LECTURE NOTES

ADVANCED CONSTRUCTION TECHNIQUES & EQUIPMENT

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6TH SEMESTER

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Advanced construction materials

1.1

Fibers and plastics:-

→ The fibre is a filament or threaded like piece of any material. This term sometimes also refer to a raw material that can be drawn into threads.

→ Fibre is a small piece of reinforcing material possessing certain characteristic properties. It is a long and thin material, can be circular or flat.

→ Fibre is described by a parameter called 'Aspect ratio'. It is the ratio of length of fibre to its diameter or least lateral diameter in case of flat fibres. It ranges from 30 to 150.

→ Generally 1 percent of fibre is used in concrete.

→ The study concludes that generally longer aspect ratios produce better mechanical properties of soil blocks. Mechanical properties of soil block means compressive and tensile strength of the blocks.

→ Natural fibres such as coconut fibre
Bagasse fibre
oil palm fibre

Cotton fibres - Cloth
Glass fibres - Glass
Steel fibres, carbon fibres

Types of Fibres :-

1. Steel Fibres
2. Carbon Fibres
3. Glass Fibres
4. Plastic Fibres
5. Asbestos Fibres
6. Jute Fibres, etc

(1) Steel Fibres :-

→ Most commonly used fibres. Generally round fibres are used. The diameter may be vary from 0.25 to 0.75mm.

→ Steel fibres is likely to get rusted & lose some of its strength.

→ Use of steel fibres makes significant improvement in flexural, impact and fatigue strength of concrete.

→ Steel fibres have fairly strength i.e 280 to 440 N/mm^2 as well as high young's modulus.

→ These are useful for imparting more flexural strength as compared to polypropylene fibres.

Uses :-

→ This fibre has been extensively used in various types of structures particularly for overlays of roads, airfield pavements and bridge decks.

→ Steel fibres are used in shortcrete.
→ They are used in precast concrete construction.
→ They are used in tunnel lining work.

② Carbon Fibres :-

→ Carbon fibres have very high tensile strength 2110 to 2815 N/mm^2 and youngs modulus.
→ It has been reported that cement composites made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength

properties :-

→ Carbon fibres are chemically inert & are resistant to corrosion.
→ They have very high tensile strength.
→ Low thermal expansion and the fibres content about 85% carbon has good flexural strength.
→ They are available in low weight.

Uses :-

→ The use of carbon fibres for structures like cladding, panels & shells. ~~will~~ have
→ Carbon fibres are mostly used to reinforce composite materials.
→ These are used in reinforced carbon concrete in which they increase tensile as well as compressive strength of concrete.

③ Glass Fibres:—

Glass may be softened and drawn mechanically into thread or glass wool that finer than silk.

→ Tensile strength approaching 70,000 kg/m²

→ These may be woven into fabric or used in loosely packed form for both sound and thermal insulation in building.

→ Test have shown that 25 mm of glass wool is equivalent in terms of thermal insulation of 42mm of brick 62 cm of concrete.

Classification of plastics:—

plastics

(i) Behaviour w.r.t heating
(ii) Structure
(iii) physical & chemical properties
(iv) Types of Resin

① Thermoplastics (recyclable)

② Thermosetting (not recyclable easily)

Ex- P

(ii) Structure ① Homogeneous

② Heterogeneous

(iii) physical & chemical properties:—

Soft – Rigid

Ex Eleastomers – Semirigid

(iv) Types of Resin

PET   LDPE
HDPE   PP
PVC   PS
(Type 1 to 7)

(PVC coming from napthalene which is from fraction distillation of crude petroleum)

Classification based Resin Identification code

Code 1: PET (Polyethylene terephthalate) plastic bottles, packaging of food etc

code 2: HDPE (High density polyethylene) containers for milk, motor oil, shampoos & conditioner, plastic bottle cap)

Code 3: PVC (Poly vinyl chloride) pipes, wire and cable insulation.

Code 4: LDPE (Low density polythylene) Flexible products like plastic bags

Code 5: PP (Polypropylene)

code 6: PS (Polystyrene)

code 7: other plastics including polycarbonate acrylic, liquid crystal polymer (LCP), and nylon.

Colored plastic sheets :-

Use of colorants, masterbatch etc.
Ex:- zinc oxide, barytes etc.

→ plastic sheets are made by squeezing molten polymer through a narrow slit in a process called film casting.

→ Materials:- Nylon, Delrin, PP, HDPE, polycarbonate, Acrylic, ABS (Acrylonitrile - Butadiene - styrene)

Resin

polymer chemistry and materials science, resin is a solid or highly viscous substance of plant or synthetic origin that is typically convertible into polymers. Resins are usually mixture of organic compounds.

Plastic sheets :—

ABS – Low cost plastic material with outstanding impact resistance & machinability.

Acetal – high strength, low friction engineering plastic.

Acrylic – A strong, durable, optically clear material.

Expanded PVC – Expanded PVC; lightweight, yet rigid; expanded foam polyvinyl chloride.

HDPE – It is for greater strength

High impact polystyrene – It is a low cost, tough plastic, easy to thermoform & fabricate.

KYDEX Thermoplastic sheet – outstanding toughness, appearance and formability

Nylon – Stiff, strong plastic, outstanding bearing and wear properties.

Polycarbonate – A tough, strong & stiff transparent material, shop for general purpose & specialty sheets, rods, tubes.

PETG – PETG Thermoplastic sheet; outstanding thermoformability, good impact resistance

PVC

PVC, in full polyvinyl chloride, a synthetic resin made from the polymerization of vinyl chloride. Second only to polyethylene among the plastics in production & consumption, PVC is used in an enormous range of domestic & industrial products, from raincoats & shower curtains to window frames & indoor plumbing. A lightweight, rigid plastic in its pure form, it is also manufactured in a flexible "plasticized" form.

Vinyl chloride is an organohalogen compound that has important industrial applications. When treated with certain catalysts, vinyl chloride monomers undergo polymerization & form the larger compound known as polyvinyl chloride or PVC. PVC is used in the manufacture of numerous products, including packaging films & water pipes.

Uses of PVC

It is one of the most popular plastics used in building & construction. It is used in drinking water and waste water pipes, window frames, flooring and roofing foils, wall coverings, cables & many other applications as it provides a modern alternative to traditional material such as wood, metal, rubber & glass. These products are often lighter, less expensive & offer many performance advantages.

Strong and lightweight:-
PVC's abrasion resistance, light weight, good mechanical strength and toughness are key technical advantages for its use in building & construction applications
Easy to install:-
PVC can be cut, shaped, welded & joined easily in a variety of styles. Its light weight reduces manual handling difficulties.
Durable:-
PVC is resistant to weathering, chemical rotting, corrosion, shock & abrasion. It is therefore the preferred choice for many different long-life & outdoor products. In fact, medium & long-term applications account for some 85 per cent of PVC production in the building and construction sector.

UPVC

Unplasticized polyvinyl chloride is a solid, versatile material that is resistant to a large no of chemicals. UPVC is a tough, sineway, transparent and hard wearing material, but it is very resistant to the influence of the atmosphere, moisture & chemicals, has excellent electrical properties & low flammability. Tubes and fittings made of UPVC are suitable for installation in & out of the soil. This material is resistant to aggressive environments - caused by natural phenomena or industrial outbreaks. It is also resistant to all kinds of corrosion. The advantage of tubes and fittings made of UPVC is the long life, resulting in a long period of safe installation. UPVC has excellent chemical resistance, which eliminates the formation of limescale and provides good flow characteristics. UPVC is odorless and tasteless, it is suitable for transport of processed water, wastewater, as well as for a large number of chemicals. UPVC is suitable for use at temperatures ranging from 0°c to 65°c at a wide range of operating pressures, depending on the selected system. It is also easy & simple to install - using a bundle for joints & not requiring special tools.

CPVC

Chlorinated polyvinyl chloride (CPVC) is a thermoplastic made by chlorinating the polyvinyl chloride resin. It is resistant to degradation & provides a long life span of use. In fact, the first pipeline systems used by the CPVC occurred in 1959, & they continue to work without any problems. CPVC is additionally chlorinated PVC. The chlorine bonded to the carbon atoms of the pre-chlorinated PVC contains 65-67% chlorine, which is 7% more than UPVC. Because of the increased chlorine content, it has excellent chemical resistance, primarily to acids, alkalis and salts, and is therefore very suitable as a material in the chemical process industry. The temperature range of application ranges from -40°c to +95°c. CPVC is an extremely valuable, structurally rigid and solid plastic material used in industrial media transport applications with a maximum operating temp of up to 100°C. Like other PVC systems, it is characterized by easy handling and simple and fast bonding. It also optimal force transfer of treated & untreated drinking water, demineralized water and water for spa & medical use. Another advantage is the high value of perimeter strength, which ensure extended life of the device without significant mechanical or physical damage. CPVC is characterized by its optimum temp stability, and its nonflammability which is an important factor in its use.

