UNIT – I CONCRETE TECHNOLOGY

A **cement** is a binder, a substance that sets and hardens and can bind other materials together. The word "cement" traces to the Romans, who used the term *opus caementicium* to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick supplements that were added to the burnt lime, to obtain a hydraulic binder, were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*.

Cements used in construction can be characterized as being either **hydraulic** (pozzolan) or **non-hydraulic**, depending upon the ability of the cement to be used in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting.

Hydraulic cement is made by replacing some of the cement in a mix with activated aluminium silicates, or pozzolans, such as fly ash. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack (e.g., 1824 Portland cement).

The chemical process for hydraulic cement found by ancient Romans used volcanic ash (activated aluminium silicates). Presently cheaper than volcanic ash, fly ash from power stations, recovered as a pollution control measure, or other waste or by products are used as pozzolanas with plain cement to produce hydraulic cement. Pozzolanas can constitute up to 40% of Portland cement.

The most important uses of cement are as a component in the production of mortar in masonry, and of concrete, a combination of cement and an aggregate to form a strong building material.

Non-hydraulic cement, such as slaked lime (calcium hydroxide mixed with water), hardens by carbonation in the presence of carbon dioxide which is naturally present in the air. First calcium oxide is produced by lime calcination at temperatures above 825 °C (1,517 °F) for about 10 hours at atmospheric pressure:

$$CaCO_3 \rightarrow CaO + CO_2$$

The calcium oxide is then *spent* (slaked) mixing it with water to make slaked lime:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Once the water in excess from the slaked lime is completely evaporated (this process is technically called *setting*), the carbonation starts:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

This reaction takes a significant amount of time because the partial pressure of carbon dioxide in the air is low. The carbonation reaction requires the dry cement to be exposed to air, for this reason the slaked lime is a non-hydraulic cement and cannot be used under water. This whole process is called the *lime cycle*.

Conversely, the chemistry ruling the action of the **hydraulic cement** is hydration. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main components being:

Belite ($2CaO \cdot SiO_2$);
Alite ($3CaO \cdot SiO_2$);
Tricalcium aluminate ($3CaO \cdot Al_2O_3$) (historically, and still occasionally, called 'celite');
Brownmillerite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$).

The silicates are responsible of the mechanical properties of the cement, the tricalcium aluminate and the brownmillerite are essential to allow the formation of the liquid phase during the kiln sintering (firing). The chemistry of the above listed reactions is not completely clear and is still the object of research.

What are Different Grades of Cement?

The grade 43 and 53 in cement mainly corresponds to the average compressive strength attained after 28 days (6724 hours) in mega pascals (Mpa) of at least three mortar cubes (area of face 50 cm squared) composed of one part cement, 3 parts of standard s and (conforming to IS 650:1966) by mass and P/4 (P is the percentage of water required to produce a paste of standard consistency as per IS standard) + 3 percentage (of combined mass of cement plus sand) of water , prepared, stored and tested in the manner described in methods of physical test for hydraulic cement. 721 hr not less than 23 MPa for 43 grade, 27 MPa for 53 grade 1682 hrs not less than 33MPa for 43 grade, 37MPa for 53 grade 6724 hrs not less than 43MPa for 43 grade, 53 MPa for 53grade

Physical properties of Ordinary Portland Cement

Cement should be tested for its following properties:

1. Fineness

Fineness, or particle size of portland cement affects rate of hydration, which is responsible for the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, which means more area available for water-cement reaction per unit volume. Approximately 95% of cement particles are smaller than 45 micron with the average particle size about 15 micron. Fineness is measured in terms of surface area per unit mass. Fineness can be tested by /Wagner turbidimeter/ test, /Blaine Air-permeability /test, 45-micrometer sieve

and electronic particle size analyzer.

2. Soundness

Soundness refers to the ability of a hardened cement paste to retain its volume after setting. Lack of soundness is observed in the cement samples containing excessive amounts of hardburnt free lime or magnesia.
/Autoclave expansion test/ is used to determine soundness of cement.

3. Consistency

Consistency of a cement paste refers to its ability to flow. Normal consistency pastes are required to be prepared for testing cement specimens. A paste is said to have a normal consistency when the plunger of /Vicat apparatus/ penetrates it by 10±1 mm. the corresponding water-cement ratio is reported.

4. Setting Time

Initial setting time is the time that elapsed from the instance of adding water untill the pastes ceases to behave as fluid or plastic. Whereas final setting time referred to the time required for the cement paste to reach certain state of hardness to sustain some load. Setting time is tested by /Vicat apparatus/ or /Gillmore needle/.

5. Compressive Strength

Compressive strength of cement is tested by 50 mm mortar cubes made by using standard sand and cured in a prescribed way. the cubes are tested under a /compression testing machine/. The strength of cement varies with time, therefore in general it is reported as 3 day, 7 day or 28 day strength.

6. Heat of hydration

The heat generated during the reaction of cement and water is known as heat of hydration. The factors affecting heat of hydration are C3A, C2S, water-cement ration, fineness of cement and curing temperature.

/Conduction calorimeter /is used to test heat of hydration.

7. Loss on Ignition

A cement sample of known weight is heated between 900 - 1000°C (1650 - 1830°F) until a constant weight is obtained. The weight loss of the sample due to heating is then determined. A high loss on ignition (more than 3%) indicates prehydration and carbonation, which may be due to

inappropriate storage or adulteration.

8. Specific gravity (relative density)

Specific gravity is generally required in mix proportioning for concrete. The particle density (measured by excluding the air between particles) of OPC is found to be in the range of 3.1 to 3.25 Megagram per cubic meter. The relative density of OPC is assumed as 3.15. The density of cement is determined by Le Chatelier apparatus.

9. Bulk Density

The bulk density can be determined by dividing the mass of cement particles and air between particles by the volume of cement sample. Bulk density of OPC ranges from 830 kg/cu.m to 1650 kg/cu.m. This test can be done with the help of two beakers having same amount of cement. The cement in one beaker is slightly vibrated which shows a decrease in the volume.

Types of Cement in India

There are some varieties in cement that always find good demand in the market. To know their characteristics and in which area they are most required, it will be better to take a look at some of the details given below.

- **Portland Blast Furnace slag cement (PBFSC):** The rate of hydration heat is found lower in this cement type in comparison to PPC. It is most useful in massive construction projects, for example - dams.

- **Sulphate Resisting Portland Cement:** This cement is beneficial in the areas where concrete has an exposure to seacoast or sea water or soil or ground water. Under any such instances, the concrete is vulnerable to sulphates attack in large amounts and can cause damage to the structure. Hence, by using this cement one can reduce the impact of damage to the structure. This cement has high demand in India.

- **Rapid Hardening Portland Cement:** The texture of this cement type is quite similar to that of OPC. But, it is bit more fine than OPC and possesses immense compressible strength, which makes casting work easy.

- **Ordinary Portland Cement (OPC):** Also referred to as grey cement or OPC, it is of much use in ordinary concrete construction. In the production of this type of cement in India, Iron (Fe_2O_3), Magnesium (MgO), Silica (SiO_2), Alumina (AL_2O_3), and Sulphur trioxide (SO_3) components are used.

- **Portland Pozolona Cement (PPC):** As it prevents cracks, it is useful in the casting work of huge volumes of concrete. The rate of hydration heat is lower in this cement type. Fly ash, coal waste or burnt clay is used in the production of this category of cement. It can be availed at low cost in comparison to OPC.

- **Oil Well Cement:** Made of iron, coke, limestone and iron scrap, Oil Well Cement is used in constructing or fixing oil wells. This is applied on both the off-shore and on-shore of the wells.

- **Clinker Cement:** Produced at the temperature of about 1400 to1450 degree Celsius, clinker cement is needed in the construction work of complexes, houses and bridges. The ingredients for this cement comprise iron, quartz, clay, limestone and bauxite.

- **White cement:** It is a kind of Ordinary Portland Cement. The ingredients of this cement are inclusive of clinker, fuel oil and iron oxide. The content of iron oxide is maintained below 0.4% to secure whiteness. White cement is largely used to increase the aesthetic value of a construction. It is preferred for tiles and flooring works. This cement costs more than grey cement.

SlNo	Types Of Cement	Reference Indian Standard
1	Ordinary Portland Cement 33 Grade	IS:269
2	Ordinary Portland Cement 43 Grade	IS:8112
3	Ordinary Portland Cement 53 Grade	IS:12269
4	Rapid Hardening Cement	IS:8041
5	Extra Rapid Hardening Cement	—
6	Sulphate Resisting Cement	IS:12330
7	Portland Slag Cement	IS:455
8	Quick Setting Cement	—
9	Super Sulphated Cement	IS:6909
10	Low Heat Cement	IS:12600
11	Portland Pozzolana Cement (Fly ash based)	IS:1489 P-1
12	Portland Pozzolana Cement (Calcined based)	IS:1489 P-2
13	Air Entraining Cement	—
14	Coloured Cement: White Cement	IS:8042
15	Hydrophobic Cement	IS:8043
16	Masonry Cement	IS:3466
17	Expansive Cement	—
18	Oil Well Cement	IS:8229

19	Rediset Cement	—
20	Concrete Sleeper Grade Cement	IRS-R 40
21	High Alumina Cement	IS:6452
22	Very High Strength Cement	—

Types of Cement	Composition	Purpose
Rapid Hardening Cement	Increased Lime content	Attains high strength in early days it is used in concrete where form work are removed at an early stage.
Quick setting cement	Small percentage of aluminium sulphate as an accelerator and reducing percentage of Gypsum with fine grinding	Used in works is to be completed in very short period and concreting in static and running water
Low Heat Cement	Manufactured by reducing tri-calcium aluminate	It is used in massive concrete construction like gravity dams
Sulphates resisting Cement	It is prepared by maintaining the percentage of tricalcium aluminate below 6% which increases power against sulphates	It is used in construction exposed to severe sulphate action by water and soil in places like canals linings, culverts, retaining walls, siphons etc.,
Blast Furnace Slag Cement	It is obtained by grinding the clinkers with about 60% slag and resembles more or less in properties of Portland cement	It can used for works economic considerations is predominant.
High Alumina Cement	It is obtained by melting mixture of bauxite and lime and grinding with the clinker it is rapid hardening cement with initial and final setting time of about 3.5 and 5 hours respectively	It is used in works where concrete is subjected to high temperatures, frost, and acidic action.
White Cement	It is prepared from raw materials free from Iron oxide.	It is more costly and is used for architectural purposes such as pre-cast curtain wall and facing panels, terrazzo surface etc.,
Coloured cement	It is produced by mixing mineral pigments with ordinary cement.	They are widely used for decorative works in floors
Pozzolanic Cement	It is prepared by grindin pozzolanic clinker with Portland cement	It is used in marine structures, sewage works, sewage works and for laying concrete under water such as bridges, piers, dams etc.,

Air Entraining Cement	It is produced by adding indigenous air entraining agents such as resins, glues, sodium salts of Sulphates etc during the grinding of clinker.	This type of cement is specially suited to improve the workability with smaller water cement ratio and to improve frost resistance of concrete.
Hydrographic cement	It is prepared by mixing water repelling chemicals	This cement has high workability and strength

CONCRETE CHEMICALS AND APPLICATIONS
Concrete Chemicals (Admixtures) and Applications

Concrete-Admixtures

Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color. Some admixtures have been in use for a very long time in concrete construction, such as calcium chloride to provide a cold-weather setting concrete.

