LEARNING MATERIAL OF

ADVANCED CONSTRUCTION TECHNIQUES & EQUIPMENT

PREPARED BY – ER. SWARNAPRAVA PARIDA

&

ER. SUMANTA KUMAR SAHOO

Dt: 26.04.2021

Advanced construction Techniques & Equipment

Section A

1. Advanced construction materials.

2. Prefabrication :

3. Earthquake Resistant construction.

4. Retrofitting of structures

5. Building services.

6. Construction & earth moving equipment

7. Soil Reinforcing Techniques.

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Plastic

→ Plastic is a generic name for certain organic substances.

→ It is not a single material but comprises a group of materials.

⇒ Any material that possess the property of plasticity i.e capacities to undergo change when external pressure are applied and retains the new shape even after the pressure is withdrawn is known as a plastic material.

→ They are synthetic resins produced by synthetic or semi-synthetic organic polymerization or condensation based on various carbon compounds derived from petroleum products or to a very little extent of coal.

→ They are light in weight, transparent, tough organic compounds and are electrically insulating.

→ Traditional plastics are not biodegradable which is a major concern for environment degradation

Constituents of plastics :—

The basic raw materials for producing plastics are obtained from coal, petroleum, air & water.

→ The moulding composition for plastics is prepared from following →

Raw materials groups.

Binder :—

Binder may be either resins (synthetic or natural) or cellulose derivatives (Polymeter compounds)

Filler :-

→ The materials added to the plastics to improve their mechanical properties and make them economical are called fillers.

→ These are powder, fiberous & Laminated fillers.

Powder fillers :—

* Quartz powder, chalk powder talcum, organic substances i.e. ground saw dust are the powder fillers.

* These fillers improve hardness workability heat resistance & acid resistance of plastic and reduce it's cost.

Fibrous fillers:-

* Asbestos, wood wool, saw dust & glass fibres are used as fibrous fillers.
* They increase strength, reduce brittleness and enhance thermal resistance & impact strength of plastics.

Laminated fillers:-

Paper, cotton & fibre glass cloths asbestos and cardboards etc.

→ They increase mechanical strength of plastics.
→ Asbestos and cardboards also increase heat and acid resistance properties.

Plasticizers:-

The chemical added to plastics to make them soft to improve their toughness at finished stage and to make them flexible are called plasticizers

→ The plasticizers should be chemically inert, non-volatile & non-toxic.

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→ Common plasticizers are vegetable oils, aluminium streerates and dibutyl phthalate and camphor

Colouring matter:-

→ This is usually in the form of pigment and dyes and after added to monomers and gives the required colour to the plastics.
→ The colouring matter should be durable and adequately fast to light.
→ Commonly used dyes are- organic (AZO dayes, anthraquinone vat dyes) and mineral bigments.

are ochre, chromium oxide and ultramarine

Lubricants:-

→ Common lubricants are Masallic soaps and streamates

→ They facilitate moulding operation by increasing the flow of plastics mix in the dye and also prevent sticking of plastics to mould.

Catalysts:-

→ These compounds are added to accelerate the chemical reaction during the process of polymerisation of plastics.

→ These compounds also act as accelerators and hardness.

Polymers & polymerisation:-

→ The polymers are composed of a large number of repeating units (small molecules) called monomers.

→ That is the polymers made up of thousands of monomers joined together to from a large molecule of colloidal dimension called macro-molecule.

* The unique feature of a polymer is that each molecule is either a long chain or network of operating units all covanlently bonded together.

→ In some case, molecules are held together by secondary bonds.

Polymerisation :-

The process of linking together of monomers is called polymerisation.

Classification of plastics

→ Thermoplastic

→ Thermosetting.

Thermoplastic :-

→ Thermoplastic materials are those which soften the application of head, with or without pressure and require cooling to be set to a shape

→ They can be heated and cooled any number of times, only they should not be heated above their decompasition. temperatures.

→ They are highly plastic and are easy for moulding or ~~set~~ shaping.

→ The have low melting temperatures and are not so strong as the thermosetting plastics.

→ since they can be repeatedly used, they have a resale value.

→ some commercial thermoplastics are polythene, polyvinyl chloride (PVC), polystrene, polytetra-fluoro ethylene (PTEE) etc.

Polysetting malynials

→ polysetting materials are those plastics which require heat and pressure to mould then in to shape.

→ They cannot be resoftened once they have set and hardened

→ They are ideal for moulding into components which require rigidity, strength & some resistance to heat.

→ In general, resins formed by condensation are thermosetting.

→ Thermosetting resins have three-dimensional molecular structure and have very high molecular weights.

→ Due to cross-linking, thermosetting resins are hard, tough and non-swelling and brittle.

→ Hence they can't be softened or remoulded as in the case of thermosetting resins.

→ Examples of thermosetting plastics are phenolics, polyesters, Epoxies, silicones etc.

Dt. 01.05.2021 Difference between Thermosetting & thermoplastic materials:-

Thermosetting material	Thermoplastic material
→ They have three dimensional network of primary covalent bonds with cross-linking between the chains.	→ They are linear polymers without cross linking & branching.
→ They are more stronger and harder than thermoplastic materials	→ They are less strong and softer material.
→ Once they hardened & set they don't soften with the application of heat.	→ They can be repeatedly softened by heat & hardened by cooling.
→ They can't be recycled.	→ The scrap of these plastics can be recycled again, so they are economical.

→ Objects made by thermo-setting materials can be used at comparatively higher temperature without damage.

→ It is difficult to fill an intricate mould with such plastics.

Uses:-
Telephone Receivers, electric plugs radio/TV cabinets, camera bodies automobil parts circuit breakers switch panels etc.

→ Objects made by thermoplastic resins cannot be used at comparatively higher temperature as they will tend to soften under heat.

→ It is comparatively easy to fill the mould.

Uses:-
Toys, combs, toilet goods, photographic films, insulating tapes, electric insulation etc.

Thermoplastic materials:-

Important thermoplastic materials are:

Polyethylene or polythene $(C_2H_4)_n$:-

Polyethiylene are obtainable as various liquids, gums and flexible solids suitable for moulding.

Properties:-

→ They are wax like appearance, translucent, odourless and one of the lighest plastics.
→ Flexible over wide temperature range.
→ High Resistivity and dielective strength.
→ Chemically Resistant.
→ Donot absorm moisture.
→ They are relatively low in cost.

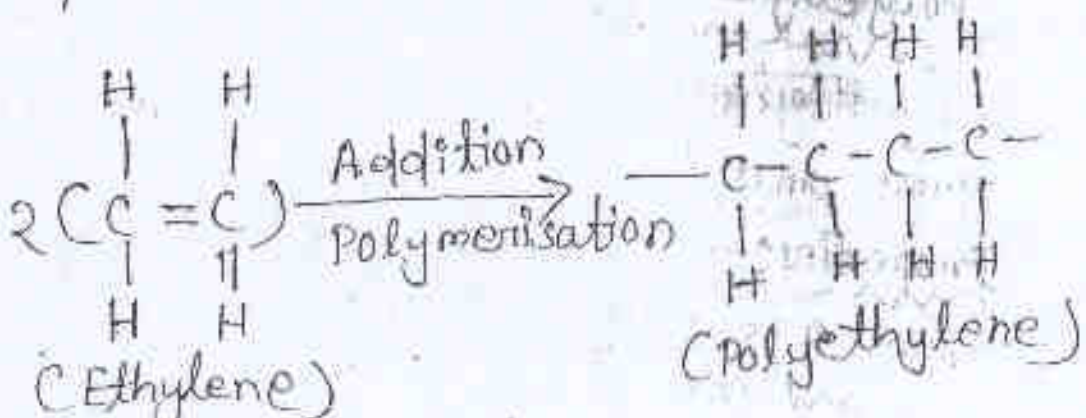
Uses:-

→ High voltage (upto 30(KV)) applications.
→ Coaxial cables
→ Packaging
→ Moisture proofing.
→ Coating ice-cubes trays.
→ Pipes and tanks for water storage.

* Two types of poly-ethylene are manufacturs depending upon the condition of polymerisation.
  (a) High density polyethylene (HDPE)
  (b) Low Density poly-ethylene L

(a) High density Polyethylene:-

→ This is obtained by low pressure polymerisation process.
→ It has specific gravity 0.96 and softening temperature 120 - 130°C.



(Ethylene) (Polyethylene)

Low Density polyethylene (LDPE):-

→ This is obtained by high pressure process.
→ It has specific gravity 0.90 and softening temperature 86°C.

→ Polythene is prone to degradation and embrittlement by sunlight due to cross-linking but performance can be improved by addition of black pigment such as carbon black, which absorbs rays and prevents damage.

→ Under ground polythene is not affected by salts in the soil and has excellent resistance to salts and bacteria.
However, it is attacked by strong acids.

→ It is a good electrical insulator.

→ Polyethylenes, in particular LDPE, have high permeability to gases and they are therefore not considered for gas service.

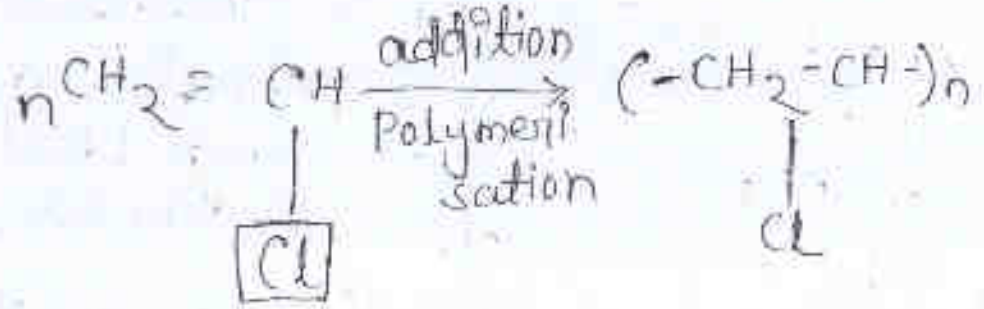
Polyvinyl chloride (PVC):

→ This is cheapest & most widely used.

→ The vinylchlorides are formed from hydrochloric acid, limestone and natural gas or coal. The forms of vinylchloride are almost unlimited.

→ It is manufactured by addition polymerisation of vinylchloride polymerisation is carried out in presence of catalyst.

→ It is different from polythylene. In pvc one in four hydrogen atoms is replaced by a chlorine atom. Hence it has greater rigidity



→ PVC can be manufactured in expanded or cellular form. It is available in two forms namely flexible & rigid.