Thanks to its long life in aggressive & corrosive environments, CPVC is becoming more & more important

FRP

It is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass (in fibreglass), carbon (in carbon fiber reinforced polymer), aramid, or basalt. Rarely, other fibres such as paper, wood, or asbestos have been used. The polymer is usually an epoxy, vinyl ester, or polyster thermosetting plastic, though phenol formaldehyde resins are still in use.

FRPS are commonly used in the aerospace, automotive, marine & construction industries. They are commonly found in ballistic armor & cylinders for self-contained breathing apparatuses.

A polymer is generally manufactured by step growth polymerization or addition polymerization. When combined with various agents to enhance or in any way alter the material proporties of polymers, the result is reffered to as a plastic. Composite plastics refers to those types of plastics that result from bonding two or more homogeneous materials with different material properties to derive a final product with certain desired material & mechanical properties. Fibre reinforced plastics are a category of composite plastics that specifically use fibre material to mechanically enhance the strength & elasticity of plastics.

The original plastic material without fibre reinforcement is known as the matrix or binding agent. The matrix is a tough but relatively weak plastic that is reinforced by stronger stiffer reinforcing filaments or fibres.

The extent that strength and elasticity are enhanced in a fibre-reinforced plastic depends on the mechanical properties of both the fibre & matrix, their volume relative to one another, and the fibre length and orientation within the matrix. Reinforcement of the matrix occurs by definition when the FRP material exhibits increased strength or elasticity relative to the strength & elasticity of the matrix alone.

GRP

This material has initially been used for insulating houses. Today the material is commonly used in the aerospace, automotive, marine, and construction industries.

Glass(fibre) reinforced plastic is a composite material that consists of a polymer matrix & glass fibers. The polymer matrix is usually an epoxy, vinylester, or polyester thermosetting resin. The resin brings the environmental & chemical resistance to the product, is the binder for the fibers in the structural laminate & defines the form of a GRP part. The glass fibers add strength to the composite.

They may be randomly arranged or convienently oriented. The most common type of glass fiber used for GRP is E-glass, which is alumino borosilicate glass. E-CR-glass (Electrical/Chemical resistance) is also commonly used in applications that require particularly high protection against acidic corrosion.

Why it's so strong

As with many other composite materials, the two materials supplement each other to form a stronger compound. Plastic resins are strong in compressive loading; the glass fibers are very strong in tension. By combining the two materials GRP becomes a material that resists both compressive and tensile forces very well. Production methods of GRP include filament winding, centrifugal casting, hand lay-up & spray lay-up, and pultrusion.

Advantages

- Low weight at high mechanical strength.
- Resistance against chemicals & corrosion.
- UV radiation & temperature stability & environmental friendliness.
- GRP is waterproof.
- It can be customized to be fire-retardant by using non-flammable resins.
- It is a highly durable material with a very long lifetime expectancy.
- Ideally suited for a wide range of applications

Properties

→ Thermal insulation
→ Anti-slip safety
→ High strength to weight ratio
→ Does not melt, but burns similarly to wood (It can be produced fire retardant if required).
→ High energy absorption
→ chemical resistance
→ corrosion resistance
→ Can be used in enclosed electrical spaces
→ Good insulation to heat & sound.
→ Easy to shape

Uses

→ water pipes or drain coverings
→ Anti-slip protection for retrofitting dry & wet flooring
→ Helicopter rotor blades & wind turbine blades.
→ Hand railings
→ Electronic enclosures
→ safety grating in industrial & public areas.

Difference betn PVC and UPVC

→ PVC contains plasticisers while UPVC doesn't.
→ plasticisers make PVC more soft & flexible, which means PVC is the perfect material for cables, toys, shower curtains & even clothes. UPVC, in contrast, is hard & rigid, so it's good for things like window frames & pipes

1.2

Artificial timber

Artificial timber is nothing but timber product manufactured scientifically in factories. Because of its scientific nature, it is stronger & durable than ordinary timber materials. It also contains desired shape & size.

Forms of artificial timber :-

→ Veneers
→ plywood
→ Fiber boards
→ Impreg timbers
→ compreg timbers
→ Hard boards
→ Glulam
→ chip board
→ Block board
→ Flush door shutters

Veneers

→ Veneers are nothing but thin layers of wood which are obtained by cutting the wood with sharp knife in rotary cutter.
→ In rotary cutter, the wood log is rotated against the sharp knife or saw & cuts it into thin sheets.
→ These thin sheets are dried in kilns and finally veneers are obtained.
→ veneers are used to manufacture different wood products like plywood, block boards etc.

Plywood

Ply means thin. plywood is a board obtained by adding thin layers of wood or veneers on one above each other. The joining of successive layers is done by suitable adhesives. The layers are glued & pressed with some pressure either in hot or cold condition. In hot conditions 150 to 200°C temp is maintained & hydraulic press is used to press the layers. In cold conditions, room temp is maintained and 0.7 to 1.4 N/mm² pressure is applied. plywood has so many uses. It is used for doors, partition walls, ceilings, paneling walls, formwork for concrete etc. Due to its decorative appearance, it is used for buildings like theaters, auditoriums, temples, churches, restaurants etc in architectural purpose.

Fiber Boards

- Fiber boards are made of wood fibers, vegetable fibers etc.
- They are rigid boards & called as reconstructed wood.
- The collected fibers are boiled in hot water & then transferred into closed vessel.
- steam with low pressure ~~increased~~ is pumped into the vessel & pressure increased suddenly.
- Due to sudden increment of pressure, the wood fibers explode & natural adhesive gets separated from the fibers.

→ Then they are cleaned & spread on wire screen in the form of loose sheets.

→ This matter is pressed in bet^n steel plates & finally fiber boards are obtained.

→ Fiber boards are used for several purposes in construction industry such as for wall paneling, ceilings, partitions, flush doors, flooring material etc. They are also used as sound insulating material.

Impreg Timbers

→ Impreg timber is a timber covered fully or partly with resin. Thin layers of wood or veneers are taken and dipped in resin solution.

→ Generally used resin is phenol formaldehyde.

→ The resin solution fills up the voids in the wood & consolidated mass occurs.

→ Then it is heated at 150 to 160°c and finally impreg timber develops.

→ This is available in market with different names such as sungloss, sunmica, Formica etc.

→ Impreg timber has good resistance against moisture, weathering, acids and electricity.

→ It is strong, durable and provides beautiful appearance.

→ It is used form making wood molds, furniture, decorative products etc

Compreg timbers

It is similar to impreg timber but in this case, the timber is cured under pressure conditions. So, it is more strengthened than impreg timber. Its specific gravity lies from 1.3 to 1.35.

Hard boards

- Hard board is usually 3 mm thick & made from wood pulp.
- Wood pulp is compressed with some pressure & made into solid boards. The top surface is smooth & hard while the bottom surface is rough.

Glulam

- Glulam means glued and laminated wood.
- Solid wood veneers are glued to form sheets and then laminated with suitable resins.
- This type of sheet is very much suitable in the construction of chemical factories, long span roofs in sports stadium, indoor swimming pools etc.
- Curved wood structures can also be constructed using glulam sheets.

Chip board

→ chip boards are another type of industrial timber which are made of wood particles or rice husk ash or bagasse.

→ These are dissolved in resins for some time & heated.

→ After then it is pressed with some pressure & boards are made. These are also called particle boards.

Block Board

→ Block board is a board containing core made of wood strips. The wood strips are generally obtained from the leftovers from solid timber conversion etc.

→ These strips are glued and made into solid form.

→ veneers are used as faces to cover this solid core.

→ The width of core < 25mm.

→ If the width of core is less than 7mm then it is called as Lamin board.

→ Block boards are generally used for partitions, paneling, marine and river crafts, railway carriages etc.