Based on their functions, admixtures can be classified into the following five major categories:

Retarding admixtures
Accelerating admixtures
Super plasticizers
Water reducing admixtures
Air-entraining admixtures

Among other important admixtures that do not fit into these categories are admixtures whose functions include bonding, shrinkage reduction, damp proofing and coloring. The following paragraphs provides details on the above-mentioned categories of concrete admixtures.
Retarding Admixtures

Retarding admixtures slow down the hydration of cement, lengthening set time. Retarders are beneficially used in hot weather conditions in order to overcome accelerating effects of higher temperatures and large masses of concrete on concrete setting time. Because most retarders also act as water reducers, they are frequently called water-reducing retarders. As per chemical admixture classification by ASTM-ASTM C 494, type B is simply a retarding admixture, while type D is both retarding and water reducing, resulting in concrete with greater compressive strength because of the lower water-cement ratio.

Retarding admixtures consists of both organic and inorganic agents. Organic retardants include unrefined calcium, sodium, NH4, salts of lignosulfonic acids, hydrocarboxylic acids, and carbohydrates. Inorganic retardants include oxides of lead and zinc, phosphates, magnesium salts, fluorates and borates. As an example of a retardant‘s effects on concrete properties, lignosulfate acids and hydroxylated carboxylic acids slow the initial setting time by at least an hour and no more than three hours when used at 65 to 100 degrees Fahrenheit. The concrete contractor, however, need not memorize these chemical-specific results. Given the specific job requirements and goals, the concrete supplier should offer appropriate admixtures and concrete mixes from which to choose.
Accelerating admixtures

Accelerators shorten the set time of concrete, allowing a cold-weather pour, early removal of forms, early surface finishing, and in some cases, early load application. Proper care must be taken while choosing the type and proportion of accelerators, as under most conditions, commonly used accelerators cause an increase in the drying shrinkage of concrete.

Calcium chloride is a common accelerator, used to accelerate the time of set and the rate of strength gain. It should meet the requirements of ASTM D 98. Excessive amounts of calcium chloride in concrete mix may result in rapid stiffening, increase in drying shrinkage and corrosion of reinforcement. In colder climates, calcium chloride should not be used as an anti-freeze. Large amount of calcium chloride is required to lower the freezing point of the concrete, which may ruin the concrete.
Super plasticizers

Super plasticizers, also known as plasticizers, include water-reducing admixtures. Compared to what is commonly referred to as a ―water reducer‖ or ―mid-range water reducer‖, super plasticizers are ―high- range water reducers‖. High range water reducers are admixtures that allow large water reduction or greater flowability (as defined by the manufacturers, concrete suppliers and industry standards) without substantially slowing set time or increasing air entrainment.

Each type of super plasticizer has defined ranges for the required quantities of concrete mix ingredients, along with the corresponding effects. They can maintain a specific consistency and workability at a greatly reduced amount of water. Dosages needed vary by the particular concrete mix and type of super plasticizer used. They can also produce a high strength concrete. As with most types of admixtures, super plasticizers can affect other concrete properties as well. The specific effects, however, should be found from the manufacturer or concrete supplier.
Water reducing admixtures

Water reducing admixtures require less water to make a concrete of equal slump, or increase the slump of concrete at the same water content. They can have the side effect of changing initial set time. Water reducers are mostly used for hot weather concrete placing and to aid pumping. A water-reducer plasticizer, however, is a hygroscopic powder, which can entrain air into the concrete mix via its effect on water‘s surface tension, thereby also, obtaining some of the benefits of air-entrainment (see below).

Air-entraining admixtures

Air-entraining agents entrain small air bubbles in the concrete. The major benefit of this is enhanced durability in freeze-thaw cycles, especially relevant in cold climates. While some strength loss typically accompanies increased air in concrete, it generally can be overcome by reducing the water-cement ratio via improved workability (due to the air-entraining agent itself) or through the use of other appropriate admixtures. As always, admixtures should only be combined in a concrete mix by a competent professional because some of them can interact in undesirable ways.
Bonding admixtures

Bonding admixtures including addition of compounds and materials such as polyvinyl chlorides and acetates, acrylics and butadiene-styrene co-polymers, can be used to assist in bonding new / fresh concrete with old / set concrete.

Coloring agents have become more commonly used, especially for patios and walkways. Most are surface applied and often have the additional effect of surface hardening. Such surface applied coloring admixtures generally should not be used on air-entrained concrete. Integrally colored concrete is also available.

Waterproofing and damp proofing admixtures

Water proofing and damp proofing admixtures including soaps, butyl stearate, mineral oil and asphalt emulsions, are used to decrease the amount of water penetration into the larger pores of concrete.

―Antifreeze‖ admixtures typically are accelerators used in very high doses, with a corresponding high price, to achieve a very fast set-time, though they do not have properties to protect against freezing on their own. However, in general, these are not used for residential work. How we make cement (wet process technology)

The manufacture of cement is a very carefully regulated process comprising the following stages:

1. **Quarrying** - a mixture of limestone and clay.
2. **Grinding** - the limestone and clay with water to form a slurry.
3. **Burning** - the slurry to a very high temperature in a kiln, to produce clinker.
4. **Grinding** - the clinker with about 5% gypsum to make cement.

Raw Materials Extraction

The limestone and clay occur together in our quarries at Cape Foulwind. It is necessary to drill and blast these materials before they are loaded in 70t capacity trucks.

The quarry trucks deliver the raw materials to the crusher where the rock is crushed to smaller than 100mm (4 inches). The raw materials are then stored ready for use.

Raw Materials Preparation

About 80% limestone and 20% clay are ground in ball mills with water, producing very fine, thin, paste called slurry. The chemical composition of the slurry is very carefully controlled by adjusting the relative amount of limestone and clay being used.

The slurry is stored in large basins ready for use.

Clinker **Burning**

The slurry is fed into the upper end of a rotary kiln, while at the lower end of the kiln, a very intense flame is maintained by blowing in finely ground coal.

The slurry slowly moves down the kiln and is dried and heated until it reaches a temperature of almost 1500 degrees Celsius producing "clinker". This temperature completely changes the limestone and clay to produce new minerals which have the property of reacting with water to form a cementitious binder. The hot clinker is used to preheat the air for burning the coal, and the cooled clinker is stored ready for use.

Cement Milling

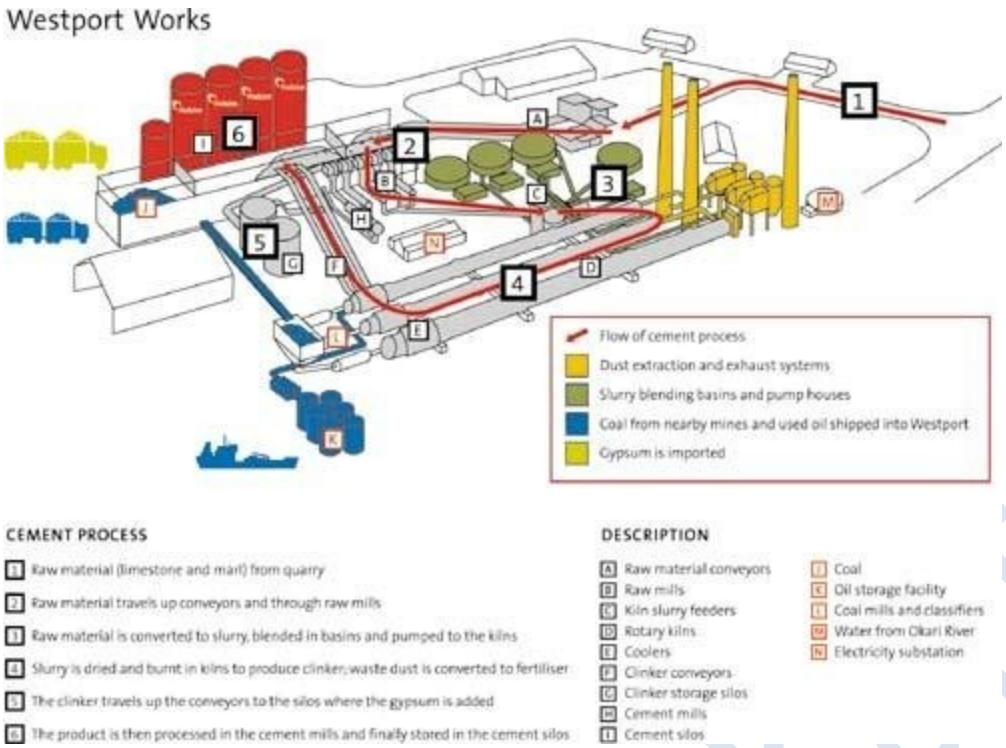
The clinker is finely ground with about 5% gypsum in another ball mill, producing cement. (The gypsum regulates the early setting characteristic of cement). The finished cement is stored in silos then carted to our wharf or packing plant facilities.

Some Facts and Figures

The mills for grinding the raw materials are 2.4m in diameter and 11.0m long and are driven by 720kw (1000HP) electric motors producing 45t/h of slurry. The cement is ground in two mills: one 2.4m x 11.0m long producing 18t/h of cement; the other 3.8m x 11.4m, powered by 2300kw (3000 HP) electric motor and producing 60 t/h of cement. The kilns are either 98m or 110m long, and produce up to 25 t/h of clinker.

Two ships, the mv "Westport" and mv "Milburn Carrier II" carry cement to depots at Onehunga, Wellington, Napier, Gisborne, Nelson, Lyttelton and Dunedin for distribution to customers.

The diagram below details the Westport Works production process.



How cement is made (dry process technology)

A new plant at Weston near Oamaru would use dry process technology to produce cement.

Limestone and silica-rich sand or rock is quarried and crushed, and transported to storage stockpiles near the kiln where pre-blending takes place.

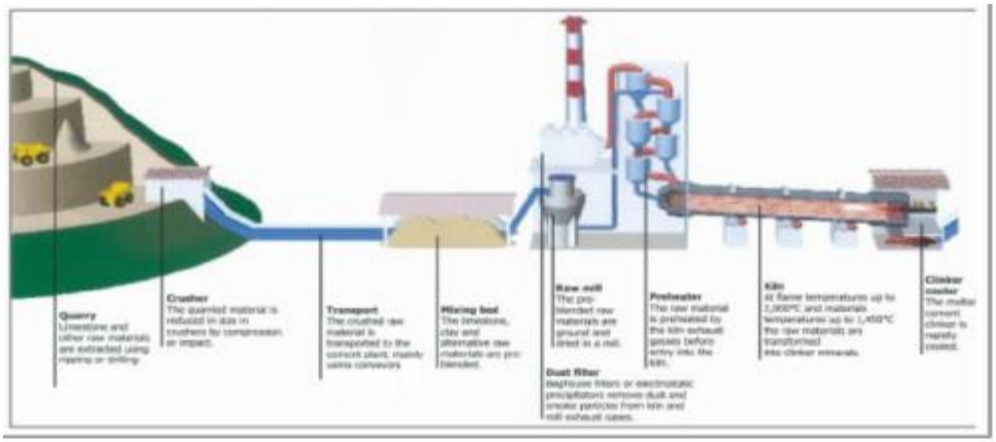
The raw materials are dried, ground and mixed to form a fine, homogenous powder, with moisture content of less than one percent.

This powder is fed into the kiln where the heat promotes the necessary chemical reactions. The kiln exhaust gases are the main source of heat used to dry the raw materials.

This is known as 'dry process' technology because no water is added to the ground raw materials. It is the process used by modern cement manufacturing plants.

Older cement kilns (including those at our current Westport plant) use a wet process, where the ground material is mixed with water to produce slurry, which is then fed to the kiln.

- How we make cement



A modern 'dry process' plant uses approximately half the energy of a 'wet process' plant

CEMENT MORTAR

What is Mortar?

Mortar is a mixture of sand and cements that is most often used to build brick or block walls. In my July blog on cement and concrete I dealt exclusively with portland cement products and uses. I also promised that at a later date I would talk about the masonry world. For those of you on the edge of your seats since then, well today is your lucky day.