→ It can be easily extruded and moulded into the desired form. The joints are obtained by solvent welding.

Properties :—

→ The flexible types are strong, tear resistant and have good ageing properties.

→ The rigid types have good dimensional stability and are water resistant. They are resistant to acids and alkalies.

→ It is attacked by aromatics and soluble in ketones and esters.

→ It resistant to impact invariably deteriorated with time.

→ It becomes soft by 80°C

→ It is self extinguishing when ignited and the source of flame removed.

→ The hard type of PVC is formulated

with less plasticizer than the general purpose grade and shows less tendency to flow at high temperature which is an advantageous when the cables are to be laid in varying hot surroundings.

→ Although its electrical properties are not so good as those of rubber it offers more resistance of oxygen ozen and sunlight.

→ PVC has tendency to decompose when it is heated or exposed to sunlight with the liberation of hydrochloric acid and gas.

→ A small amount of Lead salt. lead silicate. or Lead salt, lead silicate or Lead steate is blended into the polymer at the compounding stage to prevent the same.

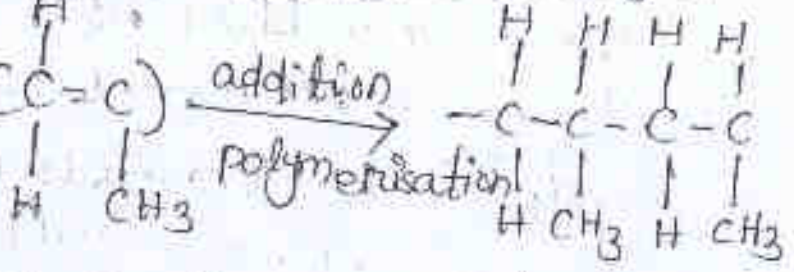
Uses:-

→ In cable jackets.
→ Lead-wire insulation.
→ Rubber-substitute.
→ Fabric coating.
→ Rain wader goods
→ Corrugated Roofing.
→ Flooring and ceiling panels etc.

Polypropylene (PP):-

→ It is manufactured by addition polymerisation of propylene

→ It is stronger and more rigid material than polyethylene owing to the presence of CH_3 group attached to the liner molecular chains.



(Propylene) Polypropylene

Properties:-

→ Its resistance to chemicals is better than that of polyethylene.

→ It has high flexibility, good heat distortion resistance & fatigue strength.

→ It is attacked by strong acids.

→ They are brittle at low temperature, transclucent & flammable.

→ They have poor resistance to ultra violet rays and weathering.

Uses:-

→ vacuum flasks

→ Filaments & fibres.

→ Electrical insulators.

→ Flash light casings

→ Hair dryers

→ Refrigeration parts.
→ Films & sheets for packing
→ Automatic parts.

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Thermosetting materials :-

Phenol formaldehyde (Baklite)

→ Phenal formaldehyde (PF) is made by condensation polymerisation of phenol & formaldehyde in an acid or alkaline medium.
→ Asbestos, glass fibres, pigments and other additives can be added to improve it's property.

Properties :-

→ The colour range is limited to black or brown (however, it discolours on ageing by sunlight)
→ It is strong, rigid and dimensionally stable.
→ It is resistant to heat, most chemicals and solvents.

Uses :-

→ Lavatory seats.
→ Paints & adhesives.
→ Thermal insulation as cellular.
→ Electrical parts.
→ Vaccum cleaner parts.
→ Handle, knobs on domestic appliances.

Amine formaldehyde:-

(Urea)

→ These plastics are obtained by condensation of urea or melamine with formaldehyde.

→ These are highly cross-link polymers.

→ They can be compounded with fillers, pigments and other additives to form moulding materials of different colour.

Properties:-

→ Melamine has more resistant to chemicals, heat and moisture but these plastics are attack by strong acids.

→ It is scratch free and more expensive.

→ It has better electrical properties.

→ It is slightly affected by sunlight.

Uses:-

→ Glus for phywood,

→ Cellulose and formed products.

→ Surface watings.

→ Paints

→ Adhesive

→ Plugs, switches, buttons etc.

Polyesters:-

→ This plastics are manufactured by condensation polymerisation of dicarboxylic acid (Maleic acid) and dihydric alcohol (Ex glycol) followed by curing with crosslinking agents (Styrene).

→ A wide variety of products can be made by varying monomers and curing agents.

Properties:-

→ They have good resistance to heat and most chemical except strong acids and alkalies.

→ They are affected by sunlight.

Uses:-

→ Safety helments.
→ Automobile body components.
→ Paints.
→ Binders for glass fibres
→ Fibres glass boats.
→ Jointing and Repair work.

Fibre Reinforced plastic (FRP):-

→ It is formed by the using two materials in conjuction which each other to form a composite material of altogether different properties.

→ In FRP, the glass fibres provides stiffness and strength while resins provides matrix

to transfer load to the fibres.

Properties of FRP:-

→ Following are the properties which have made the FRP the most commercially successful composite material of construction.

→ Aesthetic appeal.

→ Dimensional stability

→ Light weight.

→ Easy to repair.

→ Durable.

→ Corrosion resistance.

→ Requires less energy for production

→ Least maintenance required.

→ Tooling is inexpensive & fast.

→ FRP product transmits a great deal of light.

Applications:-

Application of FRP are:-

→ Water storages tanks.

→ Roof sheets.

→ Domes.

→ structural sections.

→ Doors & windows frames.

→ Concrete shuttering.

→ Internal partation and & wall panelling

→ Temporary shelters.

FIBERS

The fiber is a filament or thread like piece of any material.

→ This term sometimes also refer to a raw material that can be drawn into threads.

Fibres may be of following types.

→ Mineral fibres.
→ Animal fibres.
→ Vegetable fibres.

Mineral fibres:-

→ These fibres includes asbestos, glass fibre, slag-wool and metal wool.
→ Asbestos due to its fibrous structure combined with inflammability is peculiarly suited for thermal and electrical insulation.
→ Glass fibres and slag wool are employed for thermal insulation.
→ The metal wool is used for fibres and cleaning applications.

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Animal fibres:-

* Animal fibres are of two types
  (i) Animal hair obtained from sheep, goats, pigs etc
  (ii) Silk produced by the mulberry silk worm or from the larvae of other moths
→ The most important hair fibre is sheep wool. Its length varies from 2.5 to 20cm and its diameter from 0.0045 to 0.01cm.

→ Pig bristles are used in paint brushes. wool waste for packing glands etc. is made from carpet yarn with fibres not less than 8cm long.

→ Silk from mulberry silkworm possess high strength while varieties obtained from other moths are of lower strength comparatively.

→ Vegetable fibres:—

→ vegetable fibres consist mainly of cellulose.

→ They may be seed hairs, such as cotton or the inner bark of plants such as flax, hemp, jute.

→ The colour of cotton, flax and jute and hemp fibres are white, grey brown and brown respectively.

→ The woody types are stiff and brittle whereas those with a high proportion of cellulose flexible and elastic.

→ Cotton is used for making batting gun cotton, cloth and jute is obtained from the stalks of the jute plants by retting.

→ The short fibres are used in paper making whereas longer ones are used in the manufacture of coarse woven fabrics such as carpet building, as a substitute for hemp in twine and small ropes as a filler in cable, and adulterent for other fibres.

Artificial Timber :-

→ Invented by Roy Research and Technology.
→ Artificial timber is a wood substitute made from solid waste like fly ash, silica and bituminous tar sand, and biodegradable cellulosic ash or waste material.
→ Artificial Timber looks and feels like wood.
→ It is more profitable because it is low cost and doesnot harm the environment during production.
→ It is has a potentially to play in the utilization of coal combustion products like fly ash and bottom ash which are by-products of thermal power plants and can be found throughout the world.

Properties :-

→ Wood is warm, earthy and feels good to the touch, that's why wood substitute in furniture like plastic or metal or in flooring like ceramic tiles.
→ As wood can be cut into various sizes and shapes, own artificial timber can be re-sized for various uses in furniture flooring even construction.
→ It's density can be changed i.e it can be made heavier, stronger or lighter.
→ It resembles and feels like natural timber in grain and colour.
→ It has nail and screw holding capacity

→ It is a good thermal insulator, it helps in retain heat in wood houses.

→ It is Termite proof and borer resistant.

→ It has Resistance against the action of hot water and chemicals including salt, acids and bases.

Uses of artificial timber:—

→ It is used in making different household furnitures.

→ Artificial wood can be safely used in doors as well as in industrial uses.

→ It helps in making boats and other floating floating devices.

→ as it's density can be changed, it is considered as ideal material for building boats.

Types of artificial

→ Veneers
→ Plywood
→ Fiber boards
→ Hard boards
→ Impreg Timbers
→ Compreg Timbers
→ Black Boards

Veneers:-

→ It is nothing but thin layers of wood which are obtained by cutting the wood with sharp knife in rotary cutter

→ In rotary cutter, the woodlog is rotated against the sharp knife or saw and 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, black boards etc.

Plywood:-

→ ply means thin Plywood is a board obtained by adding thin layers of wood or veneer on one above each other.

→ The joining of successive layer is done by suitable adhesives.

→ The layers are glued and pressured with some pressure either in hot or cold conditions.

→ In hot condition 150° to 200°C temperature is marinated and hydraulic press is used to press the layers.

→ In cold conditions room temperature is maintained and 0.7 to 1.4 N/mm² pressure is applied.

→ Plywood has many uses it is used for door partition walls ceiling, panelling walls, form work for concrete etc.

→ Due to it's decorative appearance, it is used for building's like theaters, auditoriums, restaurants etc in temples, churches for architectural purpose.

Fiber Boards:-

→ Fiber boards are made of wood fiber vegetable fibers etc.

→ The are rigid boards and called as reconstructed wood.
→ The collected fibers are boiled in hot water and then transferred into closed vessel,
→ steam with low pressure is pumbed in to the vessel and pressure increased suddenly.
→ Due to sudden increment of pressure, the wood fibers explode and natural adhesives gets separated from fiber.
→ Then they are cleaned and spread on wire screen in the form by loose sheets.
→ This matter is pressed in between steel plates and finally fiber board are obtained.
→ Fiber boards are used for several purposes in construction industry. Such as wall panelling, ceilings, portions, flush doors, flooring material etc.
→ They are also sound insulating materials.