Flush door shutters :-

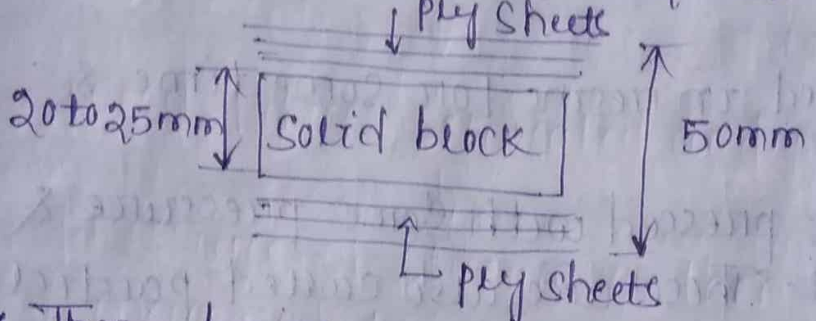
→ Flush door shutters made in factories are widely using nowadays.

→ They are generally available with 25, 30, 35 mm thickness.

→ Factory made flush board shutters are of different types such as cellular core, hollow core, block board core etc.

(a) Batten board

Total thickness - 50mm
Thickness of core - 20 to 25mm



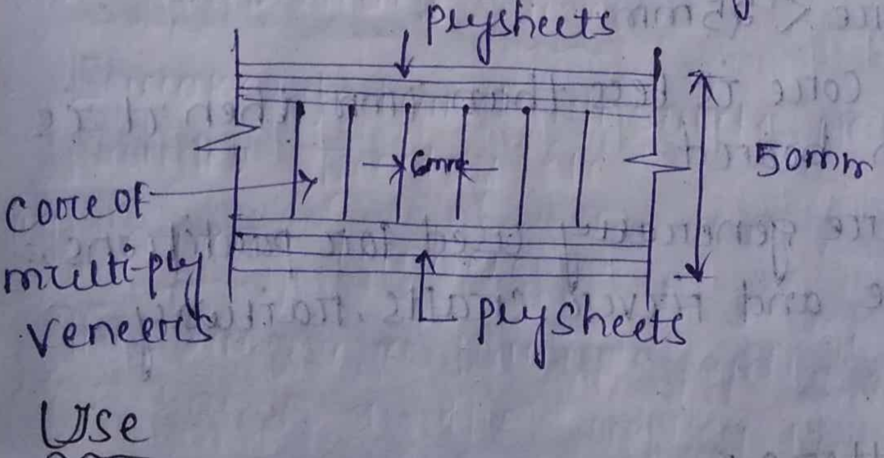
- These boards are light & strong.
- They do not crack or split easily.

Use

partition walls, packing cases, furniture ceilings, shutters of doors and windows.

(b) Lamin boards

Similar to the batten boards except that the core is made of multiply veneers.



Use

Same uses as those batten boards

(c) Metal faced plywood

The core is covered by a thin sheet of aluminium, copper, bronze, steel etc.
This plywood is rigid and it is cleaned.

pdf

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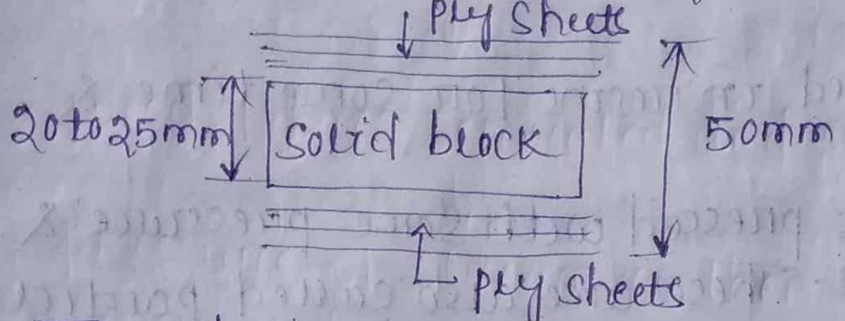

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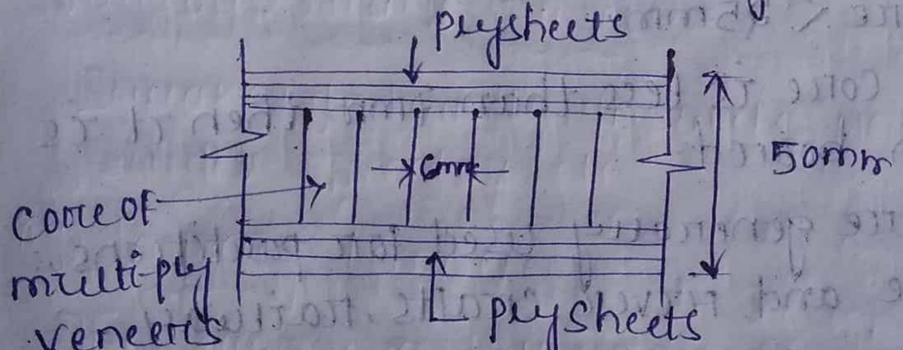


Use

Same uses as those batter boards

(c) Metal faced plywood

The core is covered by a thin sheet of aluminium, copper, bronze, steel etc.
This plywood is rigid and it is cleaned.

(d) Three-ply

The plywoods prepared from three plias only are known as the three-ply.

Thickness - up to 4mm

(e) Multiply

The plywoods prepared from more than three ply are designated as the multiply.

The number of veneers is odd

Thickness - from 6mm to 25 mm or more

(F) Veneered plywood

Facing veneer is of decorative appearance & it is used to develop an ornamental effect

According to CPWD plywood are of three grades :-

(i) Boiling water resistance (BWR)

(ii) Warm water resistance (WWR)

(iii) Cold water resistance (CWR)

③ Fibre boards :-

Rigid boards also known as pressed wood or reconstructed wood.

Thickness - 3mm to 12mm

Length - 3m to 4.5m

Width - 1.2m to 1.8m

Weight - 9600 N/m^3 max^m

500 to 600 N/m^3 min^m

→ pieces of wood, core or other vegetable fibres and chippings are collected and they are heated and boiled in hot water

↓

wood fibres separated and put in a vessel

↓

pressure of stream is then suddenly increased to $7N/mm^2$

↓

Cleaned fibres are spread on wire screens in the form of loose sheets or blankets of required thickness

↓

Loose sheets of wood fibres are prepared betⁿ steel plates and ultimately fibre boards are obtained.

Various trade names :-

Eurake, Indianite, Insulite, Mesonite, Nordex, Treetax etc

④ Impreg timber

This timber is fully or partly covered with resin is known as the impreg timber.

Resin:- phenol formaldehyde

→ The resin fills the space between wood cells and by chemically reaction, a considered mass develops.

→ It is then cured at a temp of about 150 to 160°C.

Various trade names:-

Formica, sungloss, sunmica etc.

Use

Moulds, furniture, decorative

⑤ Compreg timber

Same as that of Impreg timber except that curing is carried out under pressure. Strength is more than impreg timber.

⑥ Block boards and Lamina boards

Core made up strips of wood, each not exceeding 25mm in width.

→ The edges are glued together to form a solid sheet, which is then finished with one or two cross bonded veneers on each face.

Lamin boards:-

When the thickness of core strips not exceed 7mm, such boards are known as lamin boards.

⑦ Glulam

Means glued and laminated wood. Solid wood veneers are glued to form sheets and then laminated with suitable resin.

1.3

Wall claddings

→ Wall cladding or tiling is a process of finishing the surface with tiles. They are fixed upto a height of 1.25m above the floor level or upto ceiling, in passages, bath rooms, swimming pools, kitchens, staircases, boiler rooms, fire places and sometimes on exterior of building for decorative effect or protection from atmospheric agents.

→ They make the wall non-absorbent and easy to clean. The tiles used are either terra cotta, faience, china clay, natural stones like marble. Faience is similar to terra cotta but is twice fired.

→ These tiles are available in variety of colours and thickness. They are rectangular, square, rounded or corner type.

→ For cladding, the surface of the wall is first plastered with the cement mortar in usual manner & then the tiles, which are immersed in water at least one hour, are covered with a paste of neat cement on back and laid flat against the wall.

Plaster boards

→ These are large sheets of gypsum plaster faced on both sides with stout paper as reinforcement. plaster boards are made by mixing gypsum plaster withe fine cinders or wood chips & sufficient water to form a thin consistency.

→ They are most economical & easy to work due to light in weight. Though the plaster forms best covering on external walls but the use of plastering is not favoured due to following reasons:-

(a) plaster does not stick well to the wood work.

(b) The cracks are formed on the plastered surface due to extreme temperature variations.

(c) The plastered surface required sufficient time for setting and drying.

