hull core) is obtained, if the core is placed inside the tube frame structure.

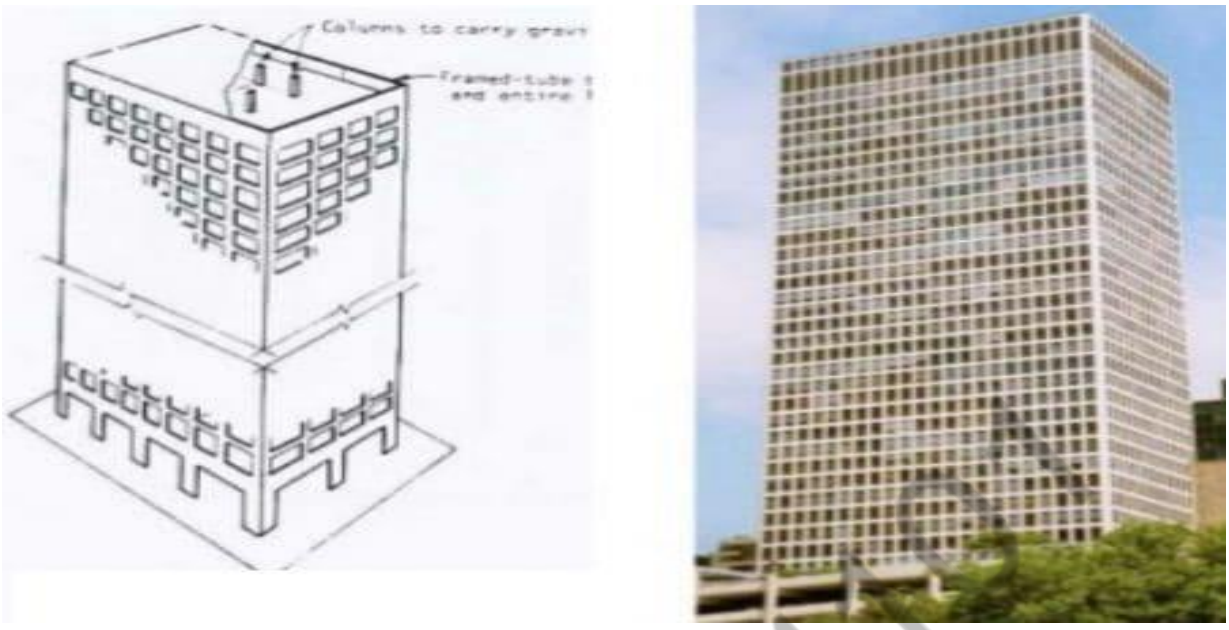


Fig.9: Framed tube structure system

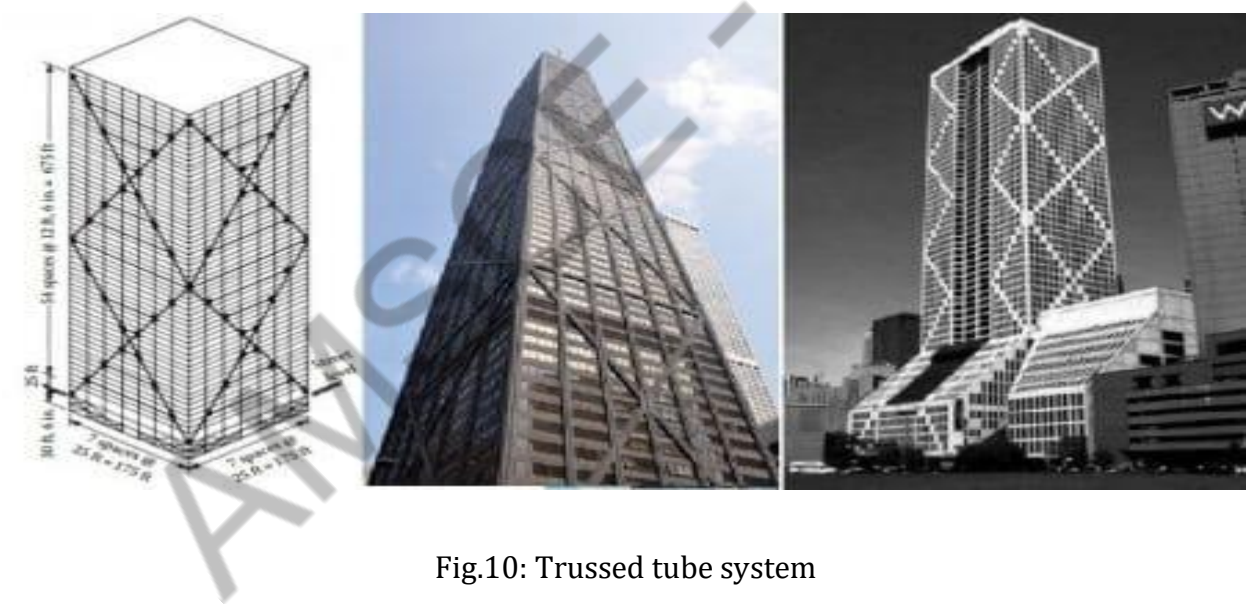


Fig.10: Trussed tube system

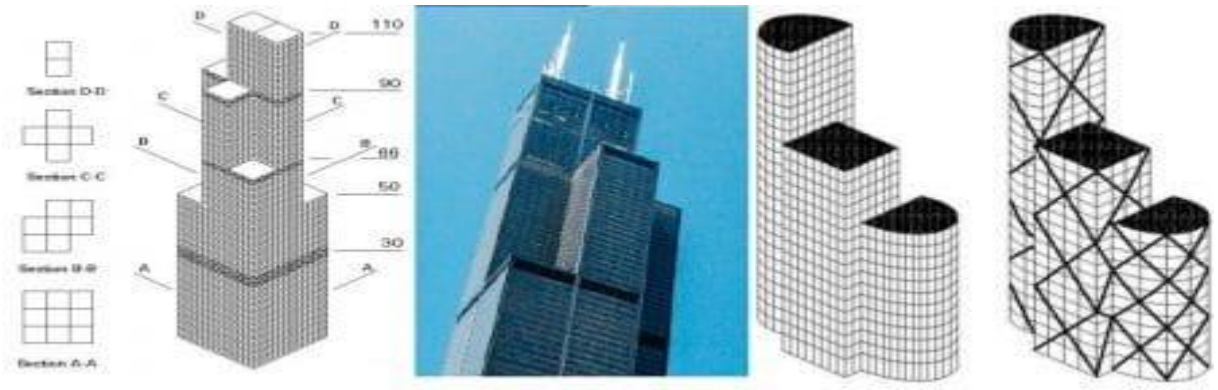


Fig.11: Bundled tube structure system

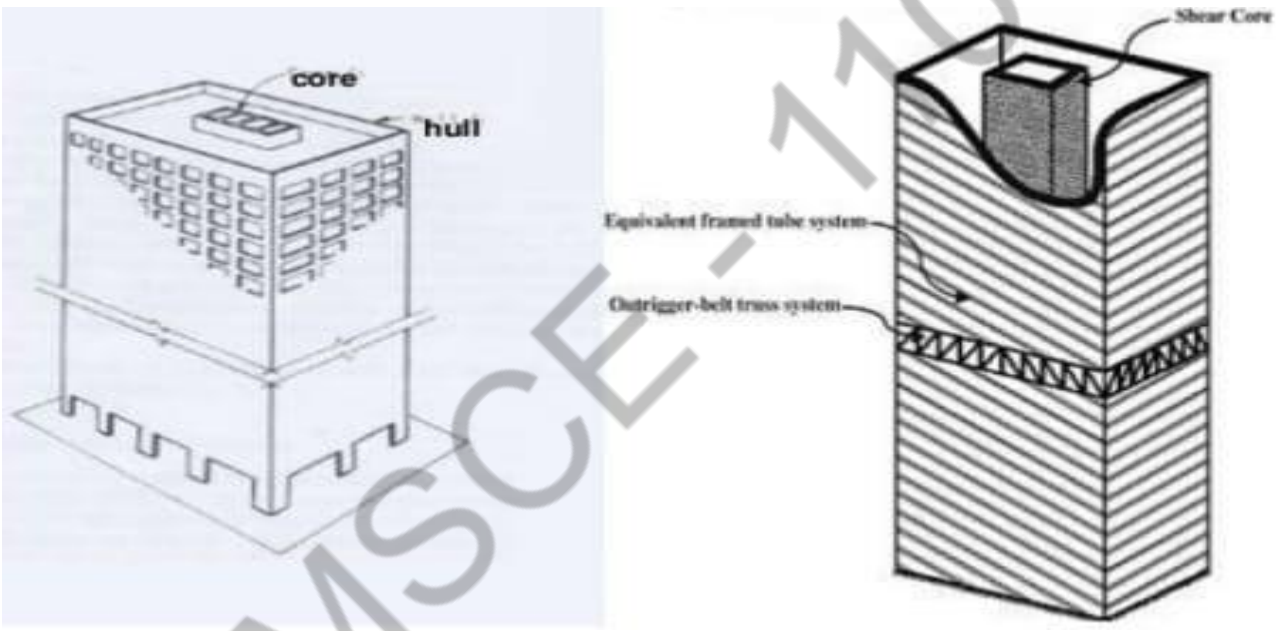


Fig.12: Tube in a tube system

9. Coupled wall system

- This system composed of two or more interconnected shear walls
- Shear walls connected at the floor levels by beam or stiff slabs.
- Stiffness of the whole system is far greater than that of its components.
- The effect of the shear-resistant connecting members is to cause the sets of walls to behave in their partly as a composite cantilever, bending about the common centroidal axis of the walls.