Impreg Timber :-

→ His a timber covered fully or partly with resin.
→ Thin layers of wood and veneers are taken and dipped in resin solution.
→ Generally used resin is phenol formaldehyde.
→ The resin solution fills up the voids in the wood and consolidated mass occurs.

→ Then it is heated at 150 to 160°C and finally impreg timbers are develops
→ This is available in market with different names such as sunglass, sunmica, formica etc.
→ Impreg timbers have good resistance against moisture, weathering, acids and electricity.
→ It is strong, durable and provides beautiful appearance.
→ It is used from making wood molds, furniture, decorative products etc.

Compreg Timbers:-

→ It is similar to impreg timbers but in this case, the timbers is cured under pressure conditions.
→ So it is more strengthened than impreg timbers.
→ Its specific gravity lies between 1.30 to 1.35.

Hard boards:-

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

Hard boards are generally classified as three types i.e.

	Density	Available thickness
→ Medium →	480-800 kg/m³	6, 8, 10, 12 mm
→ Normal →	800-1200 kg/m³	3, 4, 5, 6, 9, 12 mm
→ Tempered →	> 1200 kg/m³	3, 4, 5, 6, 9, 12 mm

Glulam:-

→ Glulam means glued and laminated wood.

→ Solid wood veneers are glued to from 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 stadia stadium indoor swimming pools etc.

→ Curved wood structures can also be constructed using glulam sheets.

Chip boards:-

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

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

→ After them it is pressed with some pressure and boards are made

→ These are also called particle boards.

Block Boards:-

→ Block boards 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 is less than 7mm then it is called as lamin boards.

→ The width of core should not exceed 25 mm.

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

Acoustic materials:-

→ An acoustic material is designed to control, reflect and manipulate the sound waves.

→ The material can either enhance or diminish the quality of the sound as per requirement on a particular given space.

Types of Acoustic materials:-

1. Sound Absorbers
2. Sound Diffusers
3. Noise Barriers
4. Sound Reflectors

1. Sound Absorbers:-

→ The sound absorbing acoustical panels and sound proofing material are used to eliminate sound reflections to improve intelligibility, reduce standing waves and prevent comb filtering.

→ Typical materials are opencell polyurethane foam, cellular melance, fiber glass, fluffy fabrics and other porous materials.

A wide verisety of materials can be applied to walls and ceilings depending on your application & environment.

→ These materials vary in thickness and in shape to achive different absorption rating depending on the specific sound Requirements.

Types:-

→ Acoustical foam panels.
→ White paintable acoustical wall panels.
→ Fabric wrapped panels.
→ Acoustical wall covering.
→ Ceiling tiles.
→ Fibre glass blankets & rolls

Acoustical foam panels:-

* This type of sound absorbers are used in wide variety of applications ranging from recording and Broadcast studios to commercial and Industrial facilities.
* It is available poly urethane or in class 1 fire-rated foam.
* These can be directly applied to the walls, hung as battles or used as freestading absorbers.

Acoustical foam panels :-

1- This type of sound absorbers are used in wide variety of application ranging from Recording and Broadcast studios to comercial and industrial facilities.

* It is available polyurethane or in class 1 fire rated foam.

* This can be directly applied to the walls, hung as beffles or used as freestading absorbers.

Fabric wrapped panels :-

> A coustical sound panels utilitie G-7 PCF glass fiber material for maximum absorption.

> It is available as wall panels ceiling tiles, hanging baffles, acoustical clouds with more than 50 standard colours to choose.

Sound Diffusers :-

> These devices reduce the intensity of sound by scattering it over as expanded area, rather than eliminating the sound reflections as an absorber would

> Traditional spatial diffusers, such as polycylindrical (barrel) shapes also double as low frequency traps.

> Temporal diffusers such as binary arrays and quadratic, scatter sound in a manner similar to diffraction of light, where the timing of reflections from an uneven surface of varying depth

causes. interference which spread the sound.

Noise Barriers / Sound Barrier :-

→ Sound barrier materials are used to reduce the transmission of airborne sound.

→ The Block Aid series of products include the standard on pound per square foot non-reinforced fibre, transparent material where observation or supervision required.

Wall Cladding

→ Wall cladding is a great way to protect a building from adverse weather elements, as well as other type of irritants that could have a negative effect of a building.

→ wall cladding is the process of layering one material on top of another material which will create a skin layer over the wall.

→ Cladding is almost exclusively used as a control feature, preventing the walls and the internal working of a room or building being damaged by water or allowing the leakage of water that could potentially become a hazard for people who are walking around inside of structure.

→ Depending on the task at hand, different types of materials can be used such as wood, brick, metal plastic or imitation stone.

→ metal cladding is usually in the form of galvanized steel and aluminium.

→ Advantages

Advantages of Exterior cladding :-

→ The main advantages of using an exterior wall cladding is to protect a building from external damage while needing little to no maintenance.

→ Once wall cladding is in place it will not need to be regularly checked or serviced like other weather protection measures have to be costing time & money.

→ If external cladding is in placed there is no need of any other preventive measures to be taken.

→ It can be easily washed and looks new as before.

→ One of the most common materials used is aluminium, as it is very durable and versatile as well as long lasting.

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Micro silica

→ Micro silica is also known as silica flume.

→ It is an amorphous (non-crystalline) polymer of silicon dioxide, silica.

→ It is an ultrafine powder collected as a by product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm.

→ The main field of application is as pozzolanic material for high performance concrete.

Properties :-

→ Silica fume is an ultrafine material with spherical particles less than 1μm in diameter, the average being about 0.15 μm.

→ This makes it approximately 100 times smaller than the average cement particle.

→ The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 to 800 kg/m³.

→ The specific gravity of silica fume is generally in the range of 2.2 to 2.3.

→ The specific surface area of silica fume can be measured with the BET method / nitrogen adsorption method.

→ It typically ranges from 15000 to 30,000 m²/kg.

Applications:-

→ Because of it's extreme fineness and high silica content silica fume is very effective pozzolanic material. So it is added to portland cement concrete to improve its properties. In compressive strength, bond strength and abrasive resistance.

→ Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion.

→ With the addition of silica fume, the slump loss with time is directly proportional to the increase in silica fume content due to introduction of large surface area in the concrete mix by it's addition.

→ Silica fume reduces bleeding because the free water is consumed in wetting of the large surface area of silica fume and hence the free water left in the mix for bleeding also decreases.

Artificial Sand

⇒ Artificial sand also called crushed sand or manufactured sand refers to rocks, mine tailing or industrial waste granules with a particle size less than 4.75 mm. It is processed by mechanical crushing and sieving.

→ Artificial sand is mainly used in the construction of hydropower systems.

→ Many Indian states have decreed the use of crushed sand in infrastructure construction because of its high compressive strength and cohesion and the adverse environmental effects of river sand mining, which is greatly boosted the demand for artificial sand.

[Factors that promote the development of artificial sand]:-

→ These are both natural and human factors in the increasing demand for artificial sand.

→ The former is that the natural sand is about to run out while human factors include peoples requirement for environmental protection and the need for high-quality concrete.

1) Natural sand depletion:-

→ With the development of infrastructure the natural sand resources formed by hundreds of thousand of years in many countries and regions have been almost exhausted, which have affected the further development of construction projects.

2. [The need for energy saving and environmental protection]

Reason-1: River sand minning causes river pollution.

Due to River sand minning the river changes the course, and affects the safety of river embankments, destroys the living environment of fish and contaminates the ground water. The chushed stone sand is an important alternative resource to change this phenomenon.

Reason-2: River sand mining cause tailing:-]

In the process of mining river sand it often produces a large amount of tailing which is not used reasonably. Especially in small mines, the tailing are pilled up at random occupying land and polluting the environment.

Reason-3: A lot of construction waste is generated.

Besides in urban planning and construction a large amount of construction waste is generated which actually can be crushed by crushers to produce the artificial sand and aggregates for promoting resource utilization.

Bonding Agents :-

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

→ It is used in repair applications such as bonding of fresh concrete, sprayed concrete or sand/cement repair mortar to hardened concrete. So the concrete has the strength of monolithically cast concrete.

Factors affecting the bonding between new and old concrete :-

→ The strength and integrity of old surfaces.

→ The cleanliness of the old surface.

Bonding agents are of two types.

→ Latex

→ Epoxy

Latex :- Emulsions.

Characteristics :-

→ Some have greater degree of water resistance than others.

→ The ~~latex~~ latex emulsions generally used in cement polymers compositions are of the oil-in water type, and some times contain more than 50% of water.

→ They are generally stable in the water/cement system.

Applications :-

→ Prepare a neat cement slurry utilizing the latex as part of mixing water.

Latex is again divided into three parts

1. Acrylic
2. Styrene Butadiene (SBR).
3. Polyvinyl Acetate (PVA).

1. Acrylic

→ These physical properties range from soft elastomers to hard plastics

→ This type of emulsion is used in cementitious compounds in much the same manner as SBR latex.

(i) Non-re-emulsifiable (PVA) :-

→ Good water resistance, ultraviolet stability and ageing characteristics.

→ It is widely used as a bonding agent and as a binder for cementitious water based paints and water proofing coatings.

(ii) Emulsifiable (PVA) :-

→ It can be softened and retackified with water

→ It is mostly used as a bonding agent for plaster, and to bond finisher base-coat gypsum, or portland cement plaster to interior surfaces of cured cast in place concrete

Property Test method	Acrylic	Polyvinyl acetate non re-emulsifiable	Butadyns styrene	Polyvinyl acetate

Epoxy

→ Various epoxy products are available for bonding freshly placed concrete to cured concrete and of concrete of steel.

→ Most products contain resins that 100% solids. The on may not content fillers.

→ Products are available in variety of consistencies ranging from a highly filled paste to liquids similar to that of water.

Classification:-

→ The specification classifies the epoxy resin bonding system by type, grade and class.

Type:-

→ Type I, for bonding hardened concrete and other materials to hardened concrete.

→ Type II, for bonding freshly mixed concrete to hardened concrete.

→ Type III, for bonding skin resistant material to hardened concrete (or for use as a binder in epoxy mortars or concretes)

Grade:-

→ The grade of a system is defined by it's flow characteristics.

Ex

→ Grades comprises of materials of low viscosity suitable for injection into cracks and where flow is required.

→ Grade-2 comprises medium-viscosity materials for general purpose and use.

→ Grade-3 materials are of non-sagging consistency for overhead work for bonding non-mating surface.

Class

→ Classified by the test temperature at which the gel times are determined (gel time is the interval between the beginning of mixing an epoxy system and the first formation

of gelationous mass within the system)

→ class A → temperature below 5°C used

→ class B → temperature between 5 and 15°C used.