(d) The plastering operation is lengthy process which takes considerable time.

→ To overcome the above objections a variety of wall boards are being used now a days. These boards are readily available in the market with different variety. These plaster boards are fire proof in nature, neither expand nor contract due to change in temperature.

Micro Silica

→ Micro silica is a light grey cementitious material composed of at least 85% ultra fine, amorphous non-crystalline (glassy) spherical silicon dioxide (SiO_2).

→ It is also called as silica fume. It is produced as a by-product during the manufacturing of silicon metal or ferrosilicon alloys by reduction of high purity quartz in a submerged arc electric furnance heated to 2000°C with coal, coke & wood chips as fuel.

→ The micro silica, which condenses from the gases escaping from the furnance, has very fine spherical particles having diameter of 0.1µm.

→ Ferro silicon alloys are produced with nominal silicon contents 60 to 98%. As the silicon content increases in the alloys, the SiO_2 content increases in the micro silica.

Properties of micro silica

- → Specific gravity - 2.20
- → Bulk density - 200 to 250 kg/m^3
- → Minimum surface area - 15,000 m^2/kg
- → Content of SiO_2 is at least 85%
- → It gives long term corrosion protections.

Advantages

It gives better application when added with portland cement

- → Micro silica increases the compressive strength.
- → It retards the chloride iron diffusion.
- → It improves the sulphate resistance.
- → It reduces water permeability
- → It improves abrasion & chemical resistance.
- → It reduces efflorescences
- → It improves the chemical resistance.

Artificial sand

→ Natural sands are obtained by the weathering action, abrasion of particles of rocks along with flow of stream. Depending on parent rock, action on particles, size and grading of natural river sand varies from place to place.

→ Dams are constructed on upstream of river, so now-a-days sands are not available on downstream of dams. At locations, grading of sand available may not contain certain fractions which are required for ideal grading

→ Strength, durability of concrete mix depends on size, shape, grading of fine aggregate. Since good quality sand may not be available, crushed sand is produced. It also helps in protecting ecological balance, by restricting use of natural resources to minimum.

→ Artificial sand is a specific purpose produced materials, which will satisfy the strength, durability, size, shape, grading requirement of fine aggregate in concrete mix. The stone metal or crushed stone waste, below 25mm from good parent rock is fed to disintegrator.

Properties

→ The density of artificial sand lies in bet^n 18 - 25 KN/m^3.

→ It doesn't contain any organic impurities.

→ Water absorption is almost negligible.

→ Specific gravity = 2.65 to 2.8

Advantages

→ Artificial sand is well graded.

→ This sand is having superior surface texture.

→ It can be compacted properly to reduce voids.

→ Less quantity of cement materials required.

→ It can be produced in required quantity & desired quality.

→ If economy at large is considered, artificial sand, many times proves to be economical.

Bonding agents

→ Bonding agents are natural, compounded or Synthetic materials used to enhance the joining of individual members of a structure without using mechanical fasteners.

→ These products are often used in repair applications such as the bonding of fresh concrete, sprayed concrete, fresh mortar & old concrete.

→ When bonding agents are applied on old concrete that time surface of old concrete work should be cleaned for proper bonding.

→ Following are the various types of emulsion used as bonding agents in the construction work.

① Epoxy latex

These emulsions are produced from liquid epoxy resins mixed with the curing agents. Most of the epoxy resins are prepared on the job site just before use because phase separation occurs in prepacked emulsions. Equal parts of epoxy and curing agents are mixed, then blended for 2 to 5 minutes and allowed to set for 20 minutes to enable polymerization to begin.

② Styrene butadiene (SBR):-

This latex is compatible with cementitious compounds, which is a copolymer. This latex may coagulate if subjected to high temperature, freezing temperatures, severe mechanical action for prolonged period of time.

③ Acrylic Latex

This type of emulsion is used in the cementitious compounds in much the same manner as SBR Latex. Acrylic ester resins are polymers and copolymers of the ester.

④ polyvinyl acetate Latex (PVA)

This type is most widely used as a bonding agent for plaster. Because of its compatibility with cement, it is widely used as a bonding agent and a binder for cementitous water-based paints and water proofing coatings. It is available in two forms; emulsifiable and non-emulsifiable.

⑤ Epoxy bonding agent

For bonding of freshly placed concrete, various products are available. Most products contain resins that are 100% solids. products are available in a variety of consistencies, ranging from a highly filled paste (for overhead tank) to liquids with a viscosity of 100cp, which is similar to water.

⑥ Latex emulsions

These emulsions are stable in the cement / water system. There is a variety of application for latex emulsions used as bonding agents. some of these have greater degree of water resistance than others.

Adhesives

→ Adhesion is attraction bet^n unlike surfaces. Cohesion is attraction bet^n like surfaces. Usually due to primary or secondary forces of attraction, adhesives are used to join two or more parts into a unit.

→ These are advantages of adhesive bonding over methods of assembly like bolting, riveting, welding etc.

→ Adhesives join the surfaces in three ways: Specific adhesion if surfaces are joined together by intermolecular forces of attraction; mechanic adhesion, if the adhesive fill the voids of porous or rough surfaces and hold the surfaces by interlocking action, and fusion of surfaces which are partially dissolved in the adhesive or its solvent

Advantages

→ Corrosion may be prevented bet^n different metals joined by adhesives.

→ The joints become impermeable for water & gas.

→ Adequate strength is produced by using adhesives.

→ The adhesive application process is economical, easy & speedy

→ Leakage problem of water can be stopped by the application of adhesives.

Disadvantages

- Adhesive requires time to attain desired strength
- Specific adhesive is required to be used for specific substances
- Adhesives are unstable at high temperature

① Animal protein glues

These glues are obtained from hide trimmings, bones and flashing by boiling these by hot water. Animal glues provide strong, tough, easily made joints, but they are affected by damp & moist conditions. It is supplied in the form of flakes, pearls, sheets, cakes, granules, cubes or jelly. Animal glues having three grades depending upon the water absorption i.e 18, 15, 10 times the dry weight of glue.

Use of animal protein glue

This is used in the manufacture of plywood, laminated timber.

② Blood albumin glues

It is made by drying raw blood & affected by damp & moist conditions. This glue has good water resistance properties & also durable.

Use of blood albumin glues

They have good adhesive properties for paper, textile & metals, hence largely used in food packaging, leather dressing and for wood working.

③ Casein adhesive

It is obtained by curdling skimmed milk by the addition of dilute acid. casein is separated, mixed with lime & preservatives & sold. casein for wet mix glue should pass through 60μ sieves & for dry mix glue should pass through 25μ sieves shaken for 10 mins. Casein glue, if properly formulated, proved highly moisture resistant glue joints but not water proof. It has less resistant to bacterial attack.

Use of casein adhesive

These glues have been used since long to from strong, water-proof wooden joints & to make durable plywoods

④ starch adhesives

It is made from vegetable starch having good dry strength but not resistant to moisture. Alkali or acid modifiers are used to make starch paste thick & tacky. This glue has poor water resistance but bond quickly to paper & textile. They are cheaper & easier to handle than animal glues.

Use of starch adhesive

This glue is spread & dried easily, they are used in automatic package machines. These glues are used in the manufacture of low strength & low water resistance plywood.

⑤ Synthetic adhesives

→ These are mostly resins used in plastic industry & are classed as thermosetting or thermoplastic glues. Thermosetting glues are permanent, once they are set, but the thermoplastic types can be made plastic again by reheating.

→ All of them are strong, water proof & fire-proof & the setting time can be regulated by varying the amount of the hardener.

⑥ Gum arabic

This forms the most useful natural resin adhesive. It contains mixed mineral salts of arabic acids, which is obtained from acacia trees.

→ It is used for joining paper & wood & in high speed packing & labelling machines.

⑦ Sodium silicate glues

This glue is made by fusion of the soda & sand in a furnance. The fused mass is cooled & dissolved in water. On loss of water, water glass is formed which possesses adhesive property. This glue is water & fungal resistance.

This glue is used in the manufacture of card-board & paper boxes.

⑧ Nitro-cellulose glues

The cellulose nitrate or propylene when mixed with other resins forms the basis of common household cements. These glues are highly flammable & as such must be handled with great care. They are used to cement glass, metals, leather cloths and ceramics.

Properties and uses of acoustics material:-

→ properties of acoustic material:-

→ Sound energy is captured and adsorbed.

→ It has a low reflection & high absorption of sound.

→ Higher density improves the sound absorption efficiency at lower frequencies.