- The system is suitable for buildings up to 40 storey height.
- Since planer shear walls support loads in their plane only, walls in two orthogonal directions need to withstand lateral loads in two directions.

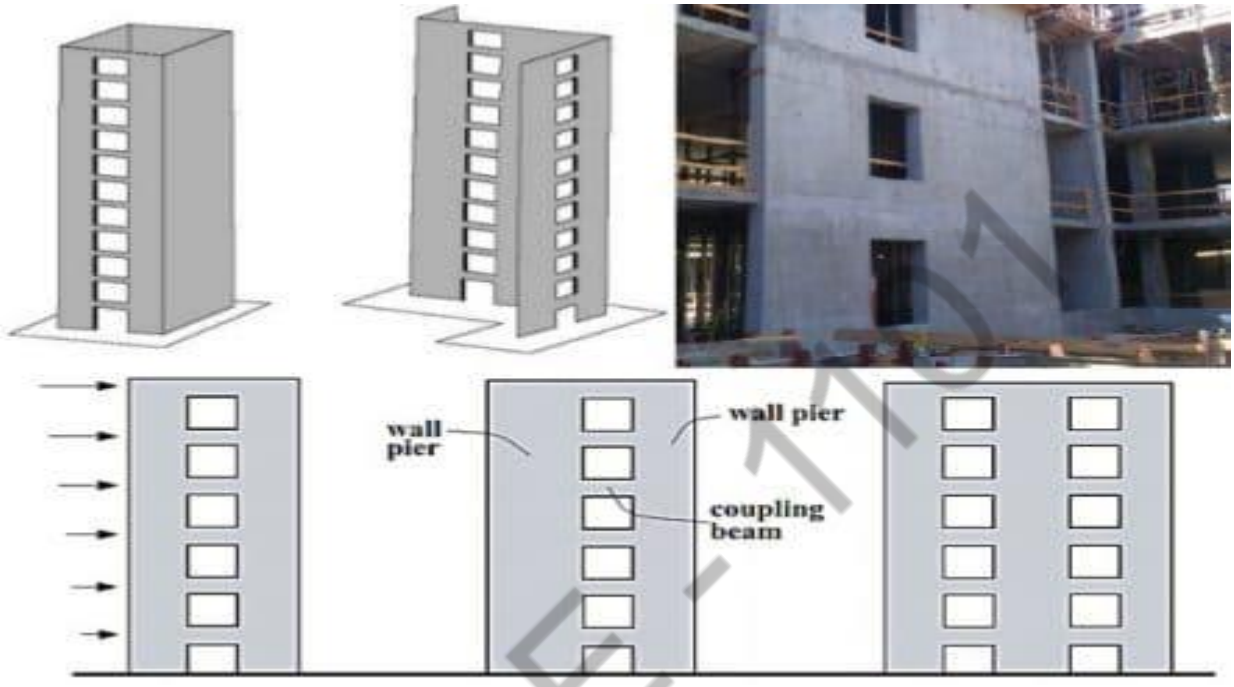


Fig.13: Coupled wall system

10. Hybrid structural system

- It is the combination of two or more of basic structural forms either by direct combination or by adopting different forms in different parts of the structure.
- Its lack of torsional stiffness requires that additional measures be taken, which resulted in one bay vertical exterior bracing and a number of levels of perimeter vierendeel “bandages”

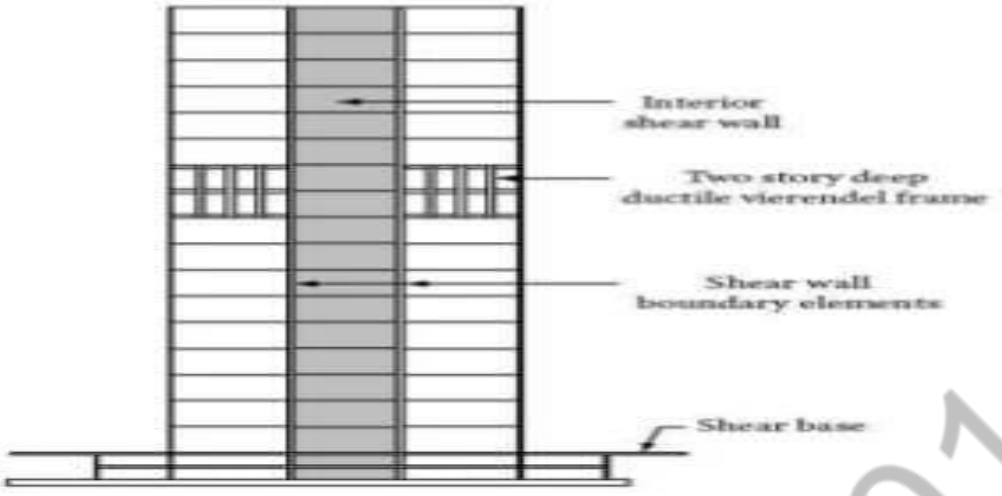


Fig.14: Vierendeel frame

- It can be used for the buildings of as high as 300m.
- According to chines code (JGJ3-2002), hybrid system can be used for the construction of buildings with maximum 150m height in seismic regions.

Fig.15: Hybrid structures

2. **Explain about building automation systems (April/May 2019)**

BUILDING AUTOMATION SYSTEM

Building automation systems control various components within a building's structure, such as heating, ventilation, air conditioning (HVAC). HVAC system performance and sustainability is key for today's building operation.

The primary goal of this type of infrastructure is to improve system efficiency, reduce costs and increase safety. A centralized building management platform brings all of these parts together, but this description is a simplification of what's really going on behind the scenes.

Main Components of a BAS

Building Automation Systems can be implemented either during initial construction or through a retrofitting process for an existing structure. It uses five component categories to provide a smart building environment.

- **Sensors:**

These devices track temperature, humidity, the number of people in a room, the lighting level and other values. The sensors transmit this information to centralized controllers.

- **Controller:**

This component acts as the "brain" of the BAS. It collects data from the sensors and then sends commands to HVAC units, lighting systems, security alarms and other connected parts.

- **Output devices:**

Once the controller sends out a command, actuators and relays go into action to follow the requirements. For example, they can reduce or increase the heating in a particular part of

the building, dim lights in unused offices, or turn on the air conditioning before people come to work.

- **Communication protocols:**

The BAS uses a specific language that's understood by the system's individual components. BACnet and Modbus are the most commonly used options.

- **Terminal interface:**

Users can interact with the BAS through this interface. It presents information so that users can monitor the condition of the building or choose to override settings manually.

Importance of User Interfaces

The terminal interface is an important part of an effective building automation system. Organizations need a way to access the data produced by the sensors, discover whether problems need troubleshooting, and look for areas of inefficiency they can address. A poorly designed user interface may not provide the necessary access or analysis that a business needs to understand its BAS performance levels.

Modern visual data overlays provide building managers with insights delivered in a user-friendly form. Managers can quickly react to changes because it's easy to see what's going on in the system on a day-to-day basis. Machine-to-machine communication guides decision-makers with objective information.

Functions of a BAS

The primary function of a BAS is to provide control over heating, cooling, ventilation, lighting and other critical building systems. However, building automation systems also monitor their individual components to alert building managers about detected problems. Depending on the issue, the system may attempt to automatically resolve a problem before

getting a human involved. The system's continually monitors and optimizes its own performance, although the building manager can make adjustments as needed.

Types of Data a BAS Collects and Its Applications

A BAS has access to a wide range of sensor data, depending on the smart systems installed in the building and the needs of the business. Temperature is one of the most common data points tracked, as this information is critical for proper climate control. The indoor air quality is monitored to ensure the correct mix of external and internal air, and this method is often used to control the humidity in the structure, as well.

Pressure and chemical sensors help the system troubleshoot problems with air quality or discover issues with mechanical aspects of the building. The security system relays data that can indicate potential intruders, such as motion in supposedly empty buildings.

Alarms can come from many parts of a building, such as power supplies, elevators or electronic doors. The data gets passed along to the UI when it meets certain requirements, such as when a data center's power has gone out and it's switched to an uninterruptible supply.

3. **Elaborate the roles of materials and methods to achieve green building concepts (April/May 2019)**

GREEN BUILDING:

A green building has four main elements or components on which it is designed: materials, energy, water and health to make green building more sustainable.