→ class C → above 15° temperature is used.

Application :-

→ Most epoxy bonding products have a pot life or setting time of 15-30 minute at 25°C making it necessary to mix only the amount that can be properly used in that period of time.

→ where extensive repair work is necessary such as slab replacement or resurfacing of vertical wall or columns. epoxy bonding agents in the combination with new concrete of an provide the most economical solution.

→ The use of bonding agents ensures that the repair will have the strength of monolithically cast concrete.

Adhesives :-

→ Adhesives can be defined as the non-metallic material. It is capable of joining permanently to surfaces by an adhesives process.

→ The use of adhesive in construction offers certain advantages owen other binding techniques.

→ These includes the ability to bind different materials together, the more efficient distribution of stress across a joint, the cost-effectiveness of an easily mechanized process and greater flexibility is design.

Types :-

→ Different types of adhesives may be found natural or produced synthetically.

Polymer adhesives

→ A polymer adhesive is a synthetic bonding substance made from polymers and is considered to be stronger, more flexible and has greater impact resistance than other form of adhesives.

→ These bonding products are used in multiple industries including automotive, aerospace, aviation, construction of electronics and electrical.

→ These are broadly classified was thermoplastic, thermo-setting depending on the molecular structure.

→ Many polymer adhesives dispersed in water and are suitable for use with both solid and engineered wood flooring.

Hot melt adhesives :-

→ Hot melt adhesives (HMA) is a form of thermoplastic adhesive that is commonly sold as solid cylindrical sticks of various diameters designed to be applied using a hot glue gun.

→ The gun uses a continuous-duty heating element to melt the plastic glue, which the user pushes through the gun either with a mechanical trigger mechanism on the gun or with direct finger pressure.

→ In industrial use, hot melt adhesive provides several advantages over solvent based adhesives. Volatile organic compounds are reduced or eliminated and the drying or curing step is eliminated.

→ Hot melt adhesives have a long shelf life and

usally can be disposed of without special precautions.

→ Some of the disadvantages involve a thermal load of substrate, limiting use to substrates not sensitive to higher temperatures and loss of bond strength at higher temperatures upto complete melting of adhesives.

→ Hot melt adhesives can also be applied by dipping or spraying and are popular with hobbyists and crafters both for affixing and as an inexpensive alternative to resin casting.

Acrylic adhesives :-

→ These are key to large sections of modern industry providing high strength bonds that work well as an alternative to rivets or other more mechanical joining technique.

→ Acrylic adhesives are useful for a wide range of surfaces, they can also be used to join acrylic

→ Acrylic adhesives are either thermoplastics which can be moulded above a certain temperature or thermosetting polymer, which cure once and cannot be remoulded.

→ Acrylic adhesives have traditionally been used for their strong structural adhesives properties

→ As a good structural adhesives acrylic adhesives are naturally high demand.

→ An an inexpensive structural adhesive they can very useful to many projects.

→ Acrylic adhesives also look good and bond easily to several different materials. This gives them great flexibility in terms of applications.

Resin adhesives

→ Resin adhesives provides superior bonding capabilities. It is manufactured in powdered, spray, emulsion and liquid forms.

→ Resin adhesives are used to enhance the reten ntion of both composites and compomers to prevent bicaterial micro leakage.

→ It can be used with various materials including wood fabric glass, china or metal.

→ It is important to note, however the epoxy resin is not considered to be water resistant.

→ Repeated moist or wet conditions can cause dete -oration over time which will affect the durabilit

Anaerobic adhesives:-

→ Anaerobic adhesives are one-part adhesives compos of dimethacrylate monomers that cure only in th absence of air

→ They are less toxic than other acrylics have a mil inoffensive odour and are not corrosive to meta

→ Anaerobic adhesives are stored in partially filled polyethylene containers, in which the mati

of air exposed surface to volume is high.

→ Anaerobic adhesives are used for structural bonds, primarily with materials such as materials and glasses and to lesser extent, wood and plastics (thermosets and some thermoplastics).

→ An aviator is often applied to one surface on both surfaces, and again adhesives are applied to one surface to begin curing

→ Joints produced using anaerobic adhesives can withstand exposure to organic solvents and water, weathering and temperature of about 200°C.

Epoxy adhesives

→ Epoxy adhesives can adhere to wide variety of materials, their high strength, their resistance to chemicals and environments and their ability to resist creep under sustained load.

→ Epoxies are most widely used structural adhesives.

→ They are available in one component heat curing and two component, room temperature curing systems

→ Unmodified epoxies cure hard, brittle solids.

→ Most adhesives formulations include modifiers to increase the flexibility or toughness of the cured adhesives.

→ This results in bond lines that can resist more peel and cleavage stress as well as impact.

→ As the most widely used structural type, adhesive epoxy adhesives are commonly offered as thin one component or two component systems.

→ One component epoxy adhesives are cured at temperatures bet^n 250 - 300°F, conditions that engineer a product of high strength excellent adhesion to metals and outstanding environmental and harsh chemical resistance.

Pressure adhesives:-

→ It remains viscous. As a result they remain permanently tacky and can wet surfaces on contact.

→ Bonds are made by bringing the adhesives film in contact with the substrate and applying pressure.

→ If inadequate pressure is applied or the processing temperature is too low, bonding faults such as bubbles or detachment can occur.

→ Since these adhesives are not true solids, the strength of pressure sensitive adhesives decreases when the temperature is increased.

→ Pressure-sensitive adhesives also tend to undergo creep when subjected to loads.

→ They are typically formulated from natural rubber, certain synthetic rubbers and polyacrylates.

Electrically conductive adhesives :-

Modern electrically conductive adhesives provide excellent adhesion and reliability.

→ They cure in times of less than two minutes, and in-line processing capability for exceptionally high throughput. An electrically conductive adhesive is an adhesive made of conductive particles suspended in a sticky compound.

→ With about 80% of the mass of the adhesive made of the conductive particles, they are spaced closely enough to each other to allow a substantial current to pass.

→ The composition of conductive adhesives can very greatly from one product to another.

→ The base adhesive is typically a 2-componet epoxy, although acrylate and polyester are also quite common.

→ The conductive component plays a huge role in determining the cost of a conductive adhesive: inexpensive ones use iron, which has poor conductivity, while the most expensive ones use either silver or copper.

Phenolic resin adhesives :-

→ Phenolic resins adhesives are the condensation products of phenol and formaldehyde and are an important class of adhesives.

→ They are relatively inexpensive and are manufactured as liquid compositions and films.

→ Thermosetting phenolic resins withstand high temperatures both under mechanical load and in severe environments with minimal deformation and

Creep.

→ The primary use of phenolic resins is as a binding agent. Phenolic resins readily penetrate and adhere to many organic and inorganic fillers and reinforcements, provide excellent mechanical, thermal, and chemically resistant properties.

→ Their exceptional compatibility with cellulose fillers makes them the ideal binder for particleboard, plywood, hardboard, and oriented strand board (OSB).

plastisol adhesives

→ plastisol are single-compount adhesives that are applied as a paste to the substrate.

→ The paste consists of solid polyvinyl chloride (PVC) particles dispersed in plasticizer.

→ To form a bond, the applied adhesive is heated so that the thermoplastic PVC swells and can take up the plasticizer.

→ plastisols have high flexibility and good peel resistance.

→ They can be flexible or rigid depending on the type and amount of plasticizer added and give good adhesion to most types of (coiled) metals, and plastics.

→ They are often the preferred material for applications where low flammability and a low cost is required of. advantages. They are also easy to apply, require no meter mixing, and allow for fast processing.

Reactive adhesive

→ Reactive adhesives require a chemical reaction for bonding two surfaces. These adhesives are

→ These adhesives are classified into one and two component reactive adhesives and have been used in applications where substrates require substantial permanency and high strength

adherence such as high-tech devices.

→ High reactive adhesives with quick gelling and hardening behavior and steep increases in bonding strength even at a low degree of chemical curing.

→ Its mixes are produced by including accelerators, special hardeners, crosslinkers and other materials.

Solvent Based adhesives

→ These are called binding agents and are dispersed in an organic solvent. When the solvent evaporates, the adhesive changes from liquid to its final solid form. the pure binding substance remains.

→ The functions of the relatively high volatile solvents is to facilitate easy transport and application of the adhesive.

→ They ensure that the binding agents stay liquid and can, therefore, be processed. Also, the solvents influence key adhesive characteristics such as adhesion, by promoting the wetting of the substrate or by biting the substrate surface or dwell time and open time, depending on how fast they evaporate.

→ The performance of solvent-based adhesives is largely determined by the polymer system in the formulation.

→ The choice of adhesive type depends on the specific substrates and environment resistance needed- temperature resistance, oil and plasticizer resistance etc.

Thermoset adhesives

→ Thermoset adhesives are crosslinked polymeric resins that are cured using heat and /or heat and pressure
→ Due to their superior strength and resistance, thermosets are widely used for structural load-bearing applications
→ Thermoset adhesives have very high strength, excellent gap filling ability, and resistance to moisture and heat.
→ Most thermoset adhesives are supplied as a two-component system although one part adhesives are used as well.
→ Two-component adhesives are typically made up of a resin and a hardener, in liquid or gel form, which are mixed to initiate the curing process.

UV curing adhesives:-

→ UV glue curing is gaining popularity over other methods of bonding such as drying on exposure to chemicals
→ Bonding with heat or drying works by evaporation, which can be inconsistent and can also take time for the ink to dry.
→ Chemical treatment can be costly to purchase materials and may expose employees to harmful ink-borne respiratory contaminants
→ UV glue curing is quick and consistent providing an instantly hardened surface with no harmful chemical exposure.

→ One big advantage to the finishes with UV curing is that it dries clear, allowing multiple layers if need be while sanding down. the finish will provide an invisible "liquid plastic" unbreakable bond.

→ Paint on strain can be applied to the finish, giving endless options for applications with various products

Water-based adhesives :-

→ Water based (or more commonly referred to as water(borne) adhesives are typically formulated from natural polymers and soluble syrthetic polymers.

→ These adhesives may be supplied as solution or formulated as dry powders which must be mixed with water before application.

→ The strength of the adhesive is attained when water is lost from the glue line by evaporation or absorption by the substrate. Because of this requirement, the use of these adhesives requires that at least one substrate is permeable. It is possible to apply a thin coat of adhesive, allow it to dry, and then activate the adhesive by lightly wiping with a wet brush or roller or spraying with water.