While Portland cement concrete is certainly one of the most widely used building product in the world, masonry mortar is close behind. It is doubtful that you live or work in a building that doesn‘t have mortar in it somewhere. The 3/8‖ gray line of material that separates the brick or block is mortar. Mortar is a very different animal than concrete. Concrete is designed to be used in thicker applications and to reach very high strengths. It achieves its durability through brute force. Mortar is also designed to be durable but achieves its goal through finesse. Its strengths are quite low compared with concrete and it is never used in thick applications. It is much creamier and more workable than concrete. If you play tennis, think of concrete as your most powerful serve when you are trying to smash the ball into or through your opponent so that they can‘t return the serve. Then think of mortar as a very gently placed lob close to the net that gets your opponent leaning the wrong way with no chance of returning the ball. Both achieve the desired result of earning you a point. The point of this long winded analogy is to let you know that using concrete and mortar interchangeably will lead to disaster.

Types of Masonry Cement & Mortar

CEMEX‘s Masonry Cements are produced in Type N Masonry Cement, Type S Masonry Cement and Type M Masonry Cement strength levels for use in preparation of ASTM Specification C-270 Type N, M or Type S Masonry Mortar, respectively without any further additions.

Table 1 is a general guide for selection of mortar type. Other factors, such as type and absorption of masonry unit, climate and exposure, applicable building codes, and engineering requirements should also be considered.

TABLE 1 Recommended Guide for Selection of Mortar Type

Building Segment	Mortar Type
Exterior, above grade, load-bearing non load-bearing parapet wall	 N or S or M N N or S
Exterior, at or below grade	S or M
Interior load-bearing non load-bearing	 N or S N

Cement Concrete

Concrete is a composite material composed of aggregate bonded together with a fluid cement which hardens over time. Most use of the term "concrete" refers to Portland cement concrete or to concretes made with other hydraulic cements. However, technically road pavement is also a type of concrete, "asphaltic concrete", where the cement material is bitumen.

Properties of Cement Concrete

The cement concrete possesses the following important properties:

1. It possesses a high compressive strength.
2. It is a corrosion resistance material and atmospheric agent has no appreciable effect on it.
3. It hardens with age the process of hardening continues for a long time after the concrete has attained sufficient strength. It is this property of cement concrete which gives it a distinct place among building materials.
4. It is more economical than steel.
5. It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as the reinforced cement concrete or simply as R.C.C.
6. Under the following two conditions, it has a tendency to shrink:
    1. There is initial shrinkage of cement concrete which is mainly due to the loss of water through forms, absorption by surfaces of forms etc.
    2. The shrinkage of cement concrete occurs as it hardens. This tendency of cement concrete can be minimized by proper curing of concrete.
7. It has a tendency to be porous. This is due to the presence of voids which are formed during and after its placing. The two precautions necessary to avoid this tendency are as follows:
    1. There should be proper grading and consolidating of the aggregates.
    2. The minimum water-cement ratio should be adopted.
8. It forms a hard surface, capable of resisting abrasion.
9. It should be remembered that apart from other materials, the concrete comes to the site in the form of raw materials only. Its final strength and quality depend entirely on local conditions and persons handling it. However the materials which concrete is composed may be subjected to rigid specifications

Process of manufacture of concrete

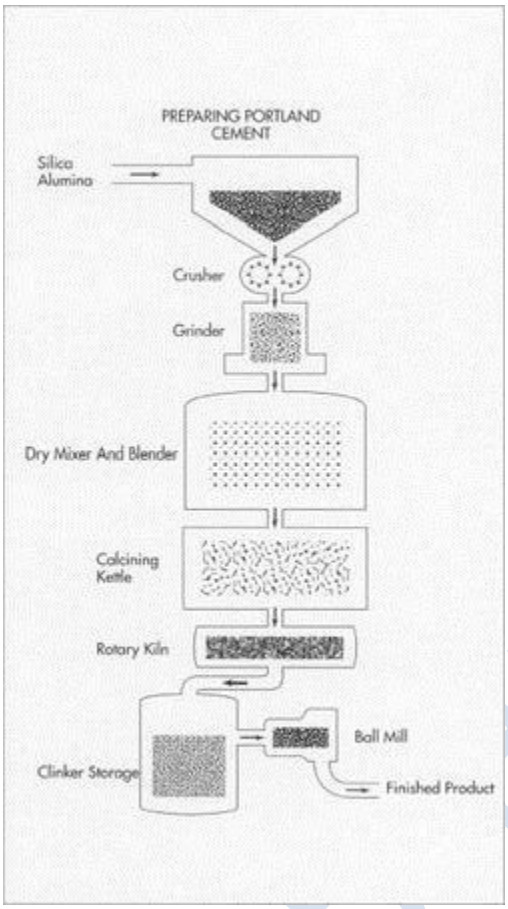
Mixing

- 3 The cement is then mixed with the other ingredients: aggregates (sand, gravel, or crushed stone), admixtures, fibers, and water. Aggregates are pre-blended or added at the ready-mix concrete plant under normal operating conditions. The mixing operation uses rotation or stirring to coat the surface of the aggregate with cement paste and to blend the other ingredients uniformly. A variety of batch or continuous mixers are used.

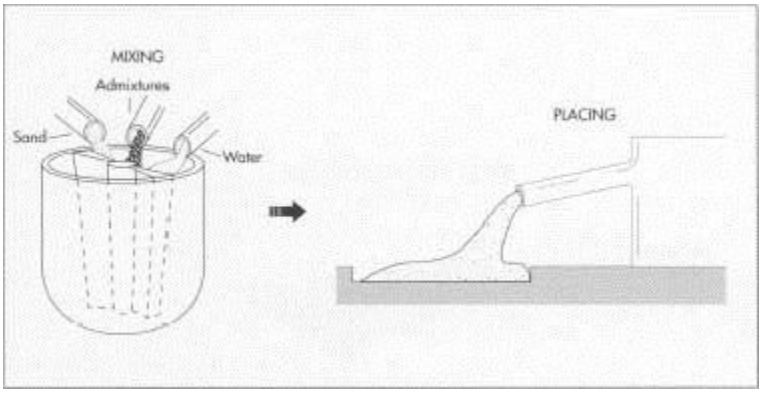
- 4 Fibers, if desired, can be added by a variety of methods including direct spraying, premixing, impregnating, or hand laying-up. Silica fume is often used as a dispersing or densifying agent.

Transport to work site

- 5 Once the concrete mixture is ready, it is transported to the work site. There are many methods of transporting concrete, including wheelbarrows, buckets, belt conveyors,



The first step in making concrete is to prepare the cement. One type of cement, Pordand cement, is considered superior to natural cement because it is stronger, more durable, and of a more consistent quality.
To make it, the raw materials are crushed and ground into a fine powder and mixed together. Next, the material undergoes two heating steps—calcining and burning. In calcining, the materials are heated to a high temperature but do not fuse together. In burning, however, the materials partially fuse together, forming a substance known as "clinker." The clinker is then ground in a ball mill—a rotating steel drum filled with steel balls that pulverize the material.



After the Portland cement is prepared, it is mixed with aggregates such as sand or gravel, admixtures, fibers, and water. Next, it is transfered to the work site and placed. During placing, segregation of the various ingredients must be avoided so that full compaction—elimination of air bubbles—can be achieved.

special trucks, and pumping. Pumping transports large quantities of concrete over large distances through pipelines using a system consisting of a hopper, a pump, and the pipes. Pumps come in several types—the horizontal piston pump with semi-rotary valves and small portable pumps called squeeze pumps. A vacuum provides a continuous flow of concrete, with two rotating rollers squeezing a flexible pipe to move the concrete into the delivery pipe.

Placing and compacting

- 6 Once at the site, the concrete must be placed and compacted. These two operations are performed almost simultaneously. Placing must be done so that segregation of the various ingredients is avoided and full compaction—with all air bubbles eliminated—can be achieved. Whether chutes or buggies are used, position is important in achieving these goals. The rates of placing and of compaction should be equal; the latter is usually accomplished using internal or external vibrators. An internal vibrator uses a poker housing a motor-driven shaft. When the poker is inserted into the concrete, controlled vibration occurs to compact the concrete. External vibrators are used for precast or thin in situ sections having a shape or thickness unsuitable for internal vibrators. These type of vibrators are rigidly clamped to the formwork, which rests on an elastic support. Both the form and the concrete are vibrated. Vibrating tables are also used, where a table produces vertical vibration by using two shafts rotating in opposite directions.

Curing

- 7 Once it is placed and compacted, the concrete must cured before it is finished to make sure that it doesn't dry too quickly. Concrete's strength is influenced by its moisture level during the hardening process: as the cement solidifies, the concrete shrinks. If site constraints prevent the concrete from contracting, tensile stresses will develop, weakening the concrete. To minimize this problem, concrete must be kept damp during the several days it requires to set and harden.

Concrete Mix Design As Per Indian Standard Code

Concrete Mix Design

Introduction

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

Requirements of concrete mix design

The requirements which form the basis of selection and proportioning of mix ingredients are :

a) The minimum compressive strength required from structural consideration

b) The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

Types of Mixes

1. Nominal Mixes

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

2. Standard mixes

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

3. Designed Mixes

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm^2. No control testing is necessary reliance being placed on the masses of the ingredients.

Factors affecting the choice of mix proportions

The various factors affecting the mix design are:

1. Compressive strength

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete

at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

2. Workability

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

3. Durability

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

4. Maximum nominal size of aggregate

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate.

IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

5. Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.

The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

6. Quality Control

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and

minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

Mix Proportion designations

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass

Factors to be considered for mix design

- The grade designation giving the characteristic strength requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.
- Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

Procedure

1. Determine the mean target strength f_t from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.

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

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

2. Obtain the water cement ratio for the desired mean target using the emperical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio.

The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

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

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

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

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

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

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

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

where V = absolute volume of concrete

= gross volume ($1m^3$) minus the volume of entrapped air

S_c = specific gravity of cement

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

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

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

f_a, C_a = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively

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

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

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

Mixing Ratio for Concrete in:

M5
* Mix ratio for M5 concrete is 1:5:10
* compressive strength is 5N/mm2 @ 28 days.

* 1 part of cement, 5 parts of sand, 4 parts of coarse aggregate.

M-7.5 -1:4:8
M-10 - 1:3:6
M-15 - 1:2:4
M-20 - 1:1.5:3
M-25 -1:1:2
M-30 - M-40

M- 40 is strongest It depends upon the design mix, . M-40 means its strengthis 40n/mm2

Water: cement: F.A.: C.A. = 0.4: 1: 1.65: 2.92

TYPES OF CONCRETE WITH APPLICATIONS

Types of concrete with applications for different structural components like beams, columns, slabs, foundations are explained here. Special concrete with uses.

Light weight concrete

One of the main advantages of conventional concrete is the self weight of concrete. Density of normal concrete is of the order of 2200 to 2600. This self weight will make it to some extend an uneconomical structural material.

Self weight of light weight concrete varies from 300 to 1850 kg/m3.

It helps reduce the dead load, increase the progress of building and lowers the hauling and handling cost.

The weight of building on foundation is an important factor in the design , particularly in case of weak soil and tall structures. In framed structure , the beam and column have to carry load of wall and floor. If these wall and floor are made of light weight concrete it will result in considerable economy.

Light weight concrete have low thermal conductivity.(In extreme climatic condition where air condition is to installed the use of light weight concrete with low thermal conductivity is advantageous from the point of thermal comfort and low power consumption.

Only method for making concrete light by inclusion of air. This is achieved by a) replacing original mineral aggregate by light weight aggregate, b) By introducing gas or air bubble in mortar c) By omitting sand fraction from concrete. This is called no – fine concrete.

Light weight aggregate include pumice, saw dust rice husk, thermocole beads, formed slag. Etc

Light weight concrete aggregate exhibit high fire resistance.