Elements of Green Building Design

Following are the components of a Green Building to make it sustainable:

1. Materials for Green Building

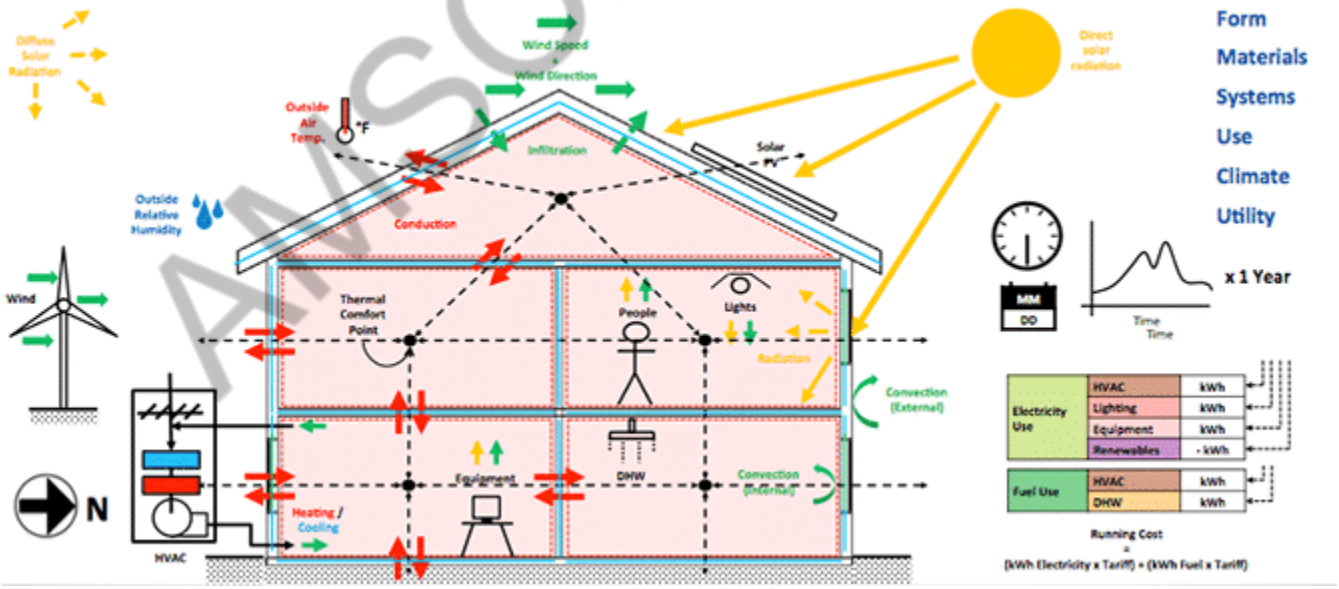
Materials for a green building are obtained from natural, renewable sources that have been managed and harvested in a sustainable way; or they are obtained locally to reduce the embedded energy costs of transportation; or salvaged from reclaimed materials at nearby sites.

Materials are assessed using green specifications that look at their Life Cycle Analysis (LCA) in terms of their embodied energy, durability, recycled content, waste minimisation, and their ability to be reused or recycled.

2 Energy Systems in Green Buildings

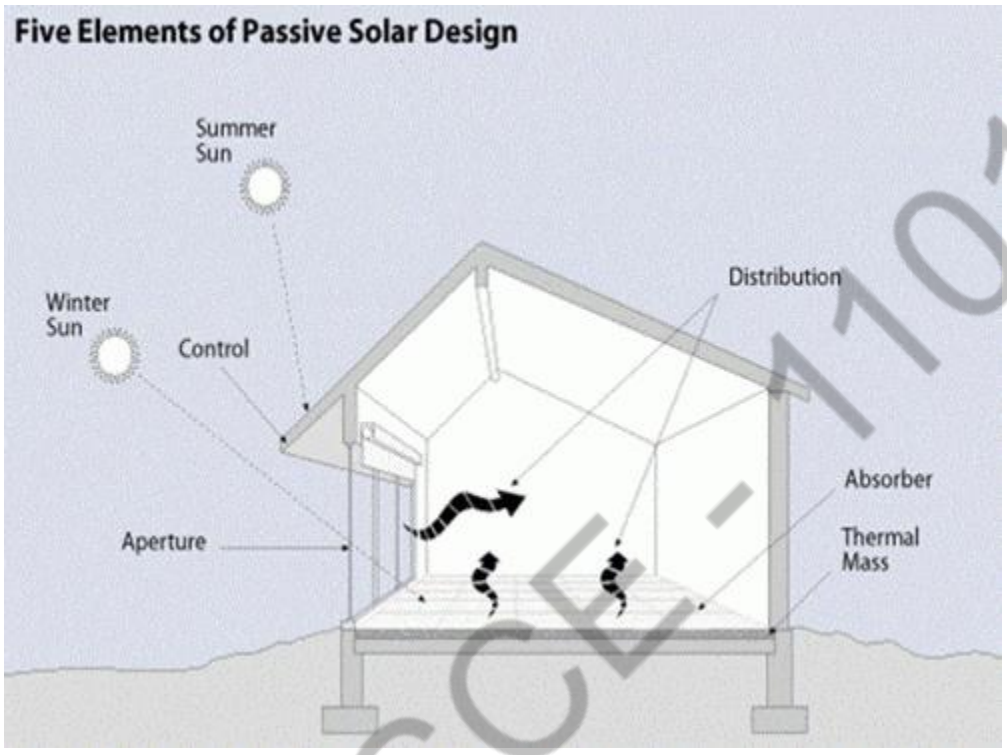
Passive solar design will dramatically reduce the heating and cooling costs of a building, as will high levels of insulation and energy-efficient windows. Natural daylight design reduces a building's electricity needs, and improves people's health and productivity.

Green buildings also incorporate energy-efficient lighting, low energy appliances, and renewable energy technologies such as wind turbines and solar panels.



Passive Solar Design

Passive solar design uses sunshine to heat, cool and light homes and other buildings without mechanical or electrical devices. It is usually part of the design of the building itself, using certain materials and placement of windows or skylights.



Rules Of Passive Solar Systems

- The building should be elongated on an east-west axis.
- The building's south face should receive sunlight between the hours of 9:00 A.M. and 3:00 P.M. (sun time) during the heating season.
- Interior spaces requiring the most light and heating and cooling should be along the south face of the building. Less used spaces should be located on the north.

The Advantages Of Passive Solar Design

- **H**igh energy performance: lower energy bills all year round.
- **I**nvestment: independent from future rises in fuel costs, continues to save money long after initial cost recovery.
- **V**alue: high owner satisfaction, high resale value.
- **A**ttractive living environment: large windows and views, sunny interiors, open floor plans.
- **L**ow Maintenance: durable, reduced operation and repair.
- **U**nwavering comfort: quiet (no operating noise), warmer in winter, cooler in summer (even during a power failure).
- **E**nvironmentally friendly : clean, renewable energy doesn't contribute to global warming, acid rain or air pollution.

Passive Solar Heating

The goal of all passive solar heating systems is to capture the sun's heat within the building's elements and release that heat during periods when the sun is not shining. At the same time that the building's elements (or materials) is absorbing heat for later use, solar heat is available for keeping the space comfortable (not overheated).

Two primary elements of passive solar heating are required:

- South facing glass
- Thermal mass to absorb, store, and distribute heat.

There are three approaches to passive systems

1. Direct Gain: Sunlight shines into and warms the living space.
2. Indirect Gain: Sunlight warms thermal storage, which then warms the living space.
3. Isolated Gain: Sunlight warms another room (sunroom) and convection brings the warmed air into the living space.