→ Higher density material help to maintain low flammability performance. Hence acoustic material should have higher density.

→ Acoustic materials reduces the energy of sound waves as they pass through.

→ It suppresses echoes, resonance & reflection.

Uses of acoustic material:-

→ Acoustic material can be used for noise reduction & noise absorption.

→ It makes the sound more audible which is clear to listen without any disturbance.

→ It suppresses echoes, reflection & resonance.

→ Acoustic foam & acoustic ceiling tiles absorb sound so as to minimise echo within a room.

→ Sound proof doors & windows are designed to reduce the transmission of sound.

→ Double wall construction or cavity wall construction can improve the sound proofing of a room.

Different materials used for acoustic materials :—

1. Fiber glass
2. Rock wool
3. open cell polyurethane foam
4. cellular melamine foam
5. Heavy curtain blankets
6. Thick fabric wall coverings

PREFABRICATION

2.1- Introduction, necessity and scope of prefabrication of buildings, history of prefabrication, current uses of prefabrication types of prefabricated systems, classification of prefabrication, advantages & disadvantages of prefabrication

2.2- The theory & process of prefabrication, design principle of prefabricated systems, types of prefabricated elements, modular coordination.

2.3- Indian standard recommendation for modular planning.

1.1

Introduction

prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies to the construction site where the structure is to be located.

Need for prefabrication

→ Used for non suitable normal construction areas (chilly region)
→ Speedy construction
→ Lack of space
→ Improve quality
→ proper utilization of space
→ Mass production
→ Durable structure with less maintenance
→ Aesthetic finish
→ Further expanses easy

Prefabrication principles :-

- Design for prefabrication, preassembly & modular coordination.
- Simplify and standardize connection details
- Simplify & separate building systems
- Minimize building components & materials
- Select fittings, fasteners, adhesives and sealants that allow for quicker assemby & facilitate the removal of reusable materials.
- Reduce building complexity
- Design of reusable material.

Uses of prefabrication

- prefabrication techniques are used in the construction of apartment slacks & housing developments with repeated housing units.
- prefabricating steel sections reduces on site cutting & weeding costs as well as the associated hazard's.
- The technique is also used in office blocks, warehouses & factory buildings.
- Able to re-use moulds.
- prefabrication can also help minimize the impact from bridge building.
- prefabricated steel & glass sections are widely used for the exterior or large buildings.

Advantages of prefabrication

- The need for work shuttering & scaffolding is greatly reduced.
- construction time is reduced & buildings are completed.

→ Skilled labour is more readily available & costs of labour, power, materials, space and overheads are lower.
→ Time spend in bad weather or hazardous environments at the construction site is minimized.

Disadvantages of prefabrication

→ Careful handling of prefabricated components such as concrete panels or steel & glass panels is required.
→ Leaks can form at joints in prefabricated components.
→ Large prefabricated structures require heavy-duty cranes & precision measurement and handling to place in position.
→ Local jobs are lost

Classification of prefabrication

→ Small prefabrication - Ex. Brick
→ Medium prefabrication - Ex. roofing systems & horizontal members
→ Large prefabrication - Ex. wall panels, roofing/flooring systems
→ caste-in-site prefabrication - construction in site
→ open system of prefabrication - wall fitting and other fixing are done on site
→ closed system of prefabrication - whole things are casted with fixings & erected on their position.

→ partial prefabrication
→ Total prefabrication- All elements are prefabricated.

prefabricated materials

→ prefabricated building materials are used for buildings that are manufactured off-site and shipped later to assemble at the final location.
→ Some of the commonly used prefabricated building materials are aluminium steel, wood, fiberglass and concrete.
→ Synthetic materials are used for the walls & roofs. To provide enhanced security a combination of both metal & cloth materials are used.
→ plastic flooring materials can be quickly assembled & are very durable.
→ prefabricated, building materials used for small prefabricated buildings are steel, wood, fiberglass plastic or aluminium materials.
→ These materials are cheaper than regular brick & concrete buildings.

Modular coordination

→ Modular coordination means the interdependent arrangement of a dimension based on a primary value accepted as a module.
→ Modular coordination is the basis for a standardization of a mass production of component
→ purpose of modular coordination
• To reduce the variety of component size reduced.
• To allow building designer greater flexibility in the arrangement of components.

Module

The basic module is known as 1M which is equivalent to 100mm.

1M = 100mm

→ There are three type of module :-
(i) Basic module (ii) Multi module

→ Basic module

→ It is the fundamental unit of size in modular coordination & for general application to building & components. The size of basic module is taken as 100mm denoted by "M".

→ Multi module

→ Certain whole multiples of basic module, usually expressed in as "M" with numeric prefix as 2M, 3M, 4M etc are preferred to as multi module.

→ It is possible to achieve a substantial reduction in the number of modular sizes

Sub module

Certain submultiples of basic module which are whole simple fractions shall be chosen when absolutely necessary for an increment smaller than the basic module. For practical considerations, this sub modular increment shall be expressed as "M" with fractional prefix as 1/5 M, 1/4 M, 1/3 M, etc.

Aims of modular coordination

→ Facilitating cooperation bet^n designers, manufacturers, suppliers & builders.

→ permits a flexible type of standardization which encourages the use of a number standardized components for the construction of buildings & building components.

→ Ensures dimensional coordination bet^n installation as well as with the rest of building

Standardization

→ Standardization is the repeated production sizes and or layouts of components or structures which may occur on site or off site.

Example

→ Modular bathroom, standard kitchen cabinet, prison cell etc.

Advantages

→ Easier in design

→ Easier in manufacture

→ Easier in erection and completion

Factors influencing standardization

→ The number of elements will be limited & they should be used in large quantities.

→ To the extent possible the largest size to be used which results in less number of joints.

→ The size & the number of the prefabricate in limited by the weight in overall dimension that can be handled by the transportation.

Systems of prefabrication

Major systems are:

- Large panel system
  - Longitudinal wall system
  - Cross wall system
  - Combined system
- Structural frame system
- Lift panel system (column slab system)
- Mixed system.

It can also be categorized as

- Open prefabricate system
- Closed prefabricate system

Process involved in manufacturing

Main process

- providing & assembling the moulds, placing reinforcement cage in position for RC work
- Fixing the wires & tubes
- pouring and vibrating
- Demoulding and stacking
- curing

Auxiliary process (necessary process covered by main process)

- Mixing and manufacturing the concrete
- prefabrication of reinforcement cage
- Finishing & testing the products.

Transportation

Transporting the structural components is also one of the important task in prefabrication. To properly deliver to the site following things should be considered.

→ careful handling must be carried

→ Avoid jerk & distress in elements

→ properly planned - Traffic rules and regulations.

→ size of transport vehicle

→ proper base packing materials

Erection

Erection & installation of components on site:

→ Requires proper attention and skill to prevent the elements from developing erection & handling stresses.

Stationary cranes

1- Guyed derrick

→ Lighter in weight

→ Used for framed buildings for erection of floor panels, columns & slab strips

2- Climbing crane

→ Tall buildings over 20 storey used

→ A horizontal jib and balancing counter weight are placed top of the shaft

→ Rotates over 360 degree

③ Tower crane

The most versatile equipment used in prefabrication is a tower moving on rails.

Crane on rails

→ portal cranes

→ Tower cranes

Mobile crane moving on ground

→ Truck mounted

→ crawler mounted

Structural components

→ slab

→ joist

→ Beams

→ wall panel

→ columns

→ The roofing / flooring system consists of R.C planks and joists.

→ The planks are casted to a standard size & they are connected with R.C.C joist which are provided at a regular interval.

→ The loads from planks are transmitted to R.C joist & then to main beams.

→ The main beams are provided with channel 10cm sections projections on the necessary sides with the spacing of joist.

→ The joists are seated in the channels & bolted together.

→ The loads from slab to the main beam will come as point loads & a typical frame with different loadings are analysed.

Slab

→ The roofing slab / flooring slab system consists of planks, which is supported over R.C.C joist.

→ Width of these slabs is 0.5m & maximum limit of length 5m without prestressing.

→ The planks can be made in any one of the following form with or without prestressing

→ According to the span & loads:

- Hollow core sections
- Double tee section / Channel section
- Light weight concrete roofing slab
- Solid rectangular planks

Joist

→ The joists are designed as small beams loaded from planks

→ These joists transmit the loads to the main beams through the channels provided in the main beams.

→ In this joist, triangular shaped stirrups are provided to get the proper bonding or connection with the planks.