Structural lightweight aggregate's cellular structure provides internal curing through water entrainment which is especially beneficial for high-performance concrete

Lightweight aggregate has better thermal properties, better fire ratings, reduced shrinkage, excellent freezing and thawing durability, improved contact between aggregate and cement matrix, less micro-cracking as a result of better elastic compatibility, more blast resistant, and has better shock and sound absorption, High-Performance lightweight aggregate concrete also has less cracking, improved skid resistance and is readily placed by the concrete pumping method

Aerated concrete is made by introducing air or gas into a slurry composed of Portland cement.

No fine concrete is made up of only coarse aggregate , cement and water.These type of concrete is used for load bearing cast in situ external walls for building. They are also used for temporary structures because of low initial cost and can be reused as aggregate.

High density concrete

The density of high density concrete varies from 3360 kg/m3 to 3840 kg/m3.They can however be produced with density upto 5820 kg/m3 using iron as both fine and coarse aggregate.

Heavyweight concrete uses heavy natural aggregates such as barites or magnetite or manufactured aggregates such as iron or lead shot. The density achieved will depend on the type of aggregate used. Typically using barites the density will be in the region of 3,500kg/m3, which is 45% greater than that of normal concrete, while with magnetite the density will be 3,900kg/m3, or 60% greater than normal concrete. Very heavy concretes can be achieved with iron or lead shot as aggregate, is 5,900kg/m3 and 8,900kg/m3 respectively.

They are mainly used in the construction of radiation shields (medical or nuclear). Offshore, heavyweight concrete is used for ballasting for pipelines and similar structures

The ideal property of normal and high density concrete are high modulus of elasticity , low thermal expansion , and creep deformation

Because of high density of concrete there will be tendency for segregation. To avoid this pre placed aggregate method of concreting is adopted.

High Modulus of Elasticity, Low thermal Expansion ,Low elasticity and creep deformation are ideal properties.

The high density. Concrete is used in construction of radiation shields. They are effective and economic construction material for permanent shielding purpose.

Most of the aggregate specific gravity is more than 3.5

Mass concrete

Mass concrete is defined in ACI as ―any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking.‖ The design of mass concrete structures is generally based on

durability, economy, and thermal action, with strength often being a secondary, rather than a primary, concern. The one characteristic that distinguishes mass concrete from other concrete work is thermal behavior. Because the cement-water reaction is exothermic by nature, the temperature rise within a large concrete mass,

where the heat is not quickly dissipated, can be quite high. Significant tensile stresses and strains may result from the restrained volume change associated with a decline in temperature as heat of hydration is dissipated. Measures should be taken where cracking due to thermal behavior may cause a loss of structural integrity and monolithic action, excessive seepage and shortening of the service life of the structure, or be aesthetically objectionable. Many of the principles in mass concrete practice can also be applied to general concrete work, whereby economic and other benefits may be realized. Mass concreting practices were developed largely from concrete dam construction, where temperature-related cracking was first identified. Temperature-related cracking has also been experienced in other thick-section concrete structures, including mat foundations, pile caps, bridge piers, thick walls, and tunnel linings

Ready-mix Concrete

Ready-mix concrete has cement, aggregates, water and other ingredients, which are weigh-batched at a centrally located plant. This is then delivered to the construction site in truck mounted transit mixers and can be used straight away without any further treatment. This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites. Ready-mix concrete is sometimes preferred over on-site concrete mixing because of the precision of the mixture and reduced worksite confusion. However, using a pre-determined concrete mixture reduces flexibility, both in the supply chain and in the actual components of the concrete. Ready Mixed Concrete, or RMC as it is popularly called, refers to concrete that is specifically manufactured for delivery to the customer‘s construction site in a freshly mixed and plastic or unhardened state. Concrete itself is a mixture of Portland cement, water and aggregates comprising sand and gravel or crushed stone. In traditional work sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete. Ready Mixed Concrete is bought and sold by volume – usually expressed in cubic meters. Ready Mixed Concrete is manufactured under computer-controlled operations and transported and placed at site using sophisticated equipment and methods. RMC assures its customers numerous benefits.

Advantages of Ready mix Concrete over Site mix Concrete

A centralised concrete batching plant can serve a wide area.

The plants are located in areas zoned for industrial use, and yet the delivery trucks can service residential districts or inner cities.

Better quality concrete is produced.

Elimination of storage space for basic materials at site.

Elimination of procurement / hiring of plant and machinery

Wastage of basic materials is avoided.

Labor associated with production of concrete is eliminated.

Time required is greatly reduced.

Noise and dust pollution at site is reduced.

Disadvantages of Ready-Mix Concrete

The materials are batched at a central plant, and the mixing begins at that plant, so the traveling time from the plant to the site is critical over longer distances. Some sites are just too far away, though this is usually a commercial rather than technical issue.

Access roads and site access have to be able to carry the weight of the truck and load. Concrete is approx. 2.5tonne per m^2. This problem can be overcome by utilizing so-called _minimix‘ companies, using smaller 4m^3 capacity mixers able to access more restricted sites.

Concrete‘s limited time span between mixing and going-off means that ready-mix should be placed within 2 hours of batching at the plant. Concrete is still usable after this point but may not conform to relevant specifications.

Polymer concrete

Concrete is porous. The porosity is due to air voids , water voids or due to inherent property of gel structures. On account of porosity strength of concrete is reduced , reduction of porosity result in increase in strength of concrete. The impregnation of monomer and subsequent polymerization is the latest technique adopted to reduce inherent porosity of concrete and increase strength and other properties of concrete

There are mainly 4 types of polymer concrete

1. Polymer impregnated concrete

2. Polymer cement concrete

3. Polymer concrete

4. Partially impregnated and surface coated polymer concrete.

Polymer impregnated concrete

It is a precast conventional concrete cured and dried in oven or by dielectric heating from which the air in the open cell is removed by vacuum. Then a low viscosity monomer is diffused through the open cell and polymerized by using radiation, application of heat or by chemical initiation.

Mainly the following type of monomers are used

Methyl methacrlylate(MMA)

1. Acrylonitrile

2. t- butyl styrene

3. Other thermoplastic monomer

4. The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that has occupied the total void space.

5. PIC require cast in situ
structures Polymer cement concrete

Polymer cement concrete is made by mixing cement, aggregate, water and monomer. Such plastic mixture is cast in moulds , cured dried and polymerized. The monomer that are used in PCC are

1. Polyster- styrene

2. Epoxy-styrene

3. Furans

4. Vinyldene chloride

PCC produced in this way have been disappointing. In many cases material poorer than ordinary concrete is obtained.This is because organic material are incompatable with aqueous systems and some times interfere with the alkaline cement hydration process. Russians developed a superior polymer by incorporation of furfuryl alcohol and aniline hydrochloride in the wet mix. This material is dense and non shrinking and to have high corrosion resistance, low permeability and high resistance to vibration and axial extension .PCC can be cast in situ for field application.

Polymer concrete

Polymer concrete is an aggregate bound with a polymer binder instead of Portland cement as in conventional concrete. The main technique in producing PC is to minimize void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregate. This is achieved by properly grading and mixing the aggregate to attain maximum density and minimum voids

Shotcrete

It is defined as a mortar conveyed through a hose and pneumatically projected at high velocity on to a surface. There are mainly two different methods namely wet mix and dry mix process. In wet mix process the material is conveyed after mixing with water.

Pre packed concrete

In constructions where the reinforcement is very complicated or where certain arrangements like pipe, opening or other arrangements are incorporated this type of concreting is adopted. One of the methods is concrete process in which mortar is made in a high speed double drum and grouting is done by pouring on prepacked aggregate. This is mainly adopted for pavement slabs

Vacuum concrete

Concrete poured into a framework that is fitted with a vacuum mat to remove water not required for setting of the cement; in this framework, concrete attains its 28-day strength in 10 days and has a 25% higher crushing strength. The elastic and shrinkage deformations are considerably greater than for normal-weight concrete.

Pumped concrete

Pumped concrete must be designed to that it can be easily conveyed by pressure through a rigid pipe of flexible hose for discharge directly into the desired area. Pozzocrete use can greatly improve concrete flow characteristics making it much easier to pump, while enhancing the quality of the concrete and controlling costs.

Mix Homogeneity

The designer must be aware of the need to improve the grade and maintain uniformity of the various materials used in the pumped mix in order to achieve greater homogeneity of the total mix. Three mix proportioning methods frequently used to produce pump able concrete are :

Maximum Density of Combined Materials

Maximum Density – Least Voids

Minimum Voids – Minimum Area

Mixes must be designed with several factors in mind:

1. Pumped concrete must be more fluid with enough fine material and water to fill internal voids.

2. Since the surface area and void content of fine material below 300 microns control the liquid under pressure, there must be a high quantity of fine material in a normal mix. Generally speaking, the finer the material, the greater the control.

3. Coarse aggregate grading should be continuous, and often the sand content must be increased by up to five percent at the expense of the coarser aggregate so as to balance the 500 micron fraction against the finer solids.

Pozzocrete Effective

Unfortunately, adding extra water and fine aggregate leads to a weaker concrete. The usual remedies for this are either to increase the cement content, which is costly, or to use chemical admixtures, which can also be costly and may lead to segregation in marginal mixes. There is another and far more effective alternative:

POZZOCRETE

There are many advantages to including POZZOCRETE in concrete mixes to be pumped. Among them are :

1. Particle Size. Pozzocrete meets IS 3812 Specification with 66% passing the 325 (45-micron) sieve and these fine particles are ideal for void filling. Just a small deficiency in the mix fines can often prevent successful pumping.

2. Particle Shape. Microscopic examination shows most Pozzocrete particles are spherical and act like miniature ball bearings aiding the movement of the concrete by reducing frictional losses in the pump and pining. Studies have shown that Pozzocrete can be twice as effective as cement in improving workability and, therefore, improve pumping characteristics.

Pozzolanic Activity:

his chemical reaction combines the Pozzocrete particles with the calcium hydroxide liberated through the hydration of cement to form additional cementitious compounds which increase concrete strength.

Water Requirement:

Excess water in pumped mixes resulting in over six inch slumps will often cause material segregation and result in line blockage. As in conventionally placed mixes, pumped concrete mixes with excessive water also contribute to lower strength, increased bleeding and shrinkage. The use of Pozzocrete in pumped or conventionally placed mixes can reduce the water requirement by 2% to 10% for any given slump.

Sand/Coarse Aggregate Ratio:

In pumped mixes, the inclusion of liberal quantities of coarse aggregate can be very beneficial because it reduces the total aggregate surface area, thereby increasing the effectiveness of the available cementitious paste. This approach is in keeping with the ―minimum voids, minimum area‖ proportioning method. As aggregate size increases, so does the optimum quantity of coarse aggregate. Unfortunately, this process is

frequently reversed in pump mixes, and sand would be substituted for coarse aggregate to make pumping easier. When that happens, there is a need to increase costly cementitious material to compensate for strength loss. However, if Pozzocrete is utilized, its unique workability and pump ability properties permit a better balance of sand to coarse aggregate resulting in a more economical, pump able concrete.

SHOTCRETE

Shotcrete is a process where concrete is projected or "shot" under pressure using a feeder or "gun" onto a surface to form structural shapes including walls, floors, and roofs. The surface can be wood, steel, polystyrene, or any other surface that concrete can be projected onto. The surface can be trowelled smooth while the concrete is still wet.

Benefits

Shotcrete has high strength, durability, low permeability, excellent bond and limitless shape possibilities. These properties allow shotcrete to be used in most cases as a structural material. Although the hardened properties of shotcrete are similar to conventional cast-in-place concrete, the nature of the placement process provides additional benefits, such as excellent bond with most substrates and instant or rapid capabilities, particularly on complex forms or shapes. In addition to building homes, shotcrete can also be used to build pools

Methods of Application

Wet Mix – All ingredients, including water, are thoroughly mixed and introduced into the delivery equipment. Wet material is pumped to the nozzle where compressed air is added to provide high velocity for placement and consolidation of the material onto the receiving surface.