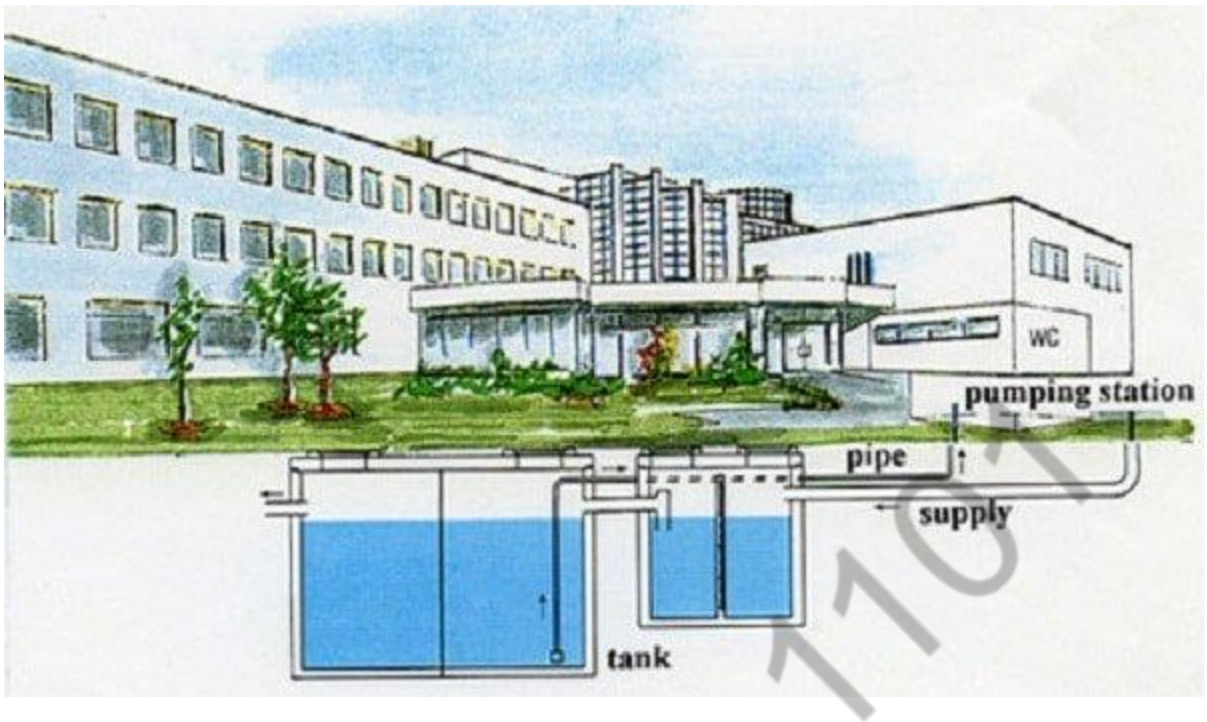
3. Water Management in Green Building

Minimizing water use is achieved by installing greywater and rainwater catchment systems that recycle water for irrigation or toilet flushing; water-efficient appliances, such as low flow showerheads, self-closing or spray taps; low-flush toilets, or waterless composting toilets. Installing point of use hot water systems and lagging pipes saves on water heating.

Rainwater Harvesting in Green Building

Rainwater harvesting is the principle of collecting and using precipitation from a catchments surface.

An old technology is gaining popularity in a new way. Rain water harvesting is enjoying a renaissance of sorts in the world, but it traces its history to biblical times.
Extensive rainwater harvesting apparatus existed 4000 years ago in the Palestine and Greece. In ancient Rome, residences were built with individual cisterns and paved courtyards to capture rain water to augment water from city's aqueducts.



Rainwater harvesting is essential

Surface water is inadequate to meet our demand and we have to depend on groundwater. Due to rapid urbanization, infiltration of rainwater into the subsoil has decreased drastically and recharging of groundwater has diminished.

As you read this guide, seriously consider conserving water by harvesting and managing this natural resource by artificially recharging the system.

Rainwater Harvesting Techniques for Green Buildings

There are two main techniques of rainwater harvestings.

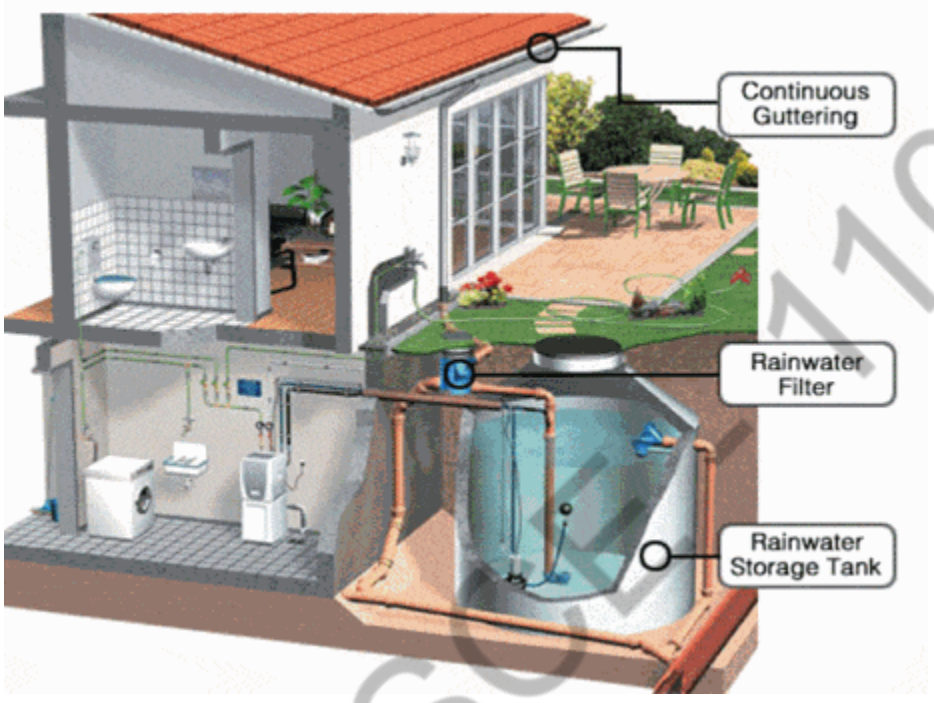
1. Storage of rainwater on surface for future use.
2. Recharge to groundwater

Storage of rainwater on surface for future use.

The storage of rainwater on surface is a traditional techniques and structures used were underground tanks, ponds, check dams, weirs etc.

Recharge to groundwater

Recharge to groundwater is a new concept of rainwater harvesting and the structures generally used are **Pits ,Trenches, Dug wells, Hand pumps, etc.**



4. Health Components of Green Building

Using non-toxic materials and products will improve indoor air quality, and reduce the rate of asthma, allergy and sick building syndrome. These materials are emission-free, have low or no VOC content, and are moisture resistant to deter moulds, spores and other microbes. Indoor air quality is also addressed through ventilation systems and materials that control humidity and allow a building to breathe.

In addition to addressing the above areas, a green building should provide cost savings to the builder and occupants, and meet the broader needs of the community, by using local labour, providing affordable housing, and ensuring the building is sited appropriately for community needs.

4. **What is the objective of curing ? explain the different methods of curing of concrete (April/May 2017)**

In order to prevent the loss of water from the surface due to evaporation or otherwise it has to be retained for which certain measures are taken which is called curing.

There are various methods of curing. The adoption of a particular method will depend upon the nature of work and the climatic conditions. The following methods of curing of concrete are generally adopted.

Curing of Concrete

- Shading concrete work
- Covering concrete surfaces with hessian or gunny bags
- Sprinkling of water
- Ponding method
- Membrane curing
- Steam curing

1. SHADING OF CONCRETE WORK

The object of shading concrete work is to prevent the evaporation of water from the surface even before setting. This is adopted mainly in case of large concrete surfaces such as road slabs. This is essential in dry weather to protect the concrete from heat, direct sun rays and wind. It also protects the surface from rain. In cold weather shading helps in preserving the heat of hydration of cement thereby preventing freezing of concrete under mild frost conditions. Shading may be achieved by using canvas stretched on frames. This method has a limited application only.

2. COVERING CONCRETE SURFACES WITH HESSIAN OR GUNNY BAGS

This is a widely used method of curing, particularly for structural concrete. Thus exposed surface of concrete is prevented from drying out by covering it with hessian, canvas or empty cement bags. The covering over vertical and sloping surfaces should be secured properly. These are periodically wetted. The interval of wetting will depend upon the rate of evaporation of water. It should be ensured that the surface of concrete is not allowed to dry even for a short time during the curing period. Special arrangements for keeping the surface wet must be made at nights and on holidays.

3. SPRINKLING OF WATER

Sprinkling of water continuously on the concrete surface provides an efficient curing. It is mostly used for curing floor slabs. The concrete should be allowed to set sufficiently before

sprinkling is started. The spray can be obtained from a perforated plastic box. On small jobs sprinkling of water may be done by hand. Vertical and sloping surfaces can be kept continuously wet by sprinkling water on top surfaces and allowing it to run down between the forms and the concrete. For this method of curing the water requirement is higher.

4. PONDING METHOD

This is the best method of curing. It is suitable for curing horizontal surfaces such as floors, roof slabs, road and air field pavements. The horizontal top surfaces of beams can also be ponded. After placing the concrete, its exposed surface is first covered with moist hessian or canvas. After 24 hours, these covers are removed and small ponds of clay or sand are built across and along the pavements. The area is thus divided into a number of rectangles. The water is filled between the ponds. The filling of water in these ponds is done twice or thrice a day, depending upon the atmospheric conditions. Though this method is very efficient, the water requirement is very heavy. Ponds easily break and water flows out. After curing it is difficult to clean the clay.

5. MEMBRANE CURING

The method of curing described above come under the category of moist curing. Another method of curing is to cover the wetted concrete surface by a layer of water proof material, which is kept in contact with the concrete surface of seven days. This method of curing is termed as membrane curing. A membrane will prevent the evaporation of water from the concrete. The membrane can be either in solid or liquid form. They are also known as sealing compounds. Bituminized water proof papers, wax emulsions, bitumen emulsions and plastic films are the common types of membrane used.

Whenever bitumen is applied over the surface for curing, it should be done only after 24 hours curing with gunny bags. The surface is allowed to dry out so that loose water is not visible and then the liquid asphalt sprayed throughout. The moisture in the concrete is thus preserved. It is quite enough for curing.

This method of curing does not need constant supervision. It is adopted with advantage at places where water is not available in sufficient quantity for wet curing. This method of curing is not efficient as compared with wet curing because rate of hydration is less. Moreover the strength of concrete cured by any membrane is less than the concrete which is moist cured. When membrane is damaged the curing is badly affected.