→ The joists are casted partially in the factory

→ The apex portion of the triangular stirrup will be projecting from the casted top surface

→ In this projecting a connecting rod will be inserted & additional base from planks also inserted

→ This will give monolithic action as well as the plank will act as a continuous slab over the joists.

Beams (Main & Secondary)

→ All the main & secondary beams are the same size of 300mmx300mm varies reinforcements are provided at varies conditions according to the moments

→ The beams are casted for the clear distance bet^n the columns

→ A square of 10cmx10cm hole or a depth of 10cm are provided on either side to achieve the connection with other beam reinforcement or column reinforcements by proper welding

→ After welding the concrete has to be done at the junction with proper care

→ At the junction of beams & columns, it is necessary to put site concreting.

→ For this purpose the top ends of the beam are tapered properly so that it will give access to site concrete and for needle vibrators to get properly compaction

Wall panels

→ The wall panels are casted with all fixing like door, ventilation, window frames

→ These wall panels are non load bearing wall Therefore neglect solid rectangular cross section wall panel with R.C.C from the view of thermal effects & safety

→ The minimum of 150mm is provided as wall thickness

→ This wall is sandwich type

→ That is cellular concrete blocks of 75mm thick is sandwiched by R.C.C

→ M25 grade concrete to a thickness of 37.5mm on either face with minimum reinforcement.
→ Since, the walls are in steel moulds there will be no need for plastering on either face of wall.

Columns

→ Many type of columns available in prefabricated system.
→ Grooves are provided on the required faces to keep the walls in position.
→ These grooves will act as a part of columns & since the area of column has been increased due to Nibs will give addition moment carrying as well as load carrying capacity of columns.
→ At the same time this grooves give a mild ornamental look to our building.

Advantages of prefabrication

→ Moving partial assemblies from a factory often costs less than moving pre-production resources to each site.
→ Deploying resources on-site can add costs; prefabricating assemblies can save costs by reducing on-site work.
→ Factory tools - shake tables, hydraulic testers, etc can offer added quality assurance.
→ Consistent indoor environments of factories eleminate most impacts of weather on production.
→ Cranes & reusable factory supports can allow shapes & sequences without expensive on-site false work.

→ Higher-precision factory tools can aid more controlled movement of building heat and air, for lower energy consumption and healthier buildings.

→ Factory production can facilitate more optional materials usage, recycling, noise capture, dust capture, etc.

→ Machine-mediated parts movement, and freedom from wind & rain can improve construction safety.

Disadvantages

→ Transportation costs may be higher for voluminous prefabricated sections than for their constituent materials, which can often be packed more densely.

→ Large prefabricated sections may require heavy duty cranes & precision measurement & handling to place in position.

Earthquake resistant construction

3.1 - Building configuration

3.2 - Lateral load resisting structures

3.3 - Building characteristics

3.4 - Effect of structural irregularities - vertical irregularities, plan configuration problems.

3.5 - Safety consideration during additional construction and alternation of existing buildings.

3.6 - Additional strengthening measures in masonry building - corner reinforcement, lintel band, sill band, plinth band, roof band, gable band etc.

Assumptions made in the earthquake resistance design of structure

(i) Earthquake causes impulsive ground motions, which are complex and irregular in character, changing in period & amplitude each lasting for a small duration. Therefore, resonance of the type as visualized under steady-state sinusoidal excitations, will not occur as it would need time to build up such amplitudes.

(ii) Earthquake is not likely to occur simultaneously with wind or maximum flood or maximum sea waves.

(iii) The value of elastic modulus of materials, wherever required, may be taken as for static analysis unless a more definite value is available for use in such conditions.

Intensity of Earthquake

Measure of the strength of shaking during the earthquake, and is indicated by a number according to the modified mercalli scale or M.S.K scale of seismic intensities

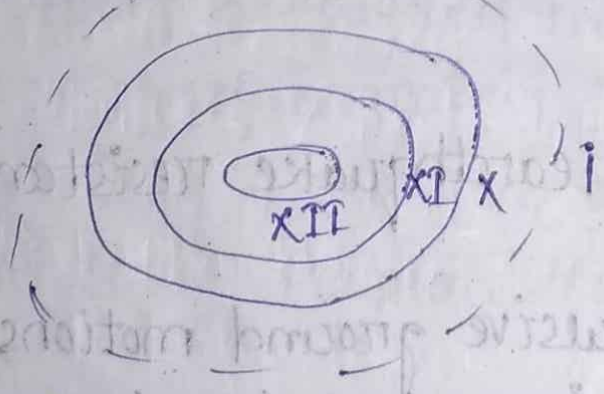
→ See Annex D

→ Earthquake intensity is a ranking based on the observed effects of a earthquake in each particular place

→ It is a qualitative measure.

→ Modified mercalli intensity scale range from 'I' (least perceptive) to XII (most severe)

→ Intensity of earthquake



→ MSK-64

→ The Medvedev-Sponheuer-Karnik scale, also known as the MSK or MSK-64, is a macroseismic intensity scale used to evaluate the severity of ground shaking on the basis of observed effects in a area of the earthquake occurrance.

Magnitude of earthquake

The magnitude of earthquake is a number, which is a measure of energy released in an earthquake

→ Magnitude is a quantitative measure of the actual size of the earthquake.

→ The magnitude of the earthquake is a single value for a given earthquake and it is the amplitude of earthquake.

Global occurrance of Earthquake

Group	Magnitude	Annual average number
→ Great	→ 8 & higher →	1
→ Strong	→ 6 - 6.9 →	120
→ Major	→ 7 - 7.9 →	18
→ Moderate	→ 5 - 5.9 →	800
→ Light	→ 4 - 4.9 →	6200
→ Minor	→ 3 - 3.9 →	49,000
→ very minor	→ < 3.0 →	M2.3 - 1000/day M1.2 - 800/day

The Richter Magnitude scale :-

→ seismic wave are recorded on instrument called seismograph.

→ The time, location, and magnitude of an earthquake can be determined from the data recorded by seismograph stations.

Design seismic base shear :-

The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined by the following expression.

$$V_B = A_h \times W$$

A_h → Design horizontal acceleration spectrum.
W → seismic weight of building.

Design horizontal seismic co-efficient (A_h) :-

$$A_h = \frac{ZISa}{2Rg}$$

$A_h \nless \frac{Z}{2}$ when $T \leq 0.1$ sec whatever the value of $\frac{I}{R}$

→ Z = Zone Factor, Z

Table '2' zone Factor, Z

Seismic Zone	II	III	IV	V
Seismic intensity	Low	moderate	Severe	very severe
Z	0.10	0.16	0.24	0.36

→ I = Importance factor, depending upon the functional use of the structures.

Table-6	"I"
(i) Important service and community buildings	1.5
(ii) All other buildings	1.0

→ R = Response reduction factor

$\frac{I}{R} \not> 1.0$

Table-7

→ $\frac{S_a}{g}$ = Average response acceleration coefficient. Depends upon type of soil and T

Distribution of design force

Vertical distribution of base shear to different floor level :-

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i,

h_i = Height of floor i measured from base,

n = Number of storey in the building is the number of levels at which the masses are located.

Fundamental Natural period (T_a), in second

$T_a = 0.075h^{0.75}$ → For RC frame building

$= 0.085h^{0.75}$ → For steel frame building (without brick infill panels)

h = height of building, in m

→ $T_a = \frac{0.09 \times h}{\sqrt{d}}$ for all other buildings with brick infill panels

h = height of building in m

d = Base dimension of building at the plinth level, in m, along the considered direction of the lateral force.

Lateral load resisting structures:—

→ The tall building need a lateral load resisting system to maintain the structure stable when lateral loads are applied to them.

→ Lateral loads from wind and earthquakes are mainly applied to buildings.

→ when building become taller & taller, horizontal loads applied to them increased. Further, the effect of the lateral load becomes more severe with the increase of the height of structure.

→ The followings are lateral loads on a building design

- wind loads
- Seismic loads
- Water pressure, etc

Different structural systems are introduced depending on the nature of the buildings to resist the lateral loads. Following methods are widely used in buildings

① Frame
② Bracings
③ Shear walls
④ Wall frame interaction

Frame :-

→ Beams and columns connected together create the frame

→ When the connection of the beam and column is rigid, the frame can transfer the lateral loads to the foundations

→ Beams and column frame structure can be used upto 15-20 stories as a lateral load resisting system.