Dry Mix – Pre-blended dry or damp materials are placed into the delivery equipment. Compressed air conveys material through a hose at high velocity to the nozzle, where water is added. Material is consolidated on the receiving surface by the high-impact velocity.

Features

The properties of both wet and dry process shotcrete can be further enhanced through the addition of many different additives or admixtures such as:

Silica Fume – Provides reduced permeability, increased compressive and flexural strength, increased resistance to alkali and chemical attack, improved resistance to water washout, reduced rebound levels and allows for thicker single pass applications.

Air-Entraining Admixtures – Improve pumpability and adhesion in wet-process shotcrete and freeze-thaw durability in both wet and dry processes.

Fibers – Control cracking, increase toughness values and improve impact resistance and energy absorption.

Accelerators – Improve placement characteristics in adverse conditions, allow for thicker single pass applications, increase production capabilities and reduce the occurrence of fallouts on structures subjected to vibratio

EQUIPEMENTS USED FOR MANUFACTURING OF CONCRETE PRESENTATION BY: MANPREET SINGH AGAM TOMAR

1. VARIOUS STAGES OF MANUFACTURING OF CONCRETE

   - BATCHING
   - MIXING
   - TRANSPORTING
   - PLACING
   - COMPACTING
   - CURING
   - FINISHING

2. **BATCHING** Batching is the process of measuring concrete mix ingredients by either mass or volume and introducing them into the mixer . To produce concrete of uniform quality, the ingredients must be measured accurately for each batch.

   - Volume batching
   - Weight batching

   Volume batching • This method is generally adopted for small jobs . • Gauge boxes are used for measuring the fine and coarse aggregate. • The volume of gauge box is equal to the volume of one bag of cement. Gauge bow are also called as FARMAS They can be made of timbers or steel. They are made generally deep and narrow Bottomless gauge boxes are generally avoided. While filling the gauge boxes the material should be filled loosely,no compaction is allowed.

   Weigh Batching • Batching by weight is more preferable to volume batching ,as it is more accurate and leads to more uniform proportioning. • It does not have uncertainties associated with bulking. It‘s equipment falls into 3 general categories : I. Manual, II. Semi automatic, III. Fully automatic.

   In case of manual batching all weighing and batching of concrete are done manually. It is used for small jobs.

   Semi automatic In case of semi automatic batching the aggregate bin gates are opened by manually operated switches . And gates are closed automatically when the material has been delivered. This system also contains interlock which prevents charging and discharging. 3)Fully automatic In case of automatic batching the material are electrically activates by a single switch and complete autographic record are made of the weight of each material. The batching plant comprises 2,3,4 or 6 compartment bins of several capacitie. Over the conveyer belt the weigh batchers discharging are provided below the bins

3. **Mixing** The mixing should be ensure that the mass becomes Homogeneous , uniform in colour and consistency . Methods of Mixing :

1. Hands(using hand shovels)
2. Stationary Mixers
3. Ready mix concrete

Hand Mixing Mixing ingredients of concrete by hands using ordinary tools like, hand shovels etc. This type of mixing is done for Less output of concrete.

Stationary Mixers • Concrete is sometime mixed at jobsite in a stationary mixer having a size of 9 cubic meter . • These mixers may be of : 1. Tilting type , 2. Non-Tilting type ,

Tilting type mixer • It consist a conical drum which rotates on an inclinable axis. • It has only one opening. • The drum charged directly and discharged by tilting and reversing the drum.

Non tilting type mixer • The mixing drum is cylindrical in shape and revolves two – horizontal axis. • It has opening on both sides. • The ingredients are charged in from one opening. • For discharging concrete chute is introducing to other opening by operating a lever.

Ready Mixed Concrete Ready mixed concrete is proportioned and mixed off at the project site and is delivered to the construction area in a freshly mixed and unhardened state. It can be manufactured by any of the following methods: 1.Central-mixed concrete 2.Truck-mixed concrete

Central Mixed Concrete • Central-mixed concrete mixed completely in a stationary mixer • delivered in Agitator Trucks A non-agitating truck

Agitator Trucks • A vehicle carrying a drum or agitator body, in which freshly mixed concrete can be conveyed from the point of mixing to that of placing, the drum being rotated continuously to agitate the contents. Advantages: Operate usually from central mixing plants Watch for: Timing of deliveries should suit job organization. Concrete crew and equipment must be ready onsite to handle concrete. Used for: Transporting concrete for all uses. Haul distances must allow discharge of concrete within 1½ hours.

Agitator Trucks

Non-agitating Trucks Used for: Transport concrete on short hauls(small distance) over smooth roadways. Advantages: Cost of non-agitating equipment is lower than that of truck agitators or mixers. Watch for: Slump should be limited. Possibility of segregation. Height upon discharge is needed

Truck-mixed concrete Used for: Intermittent (periodic) production of concrete at jobsite, or small quantities. Advantages: Combined materials transporter and batching and mixing system. One-man operation.

4. Transporting

1. Mortar Pan : Concrete is carried in small Quantities
2. Wheelbarrows and Buggies : Short flat hauls on all types of onsite concrete construction
3. Belt Conveyors : Conveying concrete horizontally or higher/lower level.
4. Cranes and Buckets : Used forWork above ground level , Buckets use with Cranes, cableways, and helicopters.
5. Pumps : Conveying concrete from central discharge point to formwork.

6. Transit Mixer : used for transporting the concrete over long distance particularly in RMC plant .

5. **Compaction of concrete** • Compaction of concrete is process adopted for expelling the entrapped air from the concrete • In the process of mixing , transporting and placing of concrete air is likely

to get entrapped in the concrete . • It has been found from the experimental studies that 1% air in the concrete approximately reduces the strength by 6%. • If we don't expel this air, it will result into honeycombing and reduced strength

Different Methods Of Concrete Compaction

1. Hand Compaction Rodding Ramming Tamping
2. Compaction by Vibration Internal vibrator Formwork Vibrator Table Vibrator Platform vibrator Surface vibrator .

Hand Compaction Hand compaction is used for ordinary and unimportant structures. Workability should be decided in such a way that the chances of honeycombing should be minimum. The various methods of hand compaction are as given below: Rodding It is a method of poking with 2m long, 16 mm dia. rod at sharp corners and edges. The thickness of layers for rodding should be 15 to 20 cm.

Ramming • It is generally used for compaction on ground in plain concrete. It is not used either in RCC or on upper floors. Tamping • It is a method in which the top surface is beaten by wooden cross beam of cross section 10 cm x 10 cm. both compaction and leveling are achieved simultaneously. It is mainly used for roof slabs and road pavements.

Compaction by Vibration • Vibration is imparted to the concrete by mechanical means. It causes temporary liquefaction so that air bubbles come on to the top and expelled ultimately. Mechanical vibration can be of various types as given under. Internal Vibration It is most commonly used technique of concrete vibration. Vibration is achieved due to eccentric weights attached to the shaft. The needle diameter varies from 20 mm to 75 mm and its length varies from 25 cm to 90 cm. the frequency range adopted is normally 3500 to 5000 rpm. The correct and incorrect methods of vibration using internal vibration needles are shown below.

External Vibration • This is adopted where internal vibration can't be used due to either thin sections or heavy reinforcement. External vibration is less effective and it consumes more power as compared to the internal vibration. The formwork also has to be made extra strong when external vibration is used

Table Vibration • It is mainly used for laboratories where concrete is put on the table

Platform Vibration • t is similar to table vibrators but these are generally used on a very large scale

Surface Vibration • These are also called screed board vibrators. The action is similar to that of tamping. The vibrator is placed on screed board and vibration is given on the surface. It is mainly used for roof slabs, road pavements etc., but it is not effective beyond 15 cm depth.

6. **Curing Methods - Methods of Curing of Concrete**
   Durability of Concrete

Curing can be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining a satisfactory moisture content and a favorable temperature in concrete during the period

immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.

If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a new born baby.
Methods of Curing Concrete

METHODS FOR CURING OF CONCRETE

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

Curing of Concrete

1. Shading concrete work
2. Covering concrete surfaces with hessian or gunny bags
3. Sprinkling of water
4. Ponding method
5. Membrane curing
6. Steam curing

1. Shading Of Concrete Work

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

2. Covering Concrete Surfaces With Hessian or Gunny Bags

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

3. Sprinkling of Water

Sprinkling of water continuously on the concrete surface provides an efficient curing. It is mostly used for curing floor slabs. The concrete should be allowed to set sufficiently before sprinkling is started. The spray can be obtained from a perforated plastic box. On small jobs sprinkling of

water may be done by hand. Vertical and sloping surfaces can be kept continuously wet by sprinkling water on top surfaces and allowing it to run down between the forms and the concrete. For this method of curing the water requirement is higher.

4. Ponding Method

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

5. Membrane Curing

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

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

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

6. Steam Curing

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

These methods can best be used in pre cast concrete work. In steam curing the temperature of steam should be restricted to a maximum of 750C as in the absence of proper humidity (about 90%) the concrete may dry too soon. In case of hot water curing, temperature may be raised to any limit, ay 1000C.

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

Tests on Concrete

SAMPLING The first step is to take a test sample from the large batch of concrete. This should be done as soon as discharge of the concrete commences. The sample should be representative of

the concrete supplied. The sample is taken in one of two ways:

For purposes of accepting or rejecting the load: Sampling after 0.2 m^3 of the load has been poured.For routine quality checks: Sampling from three places in the load.

a) Concrete Slump Test

This test is performed to check the consistency of freshly made concrete. The slump test is done to make sure a concrete mix is workable. The measured slump must be within a set range, or tolerance, from the target slump.

Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It can also be defined as the relative plasticity of freshly mixed concrete as indicative of its workability.

Tools and apparatus used for slump test (equipment):

1. Standard slump cone (100 mm top diameter x 200 mm bottom diameter x 300 mm high)
2. **Small scoop**
    1. Bullet-nosed rod (600 mm long x 16 mm diameter)
3. **Rule**
    1. Slump plate (500 mm x 500 mm)

Procedure of slump test for concrete:

1. Clean the cone. Dampen with water and place on the slump plate. The slump plate should be clean, firm, level and non-absorbent. Collect a sample of concrete to perform the slum test.

2. Stand firmly on the footpieces and fill 1/3 the volume of the cone with the sample. Compact the concrete by 'rodding' 25 times. Rodding means to push a steel rod in and out of the concrete to compact it into the cylinder, or slump cone. Always rod in a definite pattern, working from outside into the middle.

3. Now fill to 2/3 and again rod 25 times, just into the top of the first layer.

4. Fill to overflowing, rodding again this time just into the top of the second layer. Top up the cone till it overflows.

5. Level off the surface with the steel rod using a rolling action. Clean any concrete from around the base and top of the cone, push down on the handles and step off the footpieces.

6. Carefully lift the cone straight up making sure not to move the sample.

7. Turn the cone upside down and place the rod across the up-turned cone.

8. Take several measurements and report the average distance to the top of the sample.If the sample fails by being outside the tolerance (ie the slump is too high or too low), another must be taken. If this also fails the remainder of the batch should be rejected.

b) The Compression Test

The compression test shows the compressive strength of hardened concrete. The compression test shows the best possible strength concrete can reach in perfect conditions. The compression test measures concrete strength in the hardened state. Testing should always be done carefully. Wrong test results can be costly.

The testing is done in a laboratory off-site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in Megapascals (MPa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete‘s ability to resist loads which tend to crush it.

Apparatus for compression test

Cylinders (100 mm diameter x 200 mm high or 150 mm diameter x 300 mm high) (The small cylinders are normally used for most testing due to their lighter weight)

1. Small scoop
2. Bullet-nosed rod (600 mm x 16 mm)
3. Steel float
4. Steel plate

How to do a compression test?