6. STEAM CURING

Steam curing and hot water curing is sometimes adopted. With these methods of curing, the strength development of concrete is very rapid.

These methods can best be used in pre cast concrete work. In steam curing the temperature of steam should be restricted to a maximum of 75°C as in the absence of proper humidity (about 90%) the concrete may dry too soon. In case of hot water curing, temperature may be raised to any limit, ay 100°C.

At this temperature, the development of strength is about 70% of 28 days strength after 4 to 5 hours. In both cases, the temperature should be fully controlled to avoid non-uniformity. The concrete should be prevented from rapid drying and cooling which would form cracks.

5. Explain in detail about the Methods of Non-Destructive Testing of Concrete? What are its relative merits (April/May 2017), (NOV/DEC 2015)

Methods of Non-Destructive Testing of Concrete

Following are different methods of NDT on concrete:

1. Penetration method

2. Rebound hammer method
3. Pull out test method
4. Ultrasonic pulse velocity method
5. Radioactive methods

1. Penetration Tests on Concrete

The Windsor probe is generally considered to be the best means of testing penetration. Equipment consists of a powder-actuated gun or driver, hardened alloy probes, loaded cartridges, a depth gauge for measuring penetration of probes and other related equipment.

A probe, diameter 0.25 in. (6.5 mm) and length 3.125 in. (8.0 cm), is driven into the concrete by means of a precision powder charge. Depth of penetration provides an indication of the compressive strength of the concrete.

Although calibration charts are provided by the manufacturer, the instrument should be calibrated for type of concrete and type and size of aggregate used.

Benefits and Limitations

The probe test produces quite variable results and should not be expected to give accurate values of concrete strength. It has, however, the potential for providing a quick means of checking quality and maturity of in situ concrete.

It also provides a means of assessing strength development with curing. The test is essentially non-destructive, since concrete and structural members can be tested in situ, with only minor patching of holes on exposed faces.

2. Rebound Hammer Method

The rebound hammer is a surface hardness tester for which an empirical correlation has been established between strength and rebound number.

The only known instrument to make use of the rebound principle for concrete testing is the Schmidt hammer, which weighs about 4 lb (1.8 kg) and is suitable for both laboratory and field work. It consists of a spring-controlled hammer mass that slides on a plunger within a tubular housing.

The hammer is forced against the surface of the concrete by the spring and the distance of rebound is measured on a scale. The test surface can be horizontal, vertical or at any angle but the instrument must be calibrated in this position.

Calibration can be done with cylinders (6 by 12 in., 15 by 30 cm) of the same cement and aggregate as will be used on the job. The cylinders are capped and firmly held in a compression machine.

Several readings are taken, well distributed and reproducible, the average representing the rebound number for the cylinder. This procedure is repeated with several cylinders, after which compressive strengths are obtained.

Limitations and Advantages

The Schmidt hammer provides an inexpensive, simple and quick method of obtaining an indication of concrete strength, but accuracy of ±15 to ±20 per cent is possible only for specimens cast cured and tested under conditions for which calibration curves have been established.

The results are affected by factors such as smoothness of surface, size and shape of specimen, moisture condition of the concrete, type of cement and coarse aggregate, and extent of carbonation of surface.

3. Pull-Out Tests on Concrete

A pull-out test measures, with a special ram, the force required to pull from the concrete a specially shaped steel rod whose enlarged end has been cast into the concrete to a depth of 3 in. (7.6 cm).

The concrete is simultaneously in tension and in shear, but the force required to pull the concrete out can be related to its compressive strength.

The pull-out technique can thus measure quantitatively the in-situ strength of concrete when proper correlations have been made. It has been found, over a wide range of strengths, that pull-out strengths have a coefficient of variation comparable to that of compressive strength.

Limitations and Advantages

Although pullout tests do not measure the interior strength of mass concrete, they do give information on the maturity and development of strength of a representative part of it. Such tests have the advantage of measuring quantitatively the strength of concrete in place.

Their main disadvantage is that they have to be planned in advance and pull-out assemblies set into the formwork before the concrete is placed. The pull-out, of course, creates some minor damage.

The test can be non-destructive, however, if a minimum pullout force is applied that stops short of failure but makes certain that a minimum strength has been reached. This is information of distinct value in determining when forms can be removed safely.

6. Dynamic Non Destructive Test (NOV/DEC 2018)

Ultrasonic pulse velocity method_is the only one of this type that shows potential for testing concrete strength in situ. It measures the time of travel of an ultrasonic pulse passing through the concrete.

The fundamental design features of all commercially available units are very similar, consisting of a pulse generator and a pulse receiver.

Pulses are generated by shock-exciting piezoelectric crystals, with similar crystals used in the receiver. The time taken for the pulse to pass through the concrete is measured by electronic measuring circuits.

Pulse velocity tests can be carried out on both laboratory-sized specimens and completed concrete structures, but some factors affect measurement:

1. There must be smooth contact with the surface under test; a coupling medium such as a thin film of oil is mandatory.
2. It is desirable for path-lengths to be at least 12 in. (30 cm) in order to avoid any errors introduced by heterogeneity.
3. It must be recognized that there is an increase in pulse velocity at below-freezing temperature owing to freezing of water; from 5 to 30°C (41 – 86°F) pulse velocities are not temperature dependent.
4. The presence of reinforcing steel in concrete has an appreciable effect on pulse velocity. It is therefore desirable and often mandatory to choose pulse paths that avoid the influence of reinforcing steel or to make corrections if steel is in the pulse path.

Applications and Limitations

The **pulse velocity method** is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction.

Usually, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present.

High pulse velocity readings are generally indicative of good quality concrete. A general relation between concrete quality and pulse velocity is given in Table.

Table: Quality of Concrete and Pulse Velocity

General Conditions	Pulse Velocity ft/sec
Excellent	Above 15,000
Good	12,000-15,000

Questionable	10,000-12,000
Poor	7,000-10,000
Very Poor	below 7,000

Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of structural concrete to be predicted within ±20 per cent, provided the types of aggregate and mix proportions are constant.

The pulse velocity method has been used to study the effects on concrete of freeze-thaw action, sulphate attack, and acidic waters. Generally, the degree of damage is related to a reduction in pulse velocity. Cracks can also be detected.

Great care should be exercised, however, in using pulse velocity measurements for these purposes since it is often difficult to interpret results. Sometimes the pulse does not travel through the damaged portion of the concrete.

The pulse velocity method can also be used to estimate the rate of hardening and strength development of concrete in the early stages to determine when to remove formwork. Holes have to be cut in the formwork so that transducers can be in direct contact with the concrete surface.

As concrete ages, the rate of increase of pulse velocity slows down much more rapidly than the rate of development of strength, so that beyond a strength of 2,000 to 3,000 psi (13.6 to 20.4 MPa) accuracy in determining strength is less than ±20%.

Accuracy depends on careful calibration and use of the same concrete mix proportions and aggregate in the test samples used for calibration as in the structure.

In summary, ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. Its use for predicting strength is much more limited, owing to the large number of variables affecting the relation between strength and pulse velocity.

5. Radioactive Methods of NDT

Radioactive methods of testing concrete can be used to detect the location of reinforcement, measure density and perhaps establish whether honeycombing has occurred in structural concrete units. Gamma radiography is increasingly accepted in England and Europe.

The equipment is quite simple and running costs are small, although the initial price can be high. Concrete up to 18 in. (45 cm) thick can be examined without difficulty.

Purpose of Non-Destructive Tests on Concrete

A variety of Non Destructive Testing (NDT) methods have been developed or are under development for investigating and evaluating concrete structures.

These methods are aimed at estimation of strength and other properties; monitoring and assessing corrosion; measuring crack size and cover; assessing grout quality; detecting defects and identifying relatively more vulnerable areas in concrete structures.

Many of NDT methods used for concrete testing have their origin to the testing of more homogeneous, metallic system. These methods have a sound scientific basis, but heterogeneity of concrete makes interpretation of results somewhat difficult.

There could be many parameters such as materials, mix, workmanship and environment, which influence the results of measurements.

Moreover, these tests measure some other property of concrete (e.g. hardness) and the results are interpreted to assess a different property of concrete e.g. strength, which is of primary interest.

Thus, interpretation of results is very important and difficult job where generalization is not possible. As such, operators can carry out tests but interpretation of results must be left to experts having experience and knowledge of application of such non-destructive tests.

Purposes of Non-destructive Tests

- Estimating the in-situ compressive strength
- Estimating the uniformity and homogeneity
- Estimating the quality in relation to standard requirement
- Identifying areas of lower integrity in comparison to other parts
- Detection of presence of cracks, voids and other imperfections
- Monitoring changes in the structure of the concrete which may occur with time
- Identification of reinforcement profile and measurement of cover, bar diameter, etc.
- Condition of pre-stressing/reinforcement steel with respect to corrosion
- Chloride, sulphate, alkali contents or degree of carbonation
- Measurement of Elastic Modulus
- Condition of grouting in prestressing cable ducts

7. i. Describe any two type of admixture: (APRIL/MAY 2018)

Water-reducing admixture / Plasticizers:

These admixtures are used for following purposes:

(i) To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.