Prefabrication

→ Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site and transporting complete assembles or sub-assembles to the construction site where the structure is to be located.

→ The used to distinguish this process from the more conventional construction practice of transporting the basic materials to construction site where all assembly is carried out.

→ The term prefabrication also applies to the manufacturing of things other than structures at a fixed site. It is frequently when fabrication of a section of a machine or any movable structure is shifted from the main manufacturing site to another location, and the section is supplied assembled and ready to fit.

→ It is not generally used to refer to electrical or electronic components of a machine, or mechanical parts such as pumps, gearboxes and compressors which are usually supplied as separat items, but to sections of the body of the machine which in the past were fabricated with the whole machine.

→ Prefabricated parts of the body of the machine may be called sub-assemblies to distinguish them from the other components.

Advantage:

* Moving partial assemblies from a factory often costs less than moving pre-production resources to each si
* Deploying resources on-site can add costs prefa- bricating assemblies can save costs by reducing on-site work.
* Factory tools - jigs, cranes, conveyors etc - can ~~offer added quality assurance~~: make production faster and more precise.
* Factory tools - shake tables, hydraulic testers, etc. - can offer added quality assurance.
* Consistent indoor environments of factories eliminate most imparted of weather on production.
* Cranes and reusable factory supports can allow shapes and sequences without expensive on-site falsework.
* 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 optimal materials usage, recycling, noise capture, dust capture etc.
* Machine-mediated parts movements and freedom from wind and 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 and precision measurement and handling to place in position.

Dt 28-06-2021

Uses

→ The most widely used form of prefabrication in building and civil engineering is the use of prefabricated concrete and prefabricated steel sections in structures where a particular part of form is repeated many times.

→ It can be difficult to construct the formwork required to mould concrete components onsite, and delivering wet concrete to the site before it starts to set requires precise time management.

→ Pouring concrete sections in a factory brings the advantages of being able to re-use moulds and the concrete can be mixed on the spot without having to be transported to and pumped wet on a congested construction site.

→ Prefabricating steel sections reduces on site cutting and welding costs as well as the associated hazards

→ Prefabrication techniques are used in the construction of apartment blocks, and housing developments with repeated housing units. Prefabrication is an essential part of the industrialization of construction.

A variety of prefabricated housing units have developed to the point that they may not be distinguishable from traditionally built units to those that live in them.

The technique is also used in office blocks, warehouses and factory buildings. Prefabricated steel and glass sections are widely used for the exterior of large buildings.

Prefabrication has become widely used in the assembly of aircraft and spacecraft with components such as wings and fuselage sections often being manufactured in different countries or states from the final assembly site. However, this is sometimes for political rather than commercial reasons, such as for Airbus.

:- Soil Reinforcing Techniques :- New chapter

Recycled concrete aggregat :-

After demolition of concrete structure the waste concrete becomes a non-biodegradable product due to different aggregates, debris present in concrete.

→ The disposal of debris becomes a problem.

→ To minimise the disposal problem aggregates are produced from the waste concrete and are reused for various purposes including production of concrete.

Properties of Recycled aggregate.

→ qualities of Recycled aggregate and natura aggregate are different.

[Comparission of Recycled concrete aggregat and natura aggregate]

Properties	Recycled concrete aggregat	Natural concret aggregate
→ Quality	Dependent on the contamination of debris sources	Based on physical and chemical properties of source sites
→ Density	Lower than natural aggregate because of the porous and less dense residual mortar lumps that adheres to the surfaces.	→ Higher than recycled aggregate.

Recycling Procedure

Concrete debris after demolition of any structure are transported to the recyling plants for processing where it is crushed to desired sizes similar to the manufacture of natural aggregate by primary jaw crushers and the secondary cone crushers.

→ Prior to the crushing process, all the reinforcing steels embedded concrete are sorted out. There are three methods of sorting and cleaning the recycled aggregate.

* Electromagnetic Separation :-

→ In this method, the reinforcing steel is separated by magnets fitted across the conveyon or belt in the primary and secondary crusher.

* Dry separation :-

→ Here, the lighter particles are removed from the heavier stony materials by blowing out. Though this method is effective, it always causes lots of dust.

* Wet separation :-

→ In this process, low-density contaminants are removed by the water jets and float-sink tank, and this produces very clean aggregate. After crushing and separation of debris, the screening process separates the various sizes of recycled aggregate through a screening plant in which a series of large sieves separates the material into the required sizes.

4- Applications

→ Concrete used for less important works or non-structural works i.e. concrete for shoulders, median barriers, sidewalk curb stones, sub-bases for roadwork, can be produced by utilization on recycle aggregat. This can also

→ used in miscellaneous other applications such as soil stabilization, railroad ballasts, roadside concrete chains, retaining walls (gabion types) concrete kerbs, granular fill etc.

5. Advantages and disadvantages

→ The major advantage is based on environmental considerations.

→ It is estimated that more than 40% of the total waste is utilized as landfill. By recycling these materials use of normal aggregate can be minimized, thus saving the natural resource, which can be used in superior grade works.

→ The cost of recycled aggregate is cheaper than normal aggregate, which is economically ideal for unimportant construction work. Saving of energy is another major advantage of using these materials.

→ Although there are many advantages of using recycled aggregate, there are still some disadvantages. There is lack of specification and guidelines for use of recycled concrete aggregate in construction. In many cases, the strength characteristic does not meet the design criteria.

→ The recycled process causes water pollution. The wash-out water from the recycling plant is of high pH ($pH > 12$) which is a serious environment concern. This water is

toxic to fish and other aquatic life

Soil Reinforcement Techniques:-

→ Soil Reinforcement is a technique used to improve the stiffness and strength of soil using geo-engineering methods.

→ A long time ago, natural fibre was used to reinforce the soil. This old technique did not have a high yield and required a lot of time for the soil to recover.

→ In geotechnical engineering, soil is restored and reinforced with the distribution of minerals and soil nutrients.

Necessity of soil Reinforcement:-

→ Soil Reinforcement is necessary to improve the stength and stability of soil.

→ Soil Reinforcement is necessary in lands where chances of erosion are high.

→ It is particularly useful in areas with soft soil as it cannot provide adequate support to any construction or building

→ This type of soil is also highly susceptible of various environmental and natural factors such as compressibility, poor shear strength, temperature changes etc.

Materials and Types of soil Reinforcement:-

There are 3 main materials which are commonly used in the construction of Reinforced soil.

(i) Soil or fill matrix

(ii) Reinforcement or anchor system.

(iii) Geosynthetics

→ These materials are used based on soil properties.

1. Soil or fill matrix:-

→ The shear properties of soil can be enhanced as th
-etically any soils from earth can be used.

→ Usually the soils used in well graded cohesionless c
good cohesive frictional soils however in many
instances pure cohesive soils been successfully used

Advantages from using cohesionless soils:-

→ They are stable

→ Free draining

→ Not susceptible to frost

→ Relatively non-corrosive to Reinforcing elements.

Disadvantages

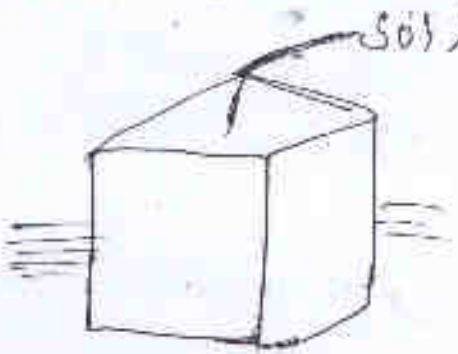
→ The main disadvantages is the cost as the envi-
niet compromise between the benefits from
cohesionless soils and economic advantages
from cohesive soils makes cohesive friction

(2) Reinforcement or anchor system:-

→ A wide range of materials such as steel, glass
concrete fibre, wood, aluminium, rubber and
thermoplastics can be utilised as reinforcing
agents.

→ These reinforcements can have the structural
forms of strips, anchors planks, materials
chains, rope or combination of these.

strips



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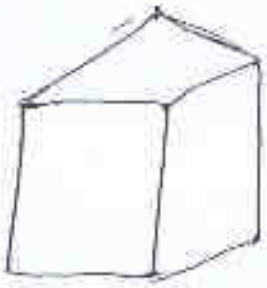
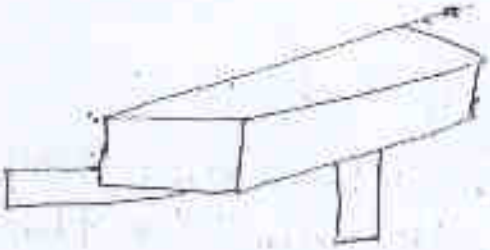


bars



Grids

→ Linear elements having their thickness less than their breadth. They can be composed to copper polymers, aluminium glass fibre or bamboo.

→ Galvanised or coated steel strips are painted with either plain or with project to increase the friction between reinforcing cement and fills.

Grids

→ Grids are also used as reinforcements. They consist of steel (in the form of plain or galvanised weld mesh or expanded metals.

Sheet :

→ This reinforcement may be formed from fabric a metals such as galvanised steel sheet sheets and expanded metals.

Construction & earth moving equipment :-

Planning and selection of construction equipment :-

The selection of earthmoving equipment is mainly dependent on the following factors:

- Quantities of material to be moved.
- The available time to complete the work the job conditions.
- The prevailing soil types, the swell and compaction factors, etc.
- The job conditions include factors such as availability of loading and dumping area, accessibility of site, traffic flows and weather conditions at site.

Different types of earthmoving equipment used in construction :-

- Earthmoving equip-ment is heavy equipment, typically heavy duty vehicles designed for construction operation which involve earthworks.
- They are used to move large amounts of earth, to dig foundations for land scaping and soon.
- Earth moving equipment may also be referred to as, heavy trucks, heavy machines, construction equipment, engineering equipment, heavy vechicles and heavy hydraulics.
- Most earthmoving equipment uses hydraulic drives as the primary source of motion.
- There are various types of earthmoving equipments used in construction few of the pivotal ones are described below

Excavators:-

- Excavators are heavy construction equipment consisting of a boom, dipper (or stick), bucket and cab on a rotating platform known as the "house"
- The house sits atop an undercarriage with tracks or wheels.
- They are a natural progression from the steam shovels and often mistakenly called power shovels.
- All movement and functions of a hydraulic excavator are accomplished through the use of hydraulic fluid, with hydraulic cylinders and hydraulic motors.
- Due to the linear actuation of hydraulic cylinders, their mode of operation is fundamentally different from cable operated excavators which use winches and steel ropes to accomplish the movements.