Procedure for compression test of concrete

1. Clean the cylinder mould and coat the inside lightly with form oil, then place on a clean, level and firm surface, ie the steel plate. Collect a sample.
2. Fill 1/2 the volume of the mould with concrete then compact by rodding 25 times. Cylinders may also be compacted by vibrating using a vibrating table.
3. Fill the cone to overflowing and rod 25 times into the top of the first layer, then top up the mould till overflowing.
4. Level off the top with the steel float and clean any concrete from around the mould.
5. Cap, clearly tag the cylinder and put it in a cool dry place to set for at least 24 hours.

After the mould is removed the cylinder is sent to the laboratory where it is cured and crushed to test compressive strength

Flow table test

Equipment; flow table, Abrams cone, waterbucket and broom.

The cone filled with concrete, prior to lifting.

The diameter of the resulting flow is measured.

The **flow table test** or **flow test** is a method to determine the consistence of fresh concrete. There is also another **flow table test** used to determine the Transportable Moisture Limit of solid bulk cargoes which are considered to be potentially liquefiable.[1]

Application When fresh concrete is delivered to a site by a truck mixer it is sometimes necessary to check its consistence before pouring it into formwork.

If the consistence is not correct, the concrete will not have the desired qualities once it has set, particularly the desired strength. If the concrete is too pasty, it may result in cavities within the concrete which leads to corrosion of the rebar, eventually leading to the formation of cracks (as the rebar expands as it corrodes) which will accelerate the whole process, rather like insufficient concrete cover. Cavities will also lower the stress the concrete is able to support.

Equipment

- Flow table with a grip and a hinge, 70 centimetres (28 in) square.
- Abrams cone, open at the top and at the bottom - 30 centimetres (12 in) high, 17 centimetres (6.7 in) top diameter, 25 centimetres (9.8 in) base diameter.
- Water bucket and broom for wetting the flow table.
- Tamping rod, 60 centimetres (24 in) long

Conducting the test

- The flow table is wetted.
- The cone is placed in the center of the flow table and filled with fresh concrete in two equal layers. Each layer is tamped 10 times with a tamping rod.

Wait 30 seconds before lifting the cone

- The cone is lifted, allowing the concrete to flow.
- The flow table is then lifted up 40mm and then dropped 15 times, causing the concrete to flow
- After this the diameter of the concrete is measured
- Home
- Products
- Concrete
- Kelly ball

Kelly ball

This method is used to determine the penetration of a hemispherical metal weight into freshly mixed concrete, which is related to the workability of the concrete.
The apparatus consists of a cylinder with one end having a hemispherical shape and the other end fit with a graduated handle. The weight assembly is lowered through a frame into the concrete and the penetration measured.

- Weight approx.: 15 kg

WORKABILITY TEST OF CONCRETE BY VEE-BEE CONSISTOMETER METHOD (IS- 1199-1956)

Objective

To determine the workability of freshly mixed concrete by using of Vee – Bee consistometer apparatus.

Scope and Significance

The workability of fresh concrete is a composite property, which includes the diverse requirements of stability, mobility, compactability, placeability and finishability. There are different methods for measuring the workability. Each of them measures only a particular aspect of it and there is really no unique test, which measures workability of concrete in its totality. This test gives an indication of the mobility and to some extent of the compactibility of freshly mixed concrete. The test measures the relative effort required to change a mass of concrete from one definite shape to another (i.e., from conical to cylindrical) by means of vibration. The amount of

effort (called remoulding effort) is taken as the time in seconds, required to complete the change. The results of this test are of value when studying the mobility of the masses of concrete made with varying amounts of water, cement and with various types of grading of aggregate. The time required for complete remoulding in seconds is considered as a measure of workability and is

expressed as the number of Vee-Bee seconds. The method is suitable for dry concrete. For concrete of slump in excess of 50mm, the remoulding is so quick that the time cannot measured.

Vee-Bee Consistometer

Apparatus

- Cylindrical container,
- Vee-Bee apparatus (consisting of vibrating table, slump cone)
- Standard tamping rod,
- Stop watch and
- Trowels.

Procedure

(1) Place the slump cone in the cylindrical container of the consistometer. Fill the cone in four layers, each approximately one quarter of the height of the cone. Tamp each layer with twenty-five strokes of the rounded end of the tamping rod. The strokes are distributed in a uniform manner over the cross-section of the cone and for the second and subsequent layers the tamping bar should penetrate into the underlying layer. After the top layer has been tamped, struck off level the concrete with a trowel making the cone exactly filled.

(2) Move the glass disc attached to the swivel arm and place it just on the top of the slump cone in the cylindrical container. Adjust the glass disc so as to touch the top of the concrete cone, and note the initial reading on the graduated rod.

(3) Remove the cone from the concrete immediately by raising it slowly and carefully in the vertical direction. Lower the transparent disc on the top of concrete. Note down the reading on the graduated rod.

(4) Determine the slump by taking the difference between the readings on the graduated rod recorded in the steps (2) and (3) above.

(5) Switch on the electrical vibrations and start the stopwatch. Allow the concrete to remould by spreading out in the cylindrical container. The vibrations are continued until the concrete is completely remoulded, i.e, the surfaces becomes horizontal and the whole concrete surface adheres uniformly to the transparent disc.

(6) Record the time required for complete remoulding seconds which measures the workability expressed as number of Vee-Bee seconds.

Observations and Calculation

Initial reading on the graduated rod, **a**

Final reading on the graduated rod, **b**

Slump = **(b) – (a),** in cm

Time for complete remoulding, seconds

Results

The consistency of the concrete is reported in seconds.

Standard Values

Workability Description	Vee-Bee Time (in Second)
Extremely Dry	32-18
Very Stiff	18-10
Stiff	10-5
Stiff Plastic	5-3

Plastic	3-0
Flowing	—

Popular NDT Tests for Concrete Used in field are:

1. Rebound Hammer Test- RH Test
2. Ultrasonic Pulse Velocity- UPV Test
3. Combined Method UPV & RH Test
4. Core Extraction for Compressive Strength Test
5. Ingredient Analysis of Concrete Core
6. Concrete Cover Measurement by Laser Based Instt.

This paper, describes in detail only Rebound Hammer (RH) test, Ultrasonic Pulse Velocity (UPV) test & Core Test which are widely used & accepted by engineers at site and also referred in IS: 456-2000, under Inspection & Testing of Structures. These are followed by a description of the combined methods approach in which more than one nondestructive method is used to estimate strength of concrete. The Ingredient Analysis, Cover Measurement, Permeability, and Density methods are of limited application and are briefly described the concluding part of the paper.

1. Rebound Hammer–RH (Schmidt) Test

In 1948, a Swiss Engineer, Ernst Schmidt from Zurich developed a test hammer for measuring the hardness of concrete by the rebound principle. Since then the Rebound Hammer (RH) test has gained recognition at construction site & precast Industry.

Principle

The Schmidt Rebound Hammer is principally a surface hardness tester with little apparent theoretical relationship between the strength of concrete and the Rebound number of the hammer. However, within limits, empirical correlations have been established between strength properties & rebound number. This correlation between the concrete strength and rebound number is required to be established at site/field laboratories before it is used for strength estimation of concrete. Sometimes it is referred as fieldcalibration of rebound hammer. Lab calibration are based on Brinell Hardness & Rebound Nos. are checked on std. calibrated Anvil for the purpose. Proper site calibrations eliminate the lab calibration, which is for the checking of hammer performance.

Rebound Number and Compressive Strength

There is a general correlation between compressive strength of concrete and the hammer rebound number. Coefficients of variation for compressive strength for a wide variety of specimens averaged 25%. The large deviations in strength can be narrowed down considerably by proper calibration of the hammer, which allows for various variables discussed earlier. By consensus, the accuracy of estimation of compressive strength of test specimens cast, cured, and tested under laboratory conditions by a properly calibrated hammer lies between ±15 and ±20%. However, the probable accuracy of prediction of concrete strength in a structure is ±25%.

Limitations and Usefulness

The limitations of the Schmidt hammer are many; these should be recognized and allowances be made when using the hammer. It cannot be overstressed that this instrument must not be regarded as a substitute for standard compression tests but as a method for determining the uniformity of concrete in the structures and comparing one concrete by the Schmidt hammer within an accuracy of ±15 to ±20% may be possible only for specimens cast, cured, and tested under identical conditions as those from which the calibration curves are established. The prediction of strength of structural concrete by using calibration charts based on the laboratory test is not recommended.

2. Ultrasonic Pulse Velocity-UPV Test

The test instrument consists of a means of producing and introducing a wave pulse into the concrete and a means of sensing the arrival of the pulse and accurately measuring the time taken by the pulse to travel through the concrete.

Portable ultrasonic testing equipment are available. The equipment is portable, simple to operate, and includes rechargeable battery and charging unit. Typically, pulse times of up to 6500 os can be measured with 0.1-os resolution. The measured travel time is prominently displayed. The instrument comes with a set of two transducers, one each for transmitting and receiving the ultrasonic pulse. Transducers with frequencies of 25 to 100 KHz are usually used for testing concrete. These transducers primarily generate compressional waves at predominantly one frequency, with most of the wave energy directed along the axis normal to the transducer face.

Factors Affecting UPV Test

Although it is relatively easy to conduct a pulse velocity test, it is important that the test be conducted such that the pulse velocity readings are reproducible and that they are affected only by the properties of the concrete under test rather than by other factors. The factors affecting the pulse velocity can be divided into two categories: (1) factors resulting directly from concrete properties; and (2) other factors. These influencing factors are discussed below:

Effects of Concrete Properties

1. Aggregate Size, Grading, Type, and Content
2. Cement Type
3. Water-Cement Ratio
4. Admixtures
5. Age of Concrete

Other Effects

1. Transducer Contact
2. Temperature of Concrete

3. Moisture and Curing Condition of Concrete
4. Path Length
5. Size and Shape of a Specimen

6. Level of Stress
7. Presence of Reinforcing Steel

Applications of UPV Tests

UPV Test being perform on Deck Slab of Flyover on NH-2 at Firozabad (U.P.), India

The pulse velocity method has been applied successfully in the laboratory as well as in the field. It can be used for quality control, as well as for the analysis of deterioration. The applications of the pulse velocity method on a concrete structure are:

1. Estimation of Strength of Concrete
2. Establishing Homogeneity of Concrete
3. Studies on the Hydration of Cement
4. Studies on Durability of Concrete
5. Measurement of Surface Crack Depth
6. Determination of Dynamic Modulus of Elasticity

Combined Method–UPV & RH Test

UPV Test being perform on Minor Bridge Pier on NH-11 at Dausa (Raj.), India

Hardness scales are arbitrarily defined measures of the resistance of a material to indentation under static or dynamic load or resistance to scratch, abrasion, wear, cutting or drilling. Concrete test hammers

evaluate surface hardness as a function of resiliency, i.e the ability of hammer to rebound or spring back.

The interpretation of the pulse velocity measurements in concrete is complicated by the heterogeneous nature of this material. The wave velocity is not determined directly, but is calculated from the time taken by a pulse to travel a measured distance. A piezoelectric transducer emitting vibration at its fundamental frequency is placed in contact with the concrete surface so that the vibrations travel through the concrete and are received by another transducer, which is in contact with the opposite face of the test object.

Conclusion

Portable Concrete Coring Machine (BOSCH) in Horizontal Operation on RCC Column

Combined nondestructive methods refer to techniques in which one test is used to improve the reliability of the in site concrete strength estimated by means of another test alone.

The validity of a combined technique can be evaluated from the degree of improvement this additional test provides to the accuracy and reproducibility of predictions, vs. the additional cost and complexity of the combined method and the extent to which it is practicable to perform the additional test in site.