(ii) To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.

(iii) To increase the workability so as to ease placing in accessible locations

(iv) Water reduction more than 5% but less than 12%

Actions involved:

1. **Dispersion:**

Surface active agents alter the physic chemical forces at the interface. They are adsorbed on the cement particles, giving them a negative charge which leads to repulsion between the particles. Electrostatic forces are developed causing disintegration and the free water become available for workability.

2. **Lubrication:**

As these agents are organic by nature, thus they lubricate the mix reducing the friction and increasing the workability.

3. **Retardation:**

A thin layer is formed over the cement particles protecting them from hydration and increasing the setting time. Most normal plasticizers give some retardation, 30–90 minutes

Super Plasticizers:

These are more recent and more effective type of water reducing admixtures also known as high range water reducer

The commonly used Super Plasticizers are as follows:

Sulphonated melamine formaldehyde condensates (**SMF**)

Give 16–25%+ water reduction. SMF gives little or no retardation, which makes them very effective at low temperatures or where early strength is most critical.

However, at higher temperatures, they lose workability relatively quickly. SMF generally give a good finish and are colorless, giving no staining in white concrete.

They are therefore often used where appearance is important.

Sulphonated naphthalene formaldehyde condensates (SNF)

Typically give 16–25%+ water reduction. They tend to increase the entrapment of larger, unstable air bubbles. This can improve cohesion but may lead to more surface defects.

Retardation is more than with SMF but will still not normally exceed 90 minutes. SNF is a very cost-effective.

Polycarboxylate ether super plasticizers (PCE)

Typically give 20–35%+ water reduction. They are relatively expensive per liter but are very powerful so a lower dose (or more dilute solution) is normally used.

In general the dosage levels are usually higher than with conventional water reducers, and the possible undesirable side effects are reduced because they do not markedly lower the surface tension of the water.

ii. List out two types of cement

1.Ordinary Portland Cement (OPC):

This is the most common type of cement which is extensively used. It has good resistance to cracking and dry shrinkage but less resistance to chemical attack. OPC is not suitable for the construction work which is exposed to sulphates in the soil.

Ordinary Portland cement is available in following types33 grade, 43 grade & 53 grade.
The grade represents the strength of cement at 28days. 33grade = 33N/mm^2

2. Rapid Hardening cement:

Rapid hardening cement is very similar to ordinary Portland cement (OPC). The early strength is achieved by adding excessive C_3S in the mix and by lowering the C_2S content in the cement. As the name itself resembling that, this type of cement is used where there is a need for high early strength. Ex.Pavements,busiestroadways
The strength of Rapid Hardening cement at age of 3 days is almost same as the 7 days strength of Ordinary Portland cement. It requires same water-cement ratio as OPC. This type of cement is not used for massive concrete constructions.

iii. What are the test conducted for concrete

- Slump test before leaving the batching plant and on arrival on site. ...
- Compressive strength test. ...
- Water Permeability test. ...
- Rapid Chloride Ion Penetration Test. ...
- Water Absorption Test. ...
- Initial Surface Absorption Test.

8. i. Explain the manufacturing process of concrete (APRIL/MAY 2018), (NOV/DEC 2016, 2017,2018)

Manufacturing of concrete

Introduction

Production of concrete requires meticulous care at every stage. The ingredients of good and bad concrete are same but good rules are not Observed it may become bad

Manufacturing of concrete includes the following stages

- Batching
- Mixing

- Transporting
- Placing
- Compacting
- Curing
- Finishing

Batching

The measurement of materials for making concrete is known as batching. Methods of batching

- Volume batching
- Weigh batching

Volume batching

- The required ingredients of conc. Are measured by volume basis
- Volume batching is done by various types of gauge boxes.
- The gauge boxes are made with comparatively deeper with narrow surface .
- Some times bottomless gauge boxes are used but it should be avoided.

- Volume batching is not a good practice because of the difficulties it offers to granular material.Some of the sand in loose condition weighs much less than the same volume ofdry compacted soil.

- For un important concrete or any small job concrete may be batched by volume.

Weigh batching

It is the correct method of measuring materials for concrete. Use of weight system in batching, facilitates accuracy flexibility and simplicity. The different types of weigh batching are there, they are used based on the different situation. In small works the weighing arrangement consist of two weighing buckets connected to the levers of spring loaded dials which indicates the load, The weighing buckets are mounted on a central spindle about which they rotate

On large works the weigh bucket type of weighing equipment used ,the materials are fed from the over head storage hopper and it discharges by gravity.

Mixing

Thorough mixing of materials is essential for the production of uniform concrete

The mixing should ensure that the mass becomes homogeneous uniform in color and consistency.

Types of mixing

Hand mixing

Machine mixing

Hand mixing

It is practiced for small scale un important concrete works. Hand mixing should be done over a impervious concrete or brick floor sufficiently large size take one bag of cement. Spread out and measured out fine aggregates and course aggregate in alternative layers.

Pour the cement on the top of it and mix them dry by showel, turning the mixture over and over again until the uniformity of color is achieved. The uniform mixture is spread out in the thickness of about 20 cm. The water is taken and sprinkled over the mixture and simultaneously turned over. The operation is continued till such time a good uniform homogeneous concrete is obtained

Machine mixing

Mixing of concrete almost invariably carried ot by machine ,for reinforced concrete work medium or large scale concrete works .

Machine mixing is not only efficient it is also economical when quantity of concrete to be produced is large

Type of mixer for mixing concrete

Batch mixer

Continuous mixer

Concrete mixers are generally designed to run at a speed of 15 to 20 revolutions per minute

For proper mixing it is seen that about 25to 30 revolutions are required in a well designed mixer

It is important that a mixer should not stop in between concreting operations for this requirement concrete mixer must be kept maintained

ii. Discuss RMC and its advantages:(Apr/may-2018)

Advantages of Ready-mix concrete (RMC) in high-level:

- Concrete is produced under controlled conditions.
- Placing and transportation is easy.
- Dust pollution is reduced.
- **RMC** uses bulk cement instead of bagged cement.
- A high speed of construction.
- Reduced noise and air pollution.
- Environment pollution is reduced

iii. Describe NDT for concrete:

Non-Destructive Testing of **Concrete** (**NDT** on **Concrete**)

Non -destructive test is a method of testing existing **concrete** structures to assess the strength and durability of **concrete** structure. ... This method of testing also helps us to investigate crack depth, micro cracks and deterioration of **concrete**.

9. Explain in detail about manufacturing process of concrete (APRIL/MAY 2019), (NOV/DEC 2017)

Manufacturing of concrete

Introduction

Production of concrete requires meticulous care at every stage. The ingredients of good and bad concrete are same but good rules are not Observed it may become bad

Manufacturing of concrete includes the following stages

- Batching
- Mixing
- Transporting
- Placing
- Compacting
- Curing
- Finishing

Batching

The measurement of materials for making concrete is known as batching. Methods of batching

- Volume batching
- Weigh batching

Volume batching

The required ingredients of concrete are measured by volume basis

- Volume batching is done by various types of gauge boxes.

- The gauge boxes are made with comparatively deeper with narrow surface .
- Sometimes bottomless gauge boxes are used but it should be avoided.

- Volume batching is not a good practice because of the difficulties it offers to granular material .Some of the sand in loose condition weighs much less than the same volume of dry compacted soil.

Weigh batching

It is the correct method of measuring materials for concrete. Use of weight system in batching, facilitates accuracy flexibility and simplicity. The different types of weigh batching are there, they are used based on the different situation. In small works the weighing arrangement consist of two weighing buckets connected to the levers of spring loaded dials which indicates the load, The weighing buckets are mounted on a central spindle about which they rotate

On large works the weigh bucket type of weighing equipment used ,the materials are fed from the over head storage hopper and it discharges by gravity.

Mixing

Thorough mixing of materials is essential for the production of uniform concrete

The mixing should ensure that the mass becomes homogeneous uniform in color and consistency.

Types of mixing

Hand mixing

Machine mixing

Hand mixing

It is practiced for small scale un important concrete works. Hand mixing should be done over a impervious concrete or brick floor sufficiently large size take one bag of cement. Spread out and measured out fine aggregates and course aggregate in alternative layers.

Pour the cement on the top of it and mix them dry by showel, turning the mixture over and over again until the uniformity of color is achieved. The uniform mixture is spread out in the thickness of about 20 cm. The water is taken and sprinkled over the mixture and simultaneously turned over. The operation is continued till such time a good uniform homogeneous concrete is obtained

Machine mixing

Mixing of concrete almost invariably carried ot by machine ,for reinforced concrete work medium or large scale concrete works .