Backhoe loader:-

- A backhoe loader, also called loader backhoe, digger in layman's terms, or colloquially shortened to backhoe within the industry is a heavy equipment vechicles that consists of a tractor-like unit fitted with a loader-style shovel/bucket on the front and a backhoe on the back.
- Due to its (relatively) small size and versatility, backhoe loaders are very common in urban engineering and small construction projects (such as building a small house, fixing urban roads, etc) as well as developing countries.
- This type of machine is similar to and derived from what is now known as a TLB (Tractor-loader Backhoe), which is to say, an agricultural tractor

fitted with a front loader and rear say, excavator backhoe attachment.

Buldozer :- A bulldozer is a tractor equipment with substantial metal plate (known as a blade) used to push large quantities of soil, sand, rubble, or other such materials during construction or conversion works and typically equipped at the rear with a claw-like device (known as a ripper) to loosen densely compacted materials

It is usually a crawler (continuous tracked) tractor.

Bulldozers can be found in a wide range of sites mines and quarries, military bases, heavy industry factories, engineering projects and farms

Wheel tractor scraper :-

A wheel tractor scraper is a piece of heavy equipment used for earthmoving. The rear part of the scraper has a vertically moveable hopper with a sharp horizontal front edge which can be raised or lowered.

The front edge cuts into the soil like a carpenter's plane cutting wood, and fills the hopper. When the hopper is full it is raised, closed, and the scraper can transport its load to the fill area where it is dumped.

With a type called an elevating scraper a conveyor belt moves material from the cutting edge into the hopper.

Dragline excavator :-

A dragline excavator is a piece of heavy equipment used in civil engineering and surface mining. Draglines fall into two broad categories: those that are based on standard, lifting cranes, and the heavy

units, which have to be built on site. Most crawler cranes, with an added winch drum on the front can act as a dragline.

→ These units (like other cranes) are designed to be dismantled and transported over the road on flat-bed trailers.

→ Draglines used in civil engineering are almost always of this smaller, crane type. These are used for road, port construction, pond and canal dredging, and as pile driving rings.

Paver

→ A paver (paver finisher, asphalt finisher, paving machine) is a piece of construction equipment used to lay asphalt on roads, bridges, parking lots and other such places. It lays the asphalt flat and provides minor compaction before it is compacted by a roller.

Dump truck :-

→ A dump truck, known also as a dumper truck or tipper truck, is used for taking dumps (such as sand, gravel, or demolition waste) for construction as well as coal.

→ A typical dump truck is equipped with an open box bed, which is hinged at the rear and equipped with hydraulic rams to lift the front, allowing the material in the bed, to be deposited ("dumped") on the ground behind the truck at the site of delivery

Different types of soil compaction Equipments

The soil compaction equipments can be di into two group.

1) Light soil compacting equipments.
2) Heavy soil compacting equipments.

1) Light soil compacting Equipments :-

→ These equipments are used for soil compad of small areas only and where the compact of small areas only and where the compad -g effort needed is less.

→ Below are light equipments for soil compactio

(i) Rammers :-

→ Rammers are used for compacting small areas by providing impact load to the soil.

→ This equipment is light and can be hand or machine operated.

→ The base size of rammers can be 15cm X150 on 20cm X20cm or more

→ For machine operated rammers, the usual weig varies from 20kg to 10 tonnes (60lbs to 22000lbs)

→ These hammers with 2-3 tonnes (4400 to 46600 lbs) weight are allowed to free fall from a height of 1m to 2m (3ft to 7ft) on the soil for the compaction of rock fragments.

→ Rammers are suitable for compacting cohesive soils as well as other soils.

→ This machine increase with difficulty in acce ss.

(ii) Vibrating plate compactors:-

→ Vibrating plate compactors are used for compaction of coarse soils with 4 to 8% fines.
→ These equipments are used for small areas.
→ The usual weights of these machines vary from 100kg to 2 tonne with plate area between 0.16 m² and 1.6 m².

(iii) Vibrotampers:-

→ Vibrotampers is used for compaction of small areas in confined space.
→ This machine is suitable for compaction of all types of soil by vibrations set up is a base plate through a spring activated by a negine driven reciprocation machanism.
→ They are usually manually guided and weight between 50 and 100 kg (100 to 220 lbs).

2) Heavy soil compaction equipments:-

→ These compacting machines are used for large area of on use on different types of soils.
→ The heavy compaction equiments are selected based on moisture content of soil and types of soil.
→ Following are different types of these equipments:-

(1) Smooth wheeled Rollers:-

→ Smooth wheeled rollers are of two types.
* Static smooth wheels rollers.
* Vibrating smooth wheeled rollers.
→ The most suitable soils for these roller type

are well graded sand, gravel, crushed rock, as ph
etc. where crushing is required.
→ These rollers are generally used for finishin
the upper surface of the soil.
→ These roller are not used for compaction of uni
rm sands.
→ The performance of smooth wheeled rollers
depends on load per cm width it transfers
to the soil and diameter of the drum.
→ The load per cm width is derived from the
gross weight of the drum.
→ The smooth wheeled rollers consists of a large
steel drum in front and two steel drums in
front and two steel drums on the rear.
→ The gross weight of these rollers is in the
rang of 8-10 tonnes (1800 to 22000 lbs)
→ The other type of smooth wheel roller is
called Tandem Roller which weights between
6-8 tonne (1300 to 1800 lbs)
→ The performance of these rollers can be
increased by increasing the increasing the
weight of the drum by ballasting the inside
of drums with wet sand or water.
→ steel sections can also be used to increase th
load of the drum by mounting on the steel frame
attached with axle.
→ The desirable speed and number of passes for
appropriate compaction of soil depends on the
type of soil and varies from location to locati
on.
→ About 8 passes are adequate for compacting
20 cm e-layers.
→ A speed of 3-6 Kmph is considered appropriate
for smooth wheel rollers.

Vibrating smooth wheeled rollers

→ In case of vibrating smooth wheeled rollers, the drums are made to vibrate by employing rotating or reciprocating mass. These rollers are helpful from several consideration like.

(i) Higher compaction level can be achieved with maximum work.

(ii) Compaction can be done up to greater depths.

(iii) Output is many times more than conventional rollers.

→ Although these rollers are expensive but in the long term the cost becomes economical due to their higher outputs and improved performance.

→ The latest work specifications for excavation recommends the use of vibratory rollers due to their advantages over static smooth wheeled rollers.

Sheepfoot roller:- fine grain soil

→ Sheepfoot roller are used for compacting fine grained soils such as heavy clays and silty clays.

→ Sheepfoot rollers are used for compaction of soils in dams, embankments, subgrade layers in pavements and rail road construction projects.

→ Sheep foot rollers are of static and vibratory types.

→ Vibratory types rollers are used for compaction of all fine grained soils and also soil.

with sand-gravels mixes. Generally this roller is used for compaction of sub grade layers in road and rail projects.

→ Sheepsfoot rollers consist of steel drums on which projecting lugs are fixed are can apply a pressure up to 14kg/Sq cm or more.

→ Different types of lugs are namely spindle shaped with widened base, prismatic and clubfoot type.

→ The weight of drums can be Increased as in the case of smooth wheeled rollers by ballasting with water, wet sand or by mounting steel sections.

→ The efficiency of sheepsfoot rollers compaction can be achived when lugs are gradual walkout of the roller lugs with successive coverage.

→ The efficiency is affected by the pressure on the foot and coverage of ground obtained per pass. For required pressure and coverage of ground, the parameters such as gross weight of the roller, the area of each foot the number of lugs in contact with the ground at any time and total number of feet per drum are considered.

→ The compaction of soil is mainly due to foots penetrating and exerting pressure on the soil.
- The pressure is maximum when a foot is vertical.

Pneumatic Tyred Rollers:-

→ Pneumatic tyre of rollers are also called as rubber tyred rollers. These rollers are used for compaction of coarse grained soils with some fines.

→ These rollers are least suitable for uniform coarse

soils and rocks. Generally pneumatic tyred rollers are used in pavement subgrade works both earthwork & bituminous works.

- Pneumatic rollers have wheels on both axles.
- These wheels are staggered for compaction of soil layers with uniform pressure throughout the width of the roller.
- The factors which affects the degree of compaction are tyre inflation pressure and the area of the contact.
- The latest rollers have an arrangement to inflate the tyre to the desired pressure automatically.
- The total weight of the roller can be increased from 11.0 tonne to 25.0 tonne or more by ballasting with steel sections or other means.

Grid Rollers:-

→ Grid rollers are used for compaction of weathered rocks, well graded coarse soils. These rollers are not suitable for clayey soils, silty clays and uniform soils. The main use of these rollers are in subgrade and sub base in road construction.

→ As the name suggests, these rollers have a cylindrical heavy steel surface consisting of a network of steel bars forming a grid with square holes.

→ The weight of this roller can be increased by ballasting with concrete blocks.

→ Typical weights vary between 5-5 tonnes net and 15 tonnes ballasted.

→ Grid rollers provide high contact pressure but little kneading action and are suitable for compacting most coarse grained soils.

Pad foot / Tamping rollers:-

→ These rollers are similar to sheepsfoot rollers with lugs of larger area than sheepsfoot rollers.

→ The static pad foot rollers also called tamping rollers have static weight in the range 15 to 40 tonnes and their static linear drum loads are between 30 and 50 kg/cm.

→ these rollers are more preferable than sheepsfoot rollers due to their high production capacity, and they are replacing sheepsfoot rollers.

→ The degree of compaction achived is more than sheepfoot rollers. The density of soil achived after compaction with this roller is more uniform.

→ These rollers operate at high speeds and the capable to breaking large lumps.

→ These rollers also consists of leveling blades to spread material. Pad foot or tamping rollers are best suitable for compacting cohesive soils.

Ownership cost :-

→ Ownership costs are fixed cost.

→ Almost all of these costs are annual & nature and include.

* Initial capital cost
* Depreciation
* Investment (or interest) cost
* Taxes
* Storage cost.

~~Initial~~ Initial cost :-

→ On an average, initial cost makes up about 20% of the total cost invested during the equipment's useful life.

→ This cost is incurred for in owning for getting equipment into the contractor's yard or construction site, and having the equipment ready for operation

→ Many kinds of ownership and operating costs are calculated using initial cost-as a basis and normally this cost can be calculated accurately

→ Initial cost consist of the following items —

* price at factory + extra equipment + salestax.
* cost of shipping
* cost of assembly and erection.