Of the various combinations proposed by different researchers and from the reported data it seems that only the combined techniques based on the Ultrasonic Pulse Velocity and surface hardness measurement have been adopted for practical evaluation of the in site compressive strength of concrete.

Concrete Core from RCC Column being Extracted after

Diamond Bit Core Drilling

The limitations of a combined method are usually those pertinent to the limitations of each component test, except when a variation in the properties of concrete affects the component test, except when a variation in the properties of concrete affects the component test results in opposite directions. In this case, the errors can be self-correcting. Development of a prior correlation relationship is essential if the estimated from the combined test are to be meanigful. The more information that can be obtained about the concrete ingredients, proportions, age, curing conditions, etc. the more reliable the estimate is likely to be.

When testing suspect quality concrete of unknown composition, it is highly desirable to develop a prior correlation relationship in which factor such as aggregate type and approximate age of concrete are introduced as constants. For most in site concrete an approximate age and petrological type of aggregate can be determined, thus reducing the number of uncontrollable variables.

Core Drilling in Progress on the Inside Wall (After Epoxy Grouting) of Box Culvert on NH-26 at Sagar, (M.P.)

The most important influences on the accuracy and reliability of strength estimates seem to be the coarse aggregate type in the concrete.

When a reliable prior correlation relationship exists for a particular concrete type, the use of combined nondestructive techniques provides a realistic alternative to destructive testing. It often possible to perform a large and thus a representative number of tests at a reduced cost compared with coring, and without an adverse effects on the integrity of structural element.

Core Extraction for Compressive Strength Test

Test Specimens

Core Dressing-Cutting in Lab using Diamond Wheel Cutter in the Lab before Capping and Curing for Compressive Strength Test on CTM

Core Specimens- A core specimen for the determination of compressive strength shall have a diameter at least three times the maximum nominal size of the coarse aggregate used in the concrete, and in no case shall the diameter of the specimen be less than twice the maximum nominal size of the coarse aggregate. The length of the specimen, when capped, shall be as nearly as practicable twice its diameter.

Procedure

Core Drilling- A core specimen taken perpendicular to a horizontal surface shall be located, when possible, with its axis perpendicular to the bed of the concrete as originally placed.

Measurement of Drilled Core Specimens

Mean Diameter- The mean diameter shall be determined to the nearest millimeter from three pairs of measurements. The two measurements in each pair shall be taken at right angles to each other, one pair being taken at the middle of the core and the other pairs at the quarter points of the depth. The mean of the six readings shall be taken as the diameter.

Position of Reinforcement- The positions of any reinforcement shall be determined by measuring to the nearest millimetre from the centre of the exposed bars to the top of the core. The diameter and, if possible, the spacing of the bars shall be recorded, and also the minimum top and bottom cover.

Extracted Three Numbers of Cores (Making One Sample) from RCC Structure-Box Culvert on NH-26 at Sagar (M.P.)

Capping- The ends of the specimen shall be capped before testing. The material used for the capping shall be such that its compressive strength is greater than that of the concrete in the core. Caps shall be made as thin as practicable and shall not flow or fracture before the concrete fails when the specimen is tested. The capped surfaces shall be at right angles to the axis of the specimen and shall not depart from a plane by more than 0.05 mm.

Apparatus

Number of Specimens- At least three specimens, preferably from different batches, shall be made for testing at each selected age.

Procedure- Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2 mm and their weight shall be noted before testing.

Capped and Cured Concrete Core Specimen under Compressive Strength Test in CTM

Calculation- The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than ± 15% of the average. Otherwise repeat tests shall be made.

A correction factor according to the height/diameter ration of specimen after capping shall be obtained from the hardened curve. The product of this correction factor and the measured compressive strength shall be known as the corrected compressive strength, this being the equivalent strength of a cylinder having a height/diameter ratio of two. The equivalent cube strength of the concrete shall be determined by multiplying the corrected cylinder strength by 5/4..

EXTREME WEATHER CONCRETING

In countries which experience extreme weather conditions special problems are encountered in preparation, placement and curing of concrete. India has regions of extreme hot weather (hot-humid and hot-arid) as well as cold weather. The Indian Standards dealing with extreme weather concreting are: IS: 7861 (Part 1-1975 Reaff. 2007)-Hot weather concreting and IS: 7861 (Part 2-1981 Reaff. 2007) -Cold weather concreting.

HOT WEATHER CONCRETING:

Special problems are encountered in the preparation, placement and curing of concrete in hot weather. High temperature result in :

- Rapid hydration of cement
- Increased evaporation of mixing water
- Greater mixing water demand
- Large volume changes in concrete resulting in cracks.
- Reduction in strength.
- The climatic factors affecting concrete in hot weather are:
- High ambient temperature
- Reduced relative humidity
- Increased wind velocity

Problems associated with hot weather concreting shall be addressed as follows:

- Controlling the temperature of concrete ingredients
- Suitable proportioning of concrete mixes.
- Controlling the temperature of concrete as placed.
- Controlling the processes such as concrete production and delivery
- Carrying out effective protection and curing of placed concrete.

Controlling the temperature of concrete ingredients:

The most direct approach to keep concrete temperature down is by controlling the temperature of its ingredients. The contribution of each ingredient to the temperature of concrete is a function of the temperature, specific heat and quantity used of that ingredient. The aggregates and mixing water exert the most pronounced effect on temperature of concrete. Thus, in hot weather all available means shall be used for maintaining these materials at as low temperatures as practicable.

Aggregates

Any one of the procedures or a combination of the procedures given below may be used for lowering the temperature or at least for preventing excessive heating of aggregates.

Shading stockpiles from direct rays of the sun.

Sprinkling the stockpiles of coarse aggregate with water and keeping them moist.

This results in cooling by evaporation, and this procedure is specially effective when relative humidity is low. Such sprinkling should not be done haphazardly because it leads to excessive variation in surface moisture and thereby impairs uniformity of workability. When coarse aggregates are stockpiled during hot weather, successive layers should be sprinkled as the stockpile is-built up. If cold water is available, heavy spraying of coarse aggregate immediately before use may also be done to have a direct cooling action. Coarse aggregates may also be cooled by methods, such as inundating them in cold water or by circulating refrigerated air through pipes or by other suitable methods.

Water

The mixing water has the greatest effect on temperature of concrete, since it has a specific heat of about 4.5 to 5 times that of cement or aggregate. The temperature of water is easier to control than that of other ingredients and, even though water is used in smaller quantities than the other ingredients, the use of cold mixing water will effect a moderate reduction in concrete placing temperatures. For a nominal concrete mixture containing 336 kg of cement, 170 kg water, 1850 kg of aggregate per ma, a change in 2°C water temperature will effect a 0.5 º C change in the concrete temperature.

Efforts shall be made to obtain cold water, and to keep it cold by protecting pipes, water storage tanks, etc. Tanks or trucks used for transporting water shall be insulated and/or coloured and maintained white or yellow. Under certain circumstances, reduction in water temperature may be most economically accomplished by mechanical‘ refrigerator or mixing with crushed ice. Use of ice as a part of the mixing water is highly effective in reducing concrete temperature since, on melting alone, it takes up heat at the rate of 80 kcal/kg. To take advantage of heat of fusion, the ice shall be incorporated directly into the

concrete as part of the mixing water. Conditions shall be such that the ice is completely melted by the time mixing is completed.

NOTE :- If the ice is not melted completely by the time mixing is completed, there can be a possibility of Ice melting after consolidation of concrete and thus leaving hollow pockets in concrete, with detrimental effects.

Recommended procedure for concreting during hot weather conditions is given below:

Ambient temperature shall be below 40□ C at the time of placement of concrete. Concreting may be planned during morning and evening hours.

The period between mixing and delivery (placing) shall be kept an absolute minimum.

Keep aggregates under shade and cool aggregates by sprinkling water.

Formwork, reinforcement shall be sprinkled with cool water just prior to placement of concrete.

Case study of Extreme weather concreting

COLD WEATHER CONCRETING:

The production of concrete in cold weather introduces special and peculiar problems which do not arise while concreting at normal temperatures. Quite apart from the problems associated with setting and hardening of cement concrete, severe damage may occur if concrete which is still in the plastic state is exposed to low temperature, thus causing ice lenses to form and expansion to occur within the pore structure. Hence it is essential to keep the temperature of the concrete above a minimum value before it is placed in the formwork. After placing, concrete may be kept above a certain temperature with the help of proper insulating methods before the protection is removed. During periods of low ambient temperature, special techniques are to be adopted to cure the concrete while it is in the formwork or after its removal.

The Precautions to be taken and methods adopted for concreting in sub-zero temperature is listed below.

a. Utilization of the heat developed by the hydration of cement and practical methods of insulation.

b. Selection of suitable type of cement

c. Economical heating of materials of concrete

(Heating of water is the easiest to be adopted)

d. Admixtures of anti-freezing materials

e. Electrical heating of concrete mass

f. Use of air-entraining agents

READY MIX CONCRETE:

Concrete is basically a mixture of Portland Cement, water and aggregates comprising sand and gravel or crushed stone. In traditional construction sites, each of these materials is procured separately and mixed in specified proportions at site to make concrete. Ready Mix

Concrete, or RMX as it is popularly called, refers to concrete that is specifically manufactured elsewhere and transported in a Transit Mixer for delivery to the customer's construction site in a ready-to-use freshly mixed state. RMX can be custom-made to suit different applications. Ready Mix Concrete is bought and sold by volume - usually expressed in cubic meters.

UNIT –II

CONSTRUCTION PRACTICES

Specification for construction

Specifications describe the materials and workmanship required for a development. They do not include cost, quantity or drawn information, and so need to be read alongside other information such as quantities, schedules and drawings.Specifications vary considerably depending on the stage to which the design has been developed, ranging from performance specifications (open specifications) that require further design work to be carried out, to prescriptive specifications (closed specifications) where the design is already complete.

Having a prescriptive specification when a contract is tendered gives the client more certainty about the end product, whereas a performance specification gives suppliers more scope to innovate, and adopt cost effective methods of work, potentially offering better value for money.Typically, performance specifications are written on projects that are straight-forward and are well-known building types, whereas prescriptive specifications are written for more complex buildings, or buildings where the client has requirements that might not be familiar to suppliers and where certainty regarding the exact nature of the completed development is more important to the client. An exception to this might be a repeat client such as a large retailer, where a specific, branded end result is required and so whilst the building type is well known, the specification is likely to be prescriptive.

Most projects will involve a combination of performance and prescriptive specifications. Items crucial to the design will be specified prescriptively (such as external cladding) whilst less critical items are specified only by performance (such as service lifts).

Key to deciding whether to specify a building component prescriptively or not, is considering who is most likely to achieve best value, the client, the designers or the contractor:

- Large clients may be able to procure certain products at competitive rates themselves (for example the government).
- Some designers may have particular experience of using a specific product (although some clients may not allow designers to specify particular products as they believe it restricts competition and innovation and may relieve the contractor of their liability for 'fitness for purpose').

The contractor may be best placed to specify products that affect buildability.

Specifications should be developed alongside the design, increasing in level of detail as the design progresses.They should not be left until the preparation of production information. By tender they should describe every aspect of the building in such a way that there is no uncertainty about what the contractor is pricing.

Aspects of the works are generally specified by:

- Products (by standard, a description of attributes, naming (perhaps allowing equivalent alternatives) or by nominating suppliers).

- Workmanship (by compliance with manufacturers requirements, reference to a code of practice or standards, or by approval of samples or by testing).
- It should be possible to verify standards of products and workmanship by testing, inspection, mock-ups and samples, and documentation such as manufacturers certificates.
- Specifications should be structured according to work packages mirroring the separation of the works into sub-contracts. This makes it easier for the contractor to price and so may result in a more accurate tender. A standard classification system should be followed such as Uniclass.