Machine mixing is not only efficient it is also economical when quantity of concrete to be produced is large

Type of mixer for mixing concrete

Batch mixer

Continuous mixer

Concrete mixers are generally designed to run at a speed of 15 to 20 revolutions per minute

For proper mixing it is seen that about 25to 30 revolutions are required in a well designed mixer

It is important that a mixer should not stop in between concreting operations for this requirement concrete mixer must be kept maintained

10. Explain in detail about the testing on fresh concrete: (APRIL/MAY 2019), (NOV/DEC 2017)

Measurement of Workability

It is discussed earlier that workability of concrete is a complex property. Just as it eludes all precise definition, it also eludes precise measurements. Numerous attempts have been made by many research workers to quantitatively measure this important and vital property of concrete. But none of these methods are satisfactory for precisely measuring or expressing this property to bring out its full meaning. Some of the tests, measure the

parameters very close to workability and provide useful information. The following tests are commonly employed to measure workability.

(*a*)Slump Test (*b*) Compaction factor test

(*c*)Flow Test (*d*) Kelly Ball Test

(*e*)Vee Bee Consistometer

Slump Test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the placeability of the concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Repeated batches of the same mix, brought to the same slump, will have the same water content and water cement ratio, provided the weights of aggregate, cement and admixtures are uniform and aggregate grading is within acceptable limits. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps. Quality of concrete can also be further assessed by giving a few tappings or blows by tamping rod to the base plate. The deformation shows the characteristics of concrete with respect to tendency for segregation.

The appartus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as under:

Bottom diameter : 20cm

Top diameter : 10cm

Height : 30cm

The thickness of the metallic sheet for the mould should not be thinner than 1.6 mm. Sometimes the mould is provided with suitable guides for lifting vertically up. For tamping the concrete, a steel tamping rod 16 mm dia, 0.6 meter along with bullet end is used. Fig. 6.1, shows the details of the slump cone appartus. The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test. The mould is placed on a smooth, horizontal, rigid and non-absorbant surface

The mould is then filled in four layers, each approximately 1/ 4 of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subsidence is referred as SLUMP of concrete.

The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm. is taken as Slump of Concrete. ASTM measure the centre of the slumped concrete as the difference in height. ASTM also specifies 3 layers.

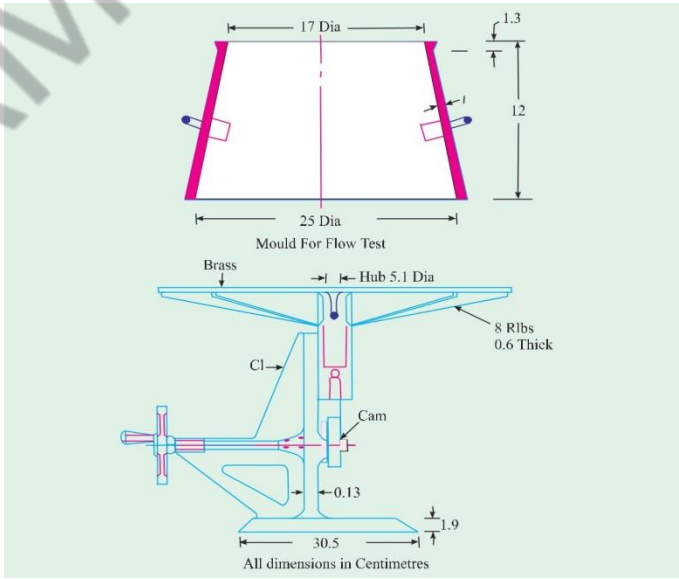
The pattern of slump is shown in Figure. It indicates the characteristic of concrete in addition to the slump value. If the concrete slumps evenly it is called true slamp. If one half

of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence. Shear slump also indicates that the concrete is non-cohesive and shows the characteristic of segregation.

It is seen that the slump test gives fairly good consistent results for a plastic-mix. This test is not sensitive for a stiff-mix. In case of dry-mix, no variation can be detected between mixes of different workability. In the case of rich mixes, the value is often satisfactory, their slump being sensitive to variations in workability. IS 456 of 2000 suggests that in the "very low" category of workability where strict control is necessary, for example, pavement quality concrete, (PQC) measurement of workability by determination of compacting factor will be more appropriate than slump and a value of 0.75 to 0.80 compacting factor is suggested.

Flow Test

This is a laboratory test, which gives an indication of the quality of concrete with respect to consistency, cohesiveness and the proneness to segregation. In this test, a standard mass of concrete is subjected to jolting. The spread or the flow of the concrete is measured and this flow is related to workability.



It can be seen that the apparatus consists of flow table, about 76 cm. in diameter over which concentric circles are marked. A mould made from smooth metal casting in the form of a frustum of a cone is used with the following internal dimensions. The base is 25 cm. in diameter, upper surface 17 cm. in diameter, and height of the cone is 12 cm.

The table top is cleaned of all gritty material and is wetted. The mould is kept on the centre of the table, firmly held and is filled in two layers. Each layer is rodded 25 times with a tamping rod 1.6 cm in diameter and 61 cm long rounded at the lower tamping end and the top layer is rodded evenly, the excess of concrete which has overflowed the mould is removed. The mould is lifted vertically upward and the concrete stands on its own without support.

The table is then raised and dropped 12.5 mm 15 times in about 15 seconds. The diameter of the spread concrete is measured in about 6 directions to the nearest 5 mm and the average spread is noted. The flow of concrete is the percentage increase in the average diameter of the spread concrete over the base diameter of the mould

Flow percent = ((Spread diameter in cm – 25) / 25) x 100

The value could range anything from 0 to 150 per cent.
A close look at the pattern of spread of concrete can also give a good indication of the characteristics of concrete such as tendency for segregation.

Flow Table Apparatus

The BIS has recently introduced another new equipment for measuring flow value of concrete. This new flow table test is in the line with BS 1881 part 105 of 1984 and DIN 1048 part I. The apparatus and method of testing is described below.

The flow table apparatus is to be constructed from a flat metal of minimum thickness 1.5 mm. The top is in plan 700 mm x 700 mm. The centre of the table is marked with a cross, the lines which run paralled to and out to the edges of the plate, and with a central circle 200 mm in diameter. The front of the flow table top is provided with a lifting handle as shown in Figure. The total mass of the flow table top is about 16 ± 1 kg.

The flow table top is hinged to a base frame using externally mounted hinges in such a way that no aggregate can become trapped easily between the hinges or hinged surfaces. The front of the base frame shall extend a minimum 120 mm beyond the flow table top in order to provide a top board. An upper stop similar to that shown in Figure is provided on each side of the table so that the lower front edge of the table can only be lifted 40 ± 1 mm. The lower front edge of the flow table top is provided with two hard rigid stops which transfer the load to the base frame. The base frame is so constructed that this load is then transferred directly to the surface on which the flow table is placed so that there is minimal tendency for the flow table top to bounce when allowed to fall.

Accessory Apparatus

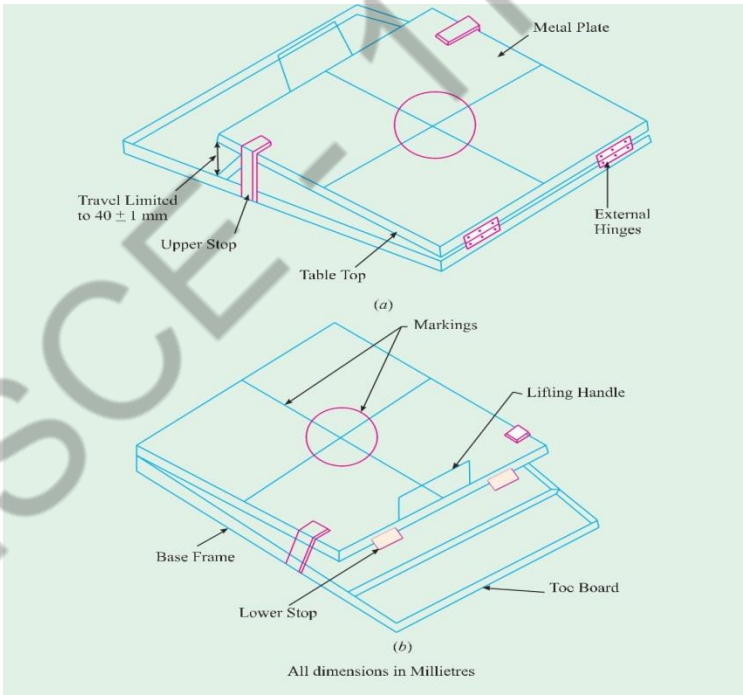
Mould:

The mould is made of metal readily not attacked by cement paste or liable to rust and of minimum thickness 1.5 mm. The interior of the mould is smooth and free from projections, such as protruding rivets, and is free from dents. The mould shall be in the form of a hollow frustum of a cone having the internal dimensions as shown in Fig. 6.7. The base and the top is open and parallel to each other and at right angles to the axis of the cone. The mould is provided with two metal foot pieces at the bottom and two handles above them.

Tamping Bar: The tamping bar is made of a suitable hardwood and having dimensions as shown in Figure.

Sampling: The sample of freshly mixed concrete is obtained.

Procedure: The table is made level and properly supported. Before commencing the test, the table-top and inner surface of the mould is wiped with a damp cloth. The slump cone is placed centrally on the table. The slump cone is filled with concrete in two equal layers, each layer tamped lightly 10 times with the wooden tamping bar. After filling the mould, the concrete is struck off flush with the upper edge of the slump cone and the free area of the table-top cleaned off.