Bracing :-

Bracing are used mostly in steel structures to improve the lateral load resisting capacity. Further, they are constructed in the concrete buildings also to improve the lateral load resistivity.

→ The following types of bracings are used in buildings.

- Single diagonals
- Cross bracings
- K-bracing
- V-bracing

→ Lateral loads applied by wind, seismic loads and national loads are resisted by these types of bracings.

Shear wall :-

A concrete wall constructed from the based level to the top of the building is considered as a shear wall. It carries the lateral loads and vertical loads applied by the structural element connected to it.

→ The shear wall alone can resist the lateral load of building having about 20 stories. Beyond that, the contribution of the frame could also be considered.

→ Stiffness of the shear wall is the key factor affecting the lateral load resistivity of the wall.

Wall frame interaction

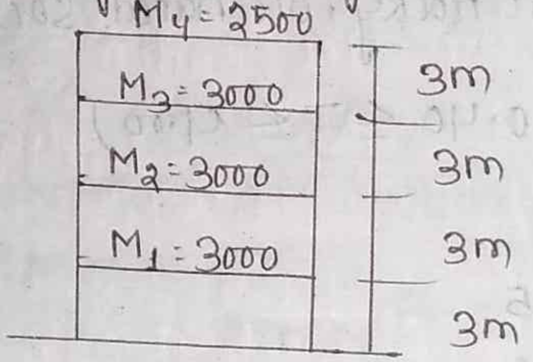
Consideration of the wall frame interaction is one of the best option that we using the inherent capacity of the structural systems.

→ Shear wall alone can resist the lateral load upto some extent. Beyond a certain level, we need some other supporting method to have the load resisting capacity. Therefore designers have to find alternatives to improve structural capacity.

→ Wall frame means combinations of shear wall and rigid frames.

QN Imp

A four storey reinforced concrete frame building as shown is situated at Roorkee. The height betn the floor is 3m and total height of the building is 12m. The dead load and normal live load is lumped at respective floor. The soil below the foundation is assumed to be hard rock. Assume building is intended to be used for as a hospital. Determine the total base shear as per IS 1983:2002. Distribute the base shear along the height of the building.



Ans

Total seismic base shear is given by

$$V_B = A_h \times W$$

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Data given

(a) Building is situated at Roorkee:-
So seismic zone is of (iv) - IS 1893-2002
page - 36

So $\boxed{Z = 0.24}$ → Table-2 IS 1893-2002
page - 16

(b) Building is used for hospital:-

So $\boxed{I = 1.5}$ - Table-6, IS 1893-2002
page no-18

(c) Reinforced concrete frame building, so
R = 5, Table-7 (page no-23)

(d) Fundamental natural period (Ta)

$T_a = 0.075 h^{0.75}$ (clause no-7.6.1)

$= 0.075 \times 12^{0.75}$

$= 0.4835$

To find $\frac{S_a}{g}$ for rocky, or hard soil

$\frac{S_a}{g} = \frac{1}{T_a}$ $(0.40 \leq T \leq 4.00)$

So $\frac{S_a}{g} = \frac{1}{0.4835}$

$= 2.06$

(e) W - Seismic Load

$W = 3000 + 3000 + 3000 + 2500$

$= 11500 KN$

The total seismic base shear is given by

$V_B = A_h \times W$

$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$

$= \frac{0.24}{2} \times \frac{1.5}{5} \times 2.06$

$= 0.07416$

$V_B = 0.07416 \times 11500 KN$

$= 852.84 KN$

The design base shear (V_B) computed shall be distributed along the height of the building as per the following expression.

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \Rightarrow Q_i = V_B \cdot \frac{W_1 h_1^2}{W_1 h_1^2 + W_2 h_2^2 + W_3 h_3^2}$$

$$\text{so } Q_1 = 852.84 \left(\frac{3000 \times 3^2}{3000 \times 3^2 + 3000 \times 6^2 + 3000 \times 9^2 + 2500 \times 12^2} \right)$$

$$= 31.20$$

$$Q_2 = 852.84 \left(\frac{3000 \times 6^2}{3000 \times 3^2 + 3000 \times 6^2 + 3000 \times 9^2 + 2500 \times 12^2} \right)$$

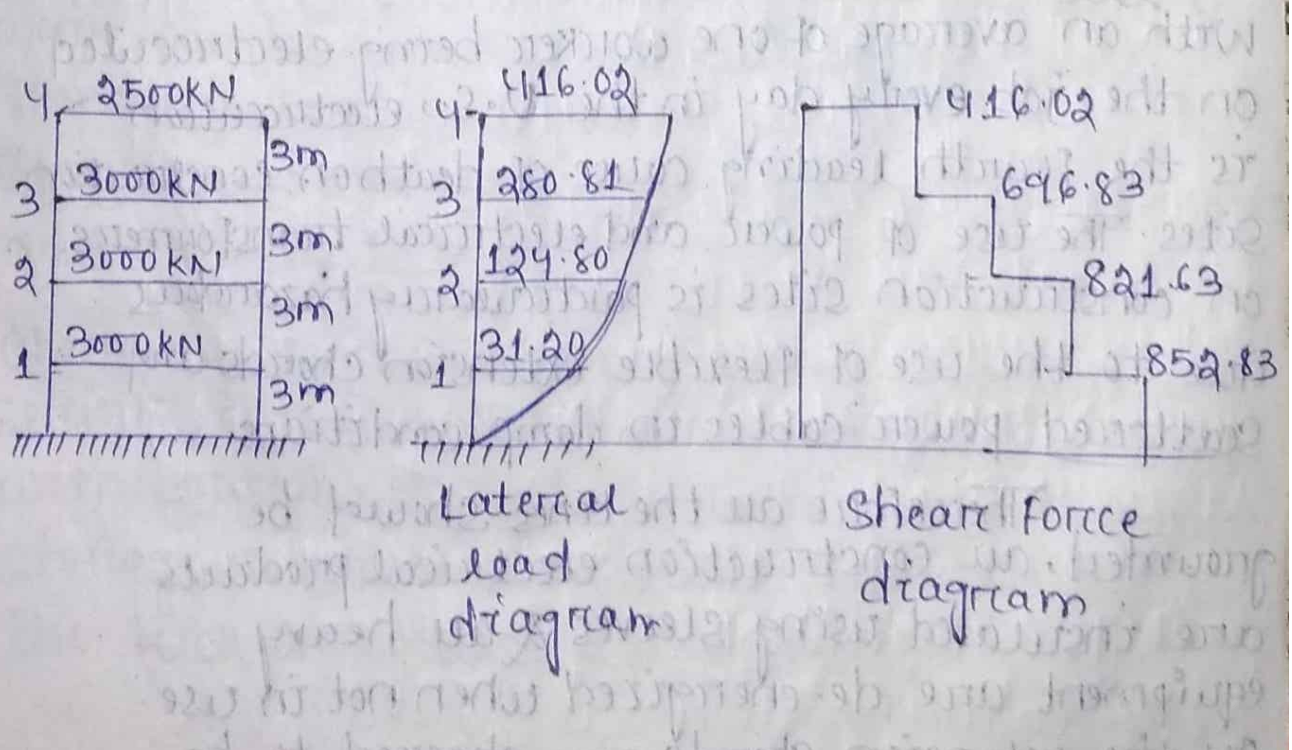
$$= 124.80$$

$$Q_3 = 852.84 \left(\frac{3000 \times 9^2}{3000 \times 3^2 + 3000 \times 6^2 + 3000 \times 9^2 + 2500 \times 12^2} \right)$$

$$= 280.81$$

$$Q_4 = 852.84 \left(\frac{2500 \times 12^2}{3000 \times 3^2 + 3000 \times 6^2 + 3000 \times 9^2 + 2500 \times 12^2} \right)$$

$$= 416.02$$



Safety consideration during additional construction and alternation of existing building

1- Manage and mitigate risk with a safety training program

Due to the risk inherent in construction work, all employees must be trained and instructed to point out high risk areas for efficient emergency management. While it is impossible to eliminate the risk completely, training programs can educate site workers to conduct regular safety audits. This will enable them to assess & address potential risks & greatly minimize the possibility of injuries, thereby ensuring a safe working environment.

2- Ensure electrical safety at construction sites

With an average of one worker being electrocuted on the job every day in the U.S., electrocution is the fourth leading cause of death on construction sites. The use of power and electrical transformers on construction sites is particularly hazardous due to the use of flexible extension chords and scattered power cables in damp conditions.