Depreciation: —

→ Depreciation represents the decline in market value of a piece of equipment due to age, wear deterioration and obsolescence.

→ Depreciation can result from.

* physical deterioration occurring from wear and tear of the machine.
* Economic decline or obsolescence occurring over the passage of time.

→ In the determination of depreciation, some factors are explicit while other factors have to be estimated

→ Generally the asset costs are known which includes

* Initial cost: - The amount needed to acquire the equipment.
* useful life: - The number of years it's expected to be of utility value.

*Qsalvage value :- The expected amount the asset will be sold at the end of its useful life.

→ However, there is always some uncertainty about the useful life of the assent and about the precise amount of salvage value, which will be realized when the asset is disposed.

→ Any assessment of depreciation, therefore, requires these value to be estimated.

→ Amount many depreciation methods the straight line method double declining balance method and sum of digital methods are the most commonly used in the construction equipment industry and will be discussed low.

→ At this point, it is important to state that the term depreciation as use in this chapter it means to represent the change in the assets value from year to year and as a means of establishing an hourly (rental) rate for that asset.

→ It is not meant in the same exact sense as is used in the tax code.

→ The term "rental rate" is the rate the equipment from its owner charges the clients for using the equipment that is the project "use agreement" the equipment from its owner.

→ In calculating depreciation the initial cost should include the costs of delivery and start up, including transportation, salesman, and initial assembly.

→ The equipment life used in calculating transportion should correspond to the equipments expected economic or useful life.

→ The reader can consult the references at the end of this chapter for a more thorough discussing of the intricacies of depreciation.

Straight-line Depreciation:-

→ Straight-line depreciation is the simplest to understand as it makes the basic assumption that the equipment will lose the same amount of value in every year of its useful life until it reaches its salvage value.

→ The depreciation in a given year can be expressed by the following equation:-

$$D_n = \frac{I_c - S - T_c}{N}$$

where D_n is the depreciation in year n, I_c the initial cost (s), S the salvage value(s), T_c the time and track costs(s), N the useful life (years) and $D_1 = D_2 = D_n$

Sum-of years-digits Depreciation:-

→ The sum-of years digits depreciation method tries to model depreciation assuming that it is not a straight line.

→ The actual market value of a piece of equipment after 1 year is less than the amount predicted by the straight line method.

→ Thus, this is an accelerated depreciation method and models more annual depreciation in the early years of a machine's life and

less in its later years.

→ The calculation is straight forward to done using the following equation

$$D_n = \frac{(\text{year "n" digit})}{1+2+\cdots\cdots+N} (IC - S - TC)$$

→ where D_n is the depreciation in year n, year n digit the reverse order, n if solving for D_1 or 1 if solving for D_n IC the initial cost (s), s the salvage value (s), TC the fine and track costs (s), and N the useful life years)

Double-Declining Balance Depreciation:-

→ The double-declining balance depreciation is another method for calculating an accelerated depreciation rate.

→ It produces more depreciation in the early years of a machine useful life than the sum-of-years' digit depreciation method.

→ This is done by depreciating the "Book value" of the equipment rather than just its initial cost.

→ The book value in the second year is merely the initial cost minus the depreciation in the first year.

→ Then the book value in the next year is merely the book value of the second year minus

the depreciation in the second year, as soon
until the book value reaches the salvage va
→ The estimator has to be careful when usi
this method and ensure that the book va
never drops below the salvage value.

$$D_n = 2/N\,(BV_{n-1} - T_c)$$

→ where D_n is the depreciation in year, n. T_c th
trains and track costs (S).
→ N the useful life (years) BV_{n-1} the book
value at the end of the previous year,
and $BV_{n-1} \geq S$.

Q Compare the depreciation in each year of the equipment's useful life for each of the above depreciation methods to the following wheeled front end bucket loader.

* Intial cost Rs. 148,000 includes delivery and other costs.
* Tire cost Rs. 16,000
* useful life 7 years
* salvage value Rs 18,000.

Soln: A sample calculation for each method will be demonstrated and the results are shown in Table 2.1

straight-line method. From Equation 2.1, the depreciation in the first year D_1 is equal to the depreciation in all the years of the loader's use ful life.

$$D_n = \frac{IC - S - TC}{N}$$

$$D_1 = \frac{148,000 + 18,000 - 16,000}{7 \text{ years}} = 16,286/\text{year}$$

Sum of-years digits method: From Equation 2.2, the depreciation in the first year D_1 and the second year D_2 are:

$$D_n = \frac{\text{year 'n' digit}}{1+2+\cdots+N} (IC - S - TC)$$

$$D_1 = \frac{7}{1+2+3+4+5+6+7} (148,000 - 18,000 - 16,000)$$
$$= 28,500$$

$$D_2 = \frac{6}{1+2+3+4+5+6+7} (148,000 - 18,000 - 16,000)$$
$$= 24,429$$

Durable-declining balance method, From Equation 2.2 the depreciation in the first year D_1 is.

$$D_1 = \frac{2}{7}(148{,}000 - 16{,}000) = 37{,}714$$

and the 'book value' at the end of year 1:

$$1 = 148{,}000 - 16{,}000 - 37{,}714 = ₹94{,}286$$

However, in year 6, this calculation would give an annual depreciation of Rs. 7,01. which when subtracted from the book value at the end of year 5 gives a book value of ₹17,531 for year 6. This is less than salvage value of Rs. 18,000, therefo the depreciation in year 6 is.

Investment (OR Interest) Cost :-

→ Investment (or interest) cost represents the annual cost (converted into an hourly cost) of capital invested in a machine. If borrowed funds are utilized for purchasing a piece of equipment, the equipment cost is simply the interest charged on these funds. However, if the equipment is purchased with company assets, an interest rate that is equal to the rate of return on company investment should be charged. Therefore, investment cost is computed as the product of interest rate multiplied by the value of the equipment which is then converted into cost per hour of operation.

→ The average annual cost of interest should be based on the average value of the equipment during its useful life.

→ The average value of equipment may be determined from the following equation:

$$P = \frac{IC(n+1)}{2}$$

where IC is the total cost, P the average value and n the useful life (years).

→ This equation assumes that a unit of equipment will have no salvage value at the end of its useful life.

→ If a unit of equipment has salvage value when it is disposed of, the average value during its life can be obtained

from the following equation:

$$P = \frac{IC(n+1) + S(n-1)}{2n}$$

where IC is the total initial cost, P the average value, S the salvage value, and n the useful life (years).

Q-2

Consider a unit of equipment costing 50,000 Rs with an estimated salvage value 15,000 Rs after 5 years.

Soln:-

Given data:-

$I_C = 50,000/-$

$S = 15,000/-$

$n = 5$ years

$P = ?$

$$P = \frac{I_C(n+1) + S(n-1)}{2n} \Rightarrow P = \frac{50,000(5+1) + 15,000(5-1)}{2(5)}$$

$$= \frac{300,000 + 60,000}{10}$$

$$= 36,000/-$$

Insurance, tax and storage costs:-

→ Insurance cost represent the cost incurred due to fire theft, accident and liability insurance for the equipment.

→ Tax cost represents the cost of property tax and licens for the equipment.

→ Storage cost includes the cost of rent and maintenance for equipment storage yards, the wages of guards and employees involved in moving equipment in and out of storage, and associated direct overhead.

→ The cost of insurance and the tax for each item of equipment may be known on annual basis.

→ In this case, the cost is simply divided by the hours of operation during the year to yield the cost per hour for these Items.

→ Storage costs are usually obtained an annual basis for the entire equipment fleet.

→ Insurance and tax costs may also be known on a fleet basis.

→ It is then necessary to pronate these costs to each item.

→ This is usually done by converting the total annual cost into a percentage rate, then dividing these costs by the total value of the equipment fleet.

→ By doing so, the rate for insurance tax and storage may simply be added to the investment cost rate for calculating the total annual cost of insurance tax and storage.

Average Rates for Investment costs :-

Item	Average value (%)
Interest	3-9
Tax	2-5
Insurance	1-3
Storage	0.5 - 1.5

→ These rates will vary according to related factors such as the type of equipment and location of the job site.

Total ownership cost :-

→ Total equipment ownership cost is calculated as the sum of depreciation, investment cost, insurance cost, tax, and storage cost.

→ As mentioned earlier, the elements of ownership cost are often known on an annual cost basis. However, while the individual elements of ownership cost are calculated on an annual cost basis on an hourly basis, total ownership cost should be expressed as an hourly cost.

→ After all elements of ownership costs have been calculated, they can be summed up to yield total ownership cost per hour of operation.

→ Although this cost may be used for estimating and for charging equipment cost to projects, it does not include job overhead or profit. Therefore, if the equipment is to be rented to others, overhead and profit should be

included to obtain an ~~several~~ hourly rental ra

Average Rates for Investment Costs :-

Item	Average Value (%)
Interest	3-9
Tax	2-5
Insurance	1-3
storage	0.5-1.5

Q Calculate the hourly ownership cost for the second year of operation of a 405 hp twin-engine scraper. This equipment will be operated 8h/day and 250 days/year in average conditions. Use the sum-of years' digits method of depreciation as the following information:

* Intial cost RS. 186,000
* Tire cost : RS. 14,000
* Estimated life : 5 years.

Average Rates for Investment costs

Item	Average Value (%)
Interest	3-9
Tax	2-5
Insurance	1-3
storage	0.5-1.5

Cost of Owning and operating Construction Equipment.

* Salvage value : Rs. 22,000
* Interest on the investment : 8%
* Insurance : 1.5%
* Taxes : 3%
* storage : 0.5%
* Fuel price : Rs 2.00/gal
* Operator's wages : Rs. 24.60/h

Depreciation in the secon year $= \frac{4}{15}(186,000 - 22,000 - 14,000)$

$= Rs\ 40,000$

$= \frac{40,000}{8(250)} = Rs.\ 20.00/h$

Investment cost, tax, insurance, and storage cost.

Cost rate = Investment + tax, insurance, and storage.

$= 8 + 3 + 1.5 + 0.5$ ~~%~~

$= 13\%$

Average investment $= \frac{186,000 + 22,000}{2(5)}$

$= Rs\ 20,800$

Investment, tax, insurance, and storage $= \frac{84,000(0.1}{2000}$

$= Rs.\ 7.56/h$

Total ownership cost = 16.53 + 7.56

= Rs 24.09/h.