Half a minute after striking off the concrete, the cone is slowly raised vertically by the handles. After this, the table-top raised by the handle and allowed to fall 15 times in 15 seconds. The concrete spreads itself out. The diameter of the concrete spread shall then be measured in two directions, parallel to the table edges. The arithmetic mean of the two diameters shall be the measurement of flow in millimeters.

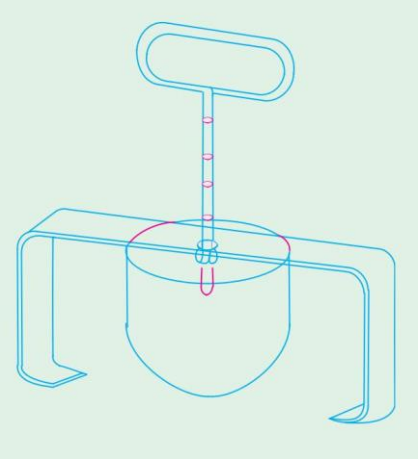
Kelly Ball Test

This is a simple field test consisting of the measurement of the indentation made by 15 cm diameter metal hemisphere weighing 13.6 kg. when freely placed on fresh concrete.

The test has been devised by Kelly and hence known as Kelly Ball Test. This has not been covered by Indian Standards Specification. The advantages of this test is that it can be performed on the concrete placed in site and it is claimed that this test can be performed faster with a greater precision than slump test.

The disadvantages are that it requires a large sample of concrete and it cannot be used when the concrete is placed in thin section.

The minimum depth of concrete must be at least 20 cm and the minimum distance from the centre of the ball to nearest edge of the concrete 23 cm.The surface of the concrete is struck off level, avoiding excess working, the ball is lowered gradually on the surface of the concrete. The depth of penetration is read immediately on the stem to the nearest 6 mm. The test can be performed in about 15 seconds and it gives much more consistent results than Slump Test



Kelly ball apparatus

11. Explain in detail of any three tests for Hardened Concrete.

The Flexural Strength of Concrete

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However, tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Therefore, the knowledge of tensile strength of concrete is of importance.

A concrete road slab is called upon to resist tensile stresses from two principal sources– wheel loads and volume change in the concrete. Wheel loads may cause high tensile stresses.

Flextural testing machine due to bending, when there is an inadequate subgrade support. Volume changes, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the subgrade.

Stresses due to volume changes alone may be high. The longitudinal tensile stress in the bottom of the pavement, caused by restraint and temperature warping, frequently amounts to as much as 2.5 MPa at certain periods of the year and the corresponding stress in the transverse direction is approximately 0.9 MPa. These stresses are additive to those produced by wheel loads on unsupported portions of the slab.

Determination of Tensile Strength

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the "pull" applied to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure flexural strength property of concrete. The value of the modulus of rupture (extreme fibre stress in bending) depends on the dimension of the beam and manner of loading. The systems of loading used in finding out the flexural tension are central point loading and third point loading. In the central point loading, maximum fibre stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two point loading, the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending moment is maximum. It can be expected that the two point loading will yield a lower value of the modulus of rupture than the centre point loading.

Compression Test

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

Cube beam and cylinder moulding

The compression test is carried out on specimens cubical or cylindrical in shape. Prism is also sometimes used, but it is not common in our country. Sometimes, the compression strength of concrete is determined using parts of a beam tested in flexure. The end parts of beam are left intact after failure in flexure and, because the beam is usually of square cross section, this part of the beam could be used to find out the compressive strength.

The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm, 10 cm size cubes may also be used as an alternative. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long. Smaller test specimens may be used but a ratio of the diameter of the specimen to maximum size of aggregate, not less than 3 to 1 is maintained.

12. Explain the Design Procedure for IS method of Concrete Mix Design or Discuss the basic concepts of concrete mix design. Explain any two methods of concrete mix design. (Nov/Dec2015)

Procedure for Concrete Mix Design

Step1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fck and the level of quality control.

ft = fck + 1.65 S

Where, S is the standard deviation obtained from the Table of approximate contents given after the design mix.

Step 2.Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

Step 3.Estimate the amount of entrapped air for maximum nominal size of the aggregate

Step 4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition).

Step 5. Determine the percentage of fine aggregate in total aggregate by absolute volume for the concrete using crushed coarse aggregate.

Step 6.Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

Step7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

Step8. From the quantities of water and cement per unit volume of concrete and the percentage ofsand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

Where, V = absolute volume of concrete = gross volume (1m3) minus the volume of entrapped air

Sc = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

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

fa, Ca = total masses of fine and coarse aggregates, per cubic meter of concrete, respectively, kg, and Sfa, Sca = specific gravities of saturated surface dry fine and coarse aggregates, respectively

Step 9. Determine the concrete mix proportions for the first trial mix.

Step 10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.

Step 11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

13. Explain in detail about concrete chemicals or chemical admixtures used in concrete and its action in fresh and hardened concrete. (Nov/Dec2016)

CHEMICAL ADMIXTURES OF CONCRETE

Water-reducing admixture / Plasticizers:

These admixtures are used for following purposes:

(v) To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
(vi) To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
(vii) To increase the workability so as to ease placing in accessible locations
(viii) Water reduction more than 5% but less than 12%

Actions involved:

1. **Dispersion:**

Surface active agents alter the physic chemical forces at the interface. They are adsorbed on the cement particles, giving them a negative charge which leads to repulsion between the particles. Electrostatic forces are developed causing disintegration and the free water become available for workability.

2. **Lubrication:**

As these agents are organic by nature, thus they lubricate the mix reducing the friction and increasing the workability.

3. **Retardation:**

A thin layer is formed over the cement particles protecting them from hydration and increasing the setting time. Most normal plasticizers give some retardation, 30–90 minutes

Super Plasticizers:

These are more recent and more effective type of water reducing admixtures also known as high range water reducer

The commonly used Super Plasticizers are as follows:

Sulphonated melamine formaldehyde condensates (**SMF**)

Give 16–25%+ water reduction. SMF gives little or no retardation, which makes them very effective at low temperatures or where early strength is most critical.

However, at higher temperatures, they lose workability relatively quickly. SMF generally give a good finish and are colorless, giving no staining in white concrete.

They are therefore often used where appearance is important.

Sulphonated naphthalene formaldehyde condensates (SNF)

Typically give 16–25%+ water reduction. They tend to increase the entrapment of larger, unstable air bubbles. This can improve cohesion but may lead to more surface defects.

Retardation is more than with SMF but will still not normally exceed 90 minutes. SNF is a very cost-effective.

Polycarboxylate ether super plasticizers (PCE)

Typically give 20–35%+ water reduction. They are relatively expensive per liter but are very powerful so a lower dose (or more dilute solution) is normally used.

In general the dosage levels are usually higher than with conventional water reducers, and the possible undesirable side effects are reduced because they do not markedly lower the surface tension of the water.

Accelerators:

An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.

Accelerating admixtures can be divided into groups based on their performance and application:

Set Accelerating Admixtures reduce the time for the mix to change from the plastic to the hardened state. Set accelerators have relatively limited use, mainly to produce an early set.

Hardening Accelerators,

Which increase the strength at 24 hours by at least 120% at 20ºC and at 5ºC by at least 130% at 48 hours. Hardening accelerators find use where early stripping of shuttering or very early access to pavements is required.

They are often used in combination with a high range water reducer, especially in cold conditions.

Set Retarders:

The function of retarder is to delay or extend the setting time of cement paste in concrete. These are helpful for concrete that has to be transported to long distance, and helpful in placing the concrete at high temperatures.

When water is first added to cement there is a rapid initial hydration reaction, after which there is little formation of further hydrates for typically 2–3 hours.

The exact time depends mainly on the cement type and the temperature. This is called the **dormant period** when the concrete is plastic and can be placed.

At the end of the dormant period, the hydration rate increases and a lot of calcium silicate hydrate and calcium hydroxide is formed relatively quickly. This corresponds to the setting time of the concrete.

Retarding admixtures delay the end of the dormant period and the start of setting and hardening. This is useful when used with plasticizers to give workability retention. Used on their own, retarders allow later vibration of the concrete to prevent the formation of cold joints between layers of concrete placed with a significant delay between them.

The mechanism of set retards is based on absorption. The large admixture anions and molecules are absorbed on the surface of cement particles, which hinders further reactions between cement and water i.e. retards setting.

Air Entrained Admixtures:

An addition for hydraulic cement or an admixture for concrete or mortar which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase its **workability** and **frost resistance.**

Air-entraining admixtures are **surfactants** that change the surface tension of the water. Traditionally, they were based on fatty acid salts or vinsol resin but these have largely been replaced by synthetic surfactants or blends of surfactants to give improved stability and void characteristics to the entrained air.

- Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

- Resistance to freeze–thaw action in the hardened concrete.
- Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.

- Compaction of low workability mixes including semi-dry concrete.

- Stability of extruded concrete.