Therefore all the lines should be grounded, all construction electrical products are insulated using sleeves & all heavy equipment are de-energized when not in use. All the extension chords are checked to be adequate for the amount of current being carried to avoid fluctuations & overloading.

③ Implement strict security and safety protocols

construction site access should be limited to ensure protection of heavy equipment & machinery from theft & damage. The safety of pedestrians from potential hazards of a construction site requires strict supervision while the work is on. only authorized visitors should be allowed on site and strict safety protocols should be enforced to protect contractors from liabilities, security breach and litigation due to negligence of safety.

④ Have a safe work assesment process in place

An SWMS (safe work method statement) must be prepared & implemented for all high-risk projects prior to the commencement of work. This statement must clearly outline the scope of work & potential risks involved along with ways to avoid or manage them. Ideally, no construction work can be commenced until all the SWMS standards have been met.

⑤ Make sure chemical storage safety requirements are strictly followed

chemicals can cause pollution, fire, explosion and serious injuries if not stored, handled or used with caution. Using high-quality and compliant storage solutions for chemicals can reduce the risk of spillage and fatalities.

⑥ Display signage clearly at the construction site

The SWMS must be clearly displayed throughout the construction site so that all the safety protocols are visible at all times. It should also include a 24-hour emergency number along with a map that leads to the office. The signage should indicate the location of Fire extinguishers, First aid supplies, emergency exits and amenities available on site.

⑦ plan and prepare for adverse environmental conditions

Unfavourable weather conditions can invite serious accidents on construction sites. Every construction site must have a contigency plan that guides workers with clear instructions to stop work in case of extreme weather conditions & steps to handle emergencies in case of natural disasters.

⑧ provide personal protective equipment

An employer is obligated to provide his staff with all the necessary PPE including safety harness, safety googles, head protection gear, & fall protection depending on the type of work.

These safety tips make a good starting point for implementing a safety program & for ensuring electrical safety at construction sites.

Additional Strengthening measures in masonry building

Corner reinforcement

The exterior corners of slabs that are supported by stiff elements such as walls and edge beams. These stiff elements restrain the slab & cause additional bending moments at the exterior corners. Corner reinforcement must be provided in the top & bottom of the slab to resist these bending moments. According to IS codes, reinforcement must be placed parallel to the diagonal in the top of the slab & perpendicular to the diagonal in the bottom of the slab. Reinforcement parallel to the slab edges is permitted to be used instead of the diagonal bars. This layout is preferred because of ease of constructability.

Horizontal & other bands

Horizontal bands are the most important earthquake-resistant feature in masonry buildings. The bands are provided to hold a masonry building as a single unit by tying all the walls together, and are similar to a closed belt provided around cardboard boxes. There are four types of bands in a typical masonry building, namely gable band, roof band, lintel band & plinth band, named after their location in the building. The lintel band is the most important of all, and needs to be provided in almost all buildings. The gable band is employed only in building with pitched or sloped roofs. In buildings with flat reinforced concrete, ~~or~~ the roof band is not required, because the roof slab also plays the role of band. However, in buildings with flat timber or CGI sheet roof, roof band needs to provided. In building with pitched or sloped roof, the roof band is very important. plinth bands are primarily used when there is concern about uneven settlement of foundation soil. The lintel band ties the walls together and creates a support for walls loaded along weak direction from walls loaded in strong direction. This band also reduces the unsupported height of the walls & thereby improves their stability in the weak direction. During the 1993 Latur earthquake (central India), the intensity of shaking in Killari village was IX on MSK scale. Most masonry houses sustained partial or complete collapse. on the other hand, there was one masonry building in the village, which had a lintel band and it sustained the shaking very well with hardly any damage.

Lintel band

During earthquake shaking, the lintel band undergoes bending & pulling actions. To resist these actions, the construction of lintel band requires special attention. Bands can be made of wood (including bamboo splits) or of reinforced concrete; the RC bands are the best. The straight lengths of the band must be properly connected at the wall corners. This will allow the band to support walls loaded in their weak direction by walls loaded in their strong direction. Small lengths of wood spacers (in wooden bands) or steel links (in RC bands) are used to make the straight lengths of wood runners or steel bars act together. In wooden bands, proper nailing of straight lengths with spacers is important. Likewise, in RC bands, adequate anchoring of steel links with steel bars is necessary.

RETROFITTING of Structures

4.1 - Seismic retrofitting of reinforced concrete building

4.2 - Sources of weakness in RC Frame building

4.3 - Classification retrofitting techniques & their uses

Retrofitting

The word Retrofit means to apply new technologies to an older system. Retrofit is a process of adding some new features that were not there before. Retrofitting in construction industry refers to re-strengthening of existing structure to make them seismic resistant.

Retrofitting is an economic approach to increase life span of an existing structure rather than redeveloping it.

Types of retrofitting

1 - Retrofitting of reinforced concrete structures:

RC structures can be retrofitted using any of the following methods;

Re-strengthen existing structure

→ Reinforcement Concrete jacketing
→ Wrapping column with CFRP.
→ Steel jacketing of column.
→ Steel caging

2- Retrofitting of masonry structures:

Repairing existing structure

→ Crack stitching in plaster

→ cement grouting in cracks

→ shotcreting

Advantages of Retrofit :-

→ Energy efficient

→ Increase life span.

→ Existing buildings can be made green later on.

→ Allows changes in future as per the need.

→ Lower carbon emissions from building activities.

→ upgrades existing elements of a building.

→ Adaptation of new technologies.

→ Material from structure can be reused in some cases.

→ Reduced maintenance cost

Disadvantages of Retrofit :-

→ It is an expensive & inconvenient method.

→ Wall insulation may reduce internal spaces.

→ Retrofitting can cause damage to heritage or ancient assets

→ More detailed research required for retrofit

→ There should be more focus on risks of retrofitting.

4.2

Sources of weakness in RC Frame

Earthquake engineering is not a pure science rather it has been developed through the observation of failure of structure during earthquake. Damage Survey reports of past earthquakes reveal the following man sources if weakness in reinforced Concrete moment resisting frame buildings.

(i) discontinuous load path

(ii) Lack of deformation compatibility of structural members

(iii) quality of workmanship and poor quality of materials

(1) Structural damage due to discontinuous load path:-

Every structure must have two load resisting Systems:

(b) vertical load resisting system for transferring the horizontal load to the vertical load system.

(a) vertical load resisting system for transferring the vertical load to the ground

(b) It is imperative that the seispic forces should properly collected by the horizontal framing System and properly transferred into vertical lateral resisting system. Any discontinuity in this load path or load transfer may cause one of the major contributions to structural damage during strong earthquakes

Therefore, all the structural and non-structural elements must have sufficient strength & ductility & should be well connected to the structural system so that the load path must be complete & sufficiently strong.

(ii) Structural damage due to lack of deformation

→ The main problems in the structural members of moment resisting frame building are the limited amount of ductility & the inability to redistribute load in order to safely with stand the deformations imposed upon in response to seismic loads

→ The regions of failure may be in columns beams walls and beam column joints

→ It is important to consider the consequences of member failure of structural performance.

→ Inadequate strength and ductility of the structural member can and will result in local or complete failure of the system.

(iii) Quality of workability and materials

→ There are numerous instances where faulty construction practices and lack of quality control have contributed to the damage.

→ The faulty construction practices may be like, lack of amount & detailing of reinforcement as per requirement of code particularly when the end of lateral reinforcement is not bent by 135° as the code specified.

→ Many buildings have been damaged due to poor quality control of design material strength as specified, spalling of concrete by the corrosion of embedded reinforcing bars, porous concrete, age of concrete, proper maintenance etc

4.3

= Classification retrofitting techniques & their uses

Retrofitting techniques

- Global
  - Adding shear wall
  - Adding in fill wall
  - Adding bracing
  - Adding will wall/ buttresses
  - Wall thickness
  - Mass reduction
  - Supplemental damping and base isolation
- Local
  - Jacketing of beam
  - Jacketing of columns
  - Jacketing of beam column joints
  - Strengthening individual footing

There are two ways to enhance the seismic capacity of existing structures.

1- The first is a structural-level approach of retrofitting which involves global modifications to the structural system.

2- The 2nd is a member level approach of retrofitting or local retrofitting which deals with an increase of the ductility of components with adequate capacities to satisfy their specific limit state.

Structural level Global retrofitting:-

Adding New shear walls:-

one of the most common methods to increase the lateral strength of the R.C. buildings. It is the last simple method.