Cost of operating construction equipment:-

→ Operating costs of the construction equipment which represent a significant cost category and should not be overlooked, are the costs associated with the operation of a piece of equipment.

→ They are incurred only when the equipments is actually used.

→ The operating costs of the equipment are also called "variable" costs because they depend on several factors, such as the number of operating hours, the types of equipment used, and the location and working condition of the operation.

→ The operating costs vary with the amount of equipment used and job-operating conditions. The best basis for estimating the cost of operating construction equipment is the use of historical data from the experience of similar equipment under similar conditions. If such data is not available, recommendations from the equipment manufacturer could be used.

Maintenance and Repair Cost:-

→ The cost of maintenance and repairs usually constitutes the largest amount of operating expense for the construction equipment.

→ Construction operations can subject equipm to considerable wear and tear, but the amount of wear varies enormously betw the different items of the equipment usec and between different job conditions.

→ Generally, the maintenance and repair cos get higher as the equipment gets older.

→ Equipment owners will aggree that good maintenace, including periodic wear measurement, timely attention to recommen -ded service and daily cleaning when conditions warrant it, can extend the life of the equipment and actually reduc the operating costs by minimizing the effects of adverse conditions.

→ All items of plant and equipment used by construction contractors will require maintenance and probably also require repairs during the course of their useful life.

→ The contractor who owns the equipment usually sets up facilities for maintenance and engages the workers qualified to perform the necessary maintenance operations on the equipment.

→ The annual cost of maintenance and repairs may be expressed as a percentage of the annual cost of depreciation on it may be expressed independently of depreciation.

7 The hourly cost of maintenace and repair ca
be obtained by dividing the annual cost b
its operating hours per year.

7 The hourly repair cost during a particular
year can be estimated by using the
following formula.

$$\text{Hourly repair cost} = \frac{\text{year digit}}{\text{sum of years-digits}} \times \frac{\text{Lifetime repair cos}}{\text{hours operated}}$$

The lifetime repair cost is usually estimated as a
percentage of the equipment's intial cost deducting th
cost of tires. It is adjusted by the operating
condition factor obtained.

Ex:- Estimated the hourly repair cost of the scraper in
Ex for the second year of operation. The intial cost of the
scraper is 186,000, tire cost 14,000, and its useful life is
5 years. Assume average operating condition and 2000h
of operation per year.

Sol^n

Lifetime repair cost factor = 0.90

Lifetime repair cost = 0.90 (186,000 − 14,000) = RJ 154,800

$$\text{Hourly repair cost} = \frac{2}{1+2+3+4+5}\left(\frac{154,800}{2000}\right) = \text{R.S. } 10.32/\text{h}$$

Tire cost

→ The tire cost represents the cost of tire repair and replacement. Because the life expectancy of rubber tires is generally far less than the life of the equipment on which they are used on, the depreciation rate of tires will be quite different from the depreciation rate of the rest of th vehicle.

→ The repair and maintenance cost of tires as a percentage of their depreciation will also be different from the percentage associated with the repair and maintenace of the vechile

→ The best source of information in estimating tire life is the historical data obtained under similar operating condition.

→ The typical ranges of tire life found in the most recent literature on the subject for various types of equipment.

→ Tire repair cost can add about 15% to tire replacement cost, so the following equation may be used to estimate tire repair and replacement cost.

$$\text{Tire repair and replacement costs} = 1.15 \times \frac{\text{cost of asset of tires}}{\text{expected tire life (h)}}$$

Consumable costs:-

→ Consumables are the items required for the operation of a piece of equipment that literally gets consumed in the course of its operation. These include, but are not limited to, fuel, lubricants, and other petroleum products

→ They also include filters, hoses, strainers, and other small parts and items that are used during the operation of the equipment.

Fuel Cost:-

→ Fuel consumption is incurred when the equipment is operated. When operating under standard conditions a gasoline engine will consume approximately 0.06 gal of fuel per flywheel horsepower hour while a diesel engine will consume approximately 0.04 gal/hwhp-h.

→ A horsepower-hour is a measure of the work performed by an engine.

→ The hourly cost of fuel is estimated by multiplying the hourly fuel consumption by the unit cost of fuel.

→ The amount of fuel consumed by the equipment can be obtained from the historical data. when the historical data is not available.

Example: Calculate the average hourly fuel consumption and hourly fuel cost for a twinengine scraper. It has a diesel engine rated at 465 hp and fuel cost Rs 2.00/gal. During a cycle of 20s, the engine may be operated at full power, while filling the bowl in tough ground requires 5s. During the balance of the cycle, the engine will use no more than 50% of its rated power. Also, the scraper will operate about 45 min/h on average. For this conditions, the approximate amount of fuel consummated during 1 h is determined as follows.

Sol^n

Rated power; 465 hp

Engine factor: 0.5

Filling the bowl, 5s/20s cycle = 0.250

Rest of cycle, 15/20 x 0.5 = 0.375

Total cycle = 0.625

Time factor, 45 min/60 min = 0.75

Operating factor 0.625 x 0.75 = 0.47

From use "unfavorable" fuel consumption factor = 0.40

Fuel consumed per hour: 0.47(465)(0.40) = 8.74 gal

Hourly fuel cost: 8.74 gal/h (Rs 2.00/gal) = Rs 17.48/h

Lubricating oil cost

→ The quantity of oil required by an engine per change will include the amount added during the charge plus the makeup oil between changes.

→ It will very with the engine size, the capacity of crankcase, the condition of the piston rings and the number of hours between oil changes. It is a common practice to change oil every 100 to 200 h.

The quantity of oil required can be estimated by using the following formula.

$$q = \frac{0.006(hp)f)}{7.4} + \frac{C}{t}$$

where, q is the quantity consumed (gal/h). hp the rated horsepower of engine.

C the capacity of crankcase (gal).

f the operating factor,

t the number of hours between changes, the consumption rate 0.006 lbs/hp-h, and the conversion factor 7.4 lbs/gal.

The comumption data on the average cost factors for oil, Lubricants, and filters for their equipment under average conditions are available from the equipment manufactures.

Mobilization and demobilization costi-

→ This is the cost of moving the equipment fro one job site to anothe. It is often overlooked because of the assumption that the previous job would have already paid for it.

→ Regardless of these calculations, the costs of equipment mobilization and demobilization can be large and are always important items in any job where substantial amounts of equipme-nt are used.

→ These costs include freight charges (other than the initial purchase), unloading cost, assembly or erection cost (if required), highway permits, duties, and special freight costs (remote or emergency).

→ For a $3-million earthmoving job, it is not unusual to have a budget from Rs 100,000 to 150,000, for move-in and move-out expenses.

→ The hourly cost can be obtained from the the total cost divided by the operating hours. Some public agencies cap the maximum amount of mobilization that will be paid before the project is finished.

→ In these instances, the estimator must check the actual costs of mobilization against the cap.

→ If the cap is exceeded, the unrecovered amount

must be allocated to other pay items to ensure that the entire cost of mobilization is recovered.

Equipment Operator cost :-

- Operator's wages are usually added as a separate item and added to other calculated operating costs.
- They should include overtime or premium charges, workmen's compensation insurance, social security taxes, bonus, and fringe benefits in the hourly wage figure.
- care must be taken by the companies that operate in more than one state or that work for federal agencies, state agencies and private owners
- The federal government required that prevailing scale (union scale) of wages be paid to workers on its project regardless of whether the state is a union state or not.
- This is a requirment of the Davis-Bacon Act and most federal contracts will contain a section in the general conditions that details the wage rates that are applicable to each trade on the project.

Special items cost:-

- The cost of replacing high-wear items, such as dozer, grader, and scraper blade cutting and end bits, as well as ripper tips, shanks, and shank protectors, should be calculated as a separate item of the operating cost. As usual, unit cost is divided by the expected life to yield cost per hour.

Methods of calculating ownership and operating cost:-

The most common methods available are the caterpilar method, Association of General contractors of America (AGC) method, the equipment guide Book (EGB) method, the dafaquest method, the corps of Engineers method, and the peurify method. Each method is described below and three examples are given in Appendix A.

Caterpillar method

The caterpillar method is based on the following principles

1. No prices for any items are provided. For reliable estimates, these must always be obtained locally.
2. Calculations are based on the complete machine. Separate estimates are not necessary for the basic machine, dozer, control etc.
3. The multiplier factors provided will work equally well in any currency expressed in decimals.
4. Because of different standards of comparison, what may seen a servere application to one machine owner may appear only average to another. Therefore, in order to better decribe machine use, the operating conditions and application are defined in zones

Ownership costs:-

Ownership costs are calculated as a sum of costs increased due to depreciation, interest, insurance,

and taxes. Usually depreciation is done to zero value with the straigh - line method, which is not based on tax consideration, but resale or residu value at replacement may be included for depreciat on or tax incentive purpose.

→ service life of several types of equipment is given in the caterpillar Performance Handbook. Arquistion or delivered costs should include costs due to freight, sales tax, delivery and installati on.

→ On rubber - tired machines tires are considered as a wear item and covered as an operating expense. Tire cost is subtracted from the delivered price.

→ The delivered price less the estimate residual value results in the value to be recovered through work, divided by the total usage hours, giving the hourly cost to project the asset's value.

→ The interst on capital used to purchase a machine must be considered, wheather the machine is purchased outright or financed. Insurance cost and property taxes can be calculated in one of the two ways.

Operating cost:-

Operating costs are based on charts and tables in the handbook. They are broken down as follows.

1. Fuel
2- Filters, oil, and grease (FOG) costs.
3- Tires
4- Repairs

5- Special Items,

6 - Operator's wages,

The factors of fuel, FOG, tires, and repairs costs can be obtained for each model from tables and charts given in the caterpillar performance Handbook. Tire costs can be estimated from previous records or from local prices.

Repairs are estimated on the basis of a repair factor that depends on the type, employment, and capital cost of the machine. The operator wages are the local wages plus the fringe benefits. the application of this method for a truck-mounted crane.

~~Cost Codes of Engineering method~~:-

Operating costs:-

1- Fuel costs: Fuel costs are calculated from records of equipment consumption, which is done in cost per gallon per hour. Fuel consumption varies depending on the machine's requirements. The fuel can be either gasoline or diesel.

2. FOG costs:- FOG costs are usually computed as percentage of the hourly fuel costs.

3. Maintenance and repair costs: These are the expense charged for parts, labour, sale taxes, and so on. Primarily, maintenance and repair costs per hour are computed by multiplying the repair factor to the new equipment cost, which is subtracted by tire cost, and divided by the number