The Building Sequence

It's fairly self-evident that to successfully build a home, you need to know not only the parts involved, but just as important, how they all go together . . . and in what order!

Here then is a description, in broad terms, of the actual construction sequence for a typical home.

An important disclaimer is in order here.

Many things including, among others, the area of the country where it is being built, the design of the home, the availability of subs and materials, and the preference of the contractor, i.e. you, determine the actual sequence of construction. Here's an example:

Many builders prefer to delay pouring the driveway until the end of the project

This is to prevent damage by heavy equipment like the drywall delivery truck,

interest, expensive. since concreteisfairly

There is a builder in Atlanta who likes to pour his driveway as soon as the foundation is in. When you

In addition, as you will discover in the pages on planning your construction schedule, frequently more than one construction activity can be going on at the same time!

With all that in mind, here is a general construction sequence with a brief explanation where terms may be unfamiliar. You will get greater detail on all of these as you link to their own page.

1. STAKE LOT

This will usually involve a surveyor who will come out and accurately drive stakes to locate your home on the lot. They will be used by the excavators and foundation subcontractors to guide their work.

2. TEMPORARY UTILITIES

You will need to have water, electric power, and toilet facilities available during the construction process.

Temporary Electric "Saw Service"

3. CLEAR AND ROUGH GRADE

Clearing is the removal of trees and undergrowth from the actual construction site and yard areas.

Rough grading is moving the dirt around to establish the approximate drainage patterns, yard areas, drive and walk levels,

etc. that you hope to achieve.

Clearing the Lot

Excavation for a basement home. Notice the temporary ramp that has been constructed so that the dozer can get down in the hole.

4. WELL

If you are going to have a well, you might as well dig it up front so that you will have the water available for construction.

5. EXCAVATE

This is where a piece of earth-moving equipment digs the hole for your foundation, and, if you will have one, your basement.

6. FOOTINGS

This is the structure where the house interfaces with the earth that supports it. All of the weight of the home rests on the footings.

This sub is drilling a hole to pour a "caisson" - a special type of footing used in areas with highly active soils.

7. FOUNDATION

The foundation is the wall on which the first floor rests. It may be short - if you will have a crawl space, or tall - if you will have a basement.

8. WATERPROOFING AND FOUNDATION DRAIN

A waterproofing material or membrane (or both) is applied to the foundation walls which will be below grade to minimize water accumulating in the basement or in the crawl space. Foundation drains run along the footings and remove water accumulating in that area.

This is a water meter pit. One copper pipe is coming from the city supply line in the street. The other pipe will supply the new home with water. A meter to supply billing information to the city will connect the two.

9. SEWER AND WATER TAPS

If you are connecting to municipal water and sewer, this is where the pipes are laid to the house and actually connected (tapped into) the water and sewer mains.

10. BACKFILL

Pushing the excavated dirt into the hole next to the foundation wall around the house (inside and out). This is a good time to establish the necessary drainage away from the house at the foundation wall.

This plumbing will be beneath and poking through a floor slab.

11. SLAB PLUMBING

Any plumbing that needs to go into the basement floor is installed here.

12. SLAB OR BASEMENT FLOOR

The “slab” is the concrete basement floor. It is poured at this point. In some parts of the country, plans may call for a “structural wood floor” (more on this later). Now is when it would be installed.

13. FRAMING, WINDOWS, AND EXTERIOR DOORS

This is where it starts to look like a house! The floors, walls, ceiling, and roof are the focus of this construction activity. The framer usually installs the windows and exterior doors.

Applying a brick veneer to wood frame construction.

14. EXTERIOR SIDING AND TRIM

Whatever you‟re using - brick veneer, siding, stucco, etc.- here is where it gets done.

15. GARAGE DOOR AND EXTERIOR LOCKS

Some people wait until the end to get the garage door in. But we think having it in place creates a good place to store materials and equipment during construction. Installing the exterior locks means that the wholehouse is secure.

16. BACK-OUT FRAMING

This is a general category that includes partition walls that have not been installed, pillars, soffits for wall cabinets, and drywall nailers.

17. FIREPLACE AND CHIMNEY

A prefabricated fireplace should be installed before the roughs (below). A prefab will have a framed chimney. A masonry fireplace and chimney can be installed before the brick veneer (see “Exterior Siding and Trim” above).

This is an insulated duct board that can be cut with a knife, which makes installation easier.

18. STAIRS

Get these in now so that the subs working inside can get from one floor to the other without depending on ladders.

19. ROUGH HVAC

The HVAC (heating, ventilation, air conditioning) sub is the first of the three “mechanical” subs (plumbing, electrical, HVAC) to come to the job. He will install the duct work for your HVAC system and possibly the furnace. He comes first because the stuff he puts into the walls is the biggest and most inflexible.

20. ROUGH PLUMBING

Next comes the plumber to install his pipes.

21. ROOFING

With plumbing and HVAC vent pipes through the roof, the roofer can install the roofing.


The Electrician.

22. ROUGH ELECTRICAL

Codes call for the house to be “dried in” before the wiring is installed. With the exterior windows and doors in place and the roof on, it‟s time. For roughs, the electrician will put in the boxes (switch, outlet, and lighting) and will pull the wires into them. Cable, telephone, speakerwires, etc. are also installed at this point.

23. ELECTRIC & GAS METER SET
You‟ll need these in place to get some heat in the house for the drywall installation.

24. GUTTERS AND DOWNSPOUTS
It‟s good to get the water away from the house as soon as possible.

25. EXTERIOR PAINT

Many surfaces on the outside need to be protected from the elements. So you‟ll want to paint as soon as is practical.

Insulated Basement.

26. INSULATION

Once everything else is in the walls and rough inspections are completed, it‟s time to insulated your home.

27. TEMPORARY HEAT

With the meters set (above), the HVAC sub can get some temporary heat in the house. This will be critical for getting the drywall joint compound (mud) to dry in a timely fashion. The carpet sub also needs a warm home so that the carpet is installed at a temperature comparable to normal living conditions.

28. DRYWALL

Sometimes called “Sheetrock®.” This will be “hung” (nailed or screwed to the wall studs and ceiling joists), taped (at the joints), and “mudded” (joint compound applied) . . . after the in-wall plumbing, HVAC, electricals, and insulation have been inspected!

29. CABINETS

Base and wall.

30. INTERIOR DOORS AND TRIM

The trim materials installed here may include the door casing, base mould, window stool and apron, window casing, chair rail, crown mould, built-in cabinets, stair railing parts, and others.

31. PAINT AND WALLPAPER

The first coat of paint is usually sprayed. Get it in before the hard wood floors are installed.

32. HARDWOOD FLOORS
Now it‟s time to install your hardwood floors.

33. COUNTER TOPS
Counter tops are next. this may involve a different sub than the one who installed the cabinets.

34. VINYL AND CERAMIC TILE
Vinyl floor coverings and ceramic tile are installed. Two different subs. Probably should have made these two different steps, but I was trying to make it come out to an even 50!

35. SAND AND FINISH WOOD FLOORS
This is the first of two finishes. The last is done just before you move in.

36. APPLIANCES AND SPECIAL EQUIPMENT
This would include all of your major appliances - washer, dryer, range, oven, refrigerator, as well as any other special equipment you have specified.

37. FINISH ELECTRICAL
Here is where the electrician comes back to install the switches, outlets, light fixtures, ceiling fans, door bells, etc. He will also hook up the appliances, furnace, air conditioner, doorbell, and so forth.

38. FINISH PLUMBING
The plumber will install the sinks, lavatories, toilets, and all the faucets.

39. FINISH HVAC & FINAL HEAT
Your heating sub will install the registers and get the furnace and air conditioning running properly.

40. SHOWER DOORS AND MIRRORS
Install shower doors. Hang mirrors.

41. CARPET
Now it‟s starting to feel like home!

42. HARDWARE AND SCREENS
Typically, this is door, window, and closet hardware. Window screens.

43. DRYWALL REPAIRS
You may need to get the drywall subcontractor back out to patch some dings caused by the other subs‟ work. This is normal.

44. CLEAN UP
This is the final interior clean up.

45. FINAL PAINT
Touching up drywall repairs and so forth.

46. FINAL WOOD FLOOR FINISH
This should be your last inside job before moving in.

47. RETAINING WALLS
These outside jobs can be going on while the work proceeds inside. You should not have these going on while the outside is being painted.


Retaining wall, steps, and walk.

48. WALKS, DRIVES, AND PATIOS You should wait until the drywall has been delivered to the home, because the drywall truck is VERY heavy, and could damage your flat work

49. SEPTIC TANK AND DRAIN FIELD
Same as above on the timing with regard to the drywall delivery. The tank holds the waste and allows microbic action on the solids. The drain field is where the effluent leaches into the soil.

50. FINISH GRADING AND LANDSCAPING
The final finished grades are established to ensure proper drainage away from the home, and to prepare the yard for landscaping. Trees, shrubs, grass, etc. are installed.

CONSTRUCTION CO ORDINATION:

Coordination can be seen as a process of managing resources in an organized manner so that a higher degree of operational efficiency can be achieved for a given project.

Two coordination methods have been identified as appropriate to be used in the design process, namely, direct contact and meetings.

Direct contact

Direct contact has been identified as the simplest form, and one that involves minimal cost among the methods of coordination .Two types of direct contacts are used in projects: direct

formal contact and direct informal contact. Each method encompasses different approaches in gathering useful information. A combination of these methods could send reasonably accurate messages quickly in all directions, and could be able to deal with all the major uncertainties that arise within the project organisation. Because of the iterative nature of the design process, the number of participants and the fragmentation of building systems, the increased use of direct contact is critically required.

Direct formal contact

Direct formal contact refers to the documented information that could be obtained by letters, memos and reports. This approach is more formal, and is widely used as a means of communication among the different organisations that are involved in a project. Direct formal contact has been identified as one of the means used by designers for obtaining design information.

In managing a risky project, proper documents are always needed to protect the participants involved. Formal documents could be used for litigation or as evidence in any contract dispute, such as variation claims in projects. Therefore, it is important to use direct formal contact in handling uncertainty in the refurbishment design, such as in design changes.

Direct informal contact

Any information obtained using informal conversations such as telephone calls or discussions is categorised under direct informal contact (Bennett, 1991). As the design process has a large number of participants and a high degree of interdependence of building design, the demand for informal contact is increased (Pietroforte, 1997). The uncertain nature of refurbishment projects requires an approach that is more flexible.

One of the advantages of using direct informal contact is that information can be gathered quickly without the need for any formal procedure. Informal contact provides clearer information in a short time, and hence is useful in confirming certain issues pertaining to the design process. The refurbishment design process involves a large amount of information flow. Therefore, direct informal contact could resolve the problem of inefficiency in flow of design information, especially when design changes occur during the construction stage.

Meeting

The purpose of meetings is to keep key participants informed, and to handle shared problems arising in the projects (Laufer *et al*, 1992). Meetings are one way to increase the amount of information in construction projects, as a meeting mostly covers the current issues of the design. All the feedback and comments from the design team's participants could be discussed instantly in the meeting. The design process normally involves participants from different organisations, who form a group known as a design team. Meetings are seen as a medium to increase interaction among the design team members. There are two types of meetings in construction projects: scheduled and unscheduled meetings (Conhenca-Zall *et al*, 1994). Both types are important in achieving better integration in the management of the refurbishment design process.

Scheduled meeting

Scheduled meetings for the design process are conducted at intervals of one a week to report on the progress of the design work and to discuss any issues that arise. The scheduled meeting for design diminishes slowly once the construction stage starts. A scheduled meeting can transform into an unscheduled meeting if any problems crop up during the construction stage. The functions of a scheduled meeting are to coordinate and to act as a means of conveying information about current progress of work and recent design changes (Perry and Sanderson, 1998). In a construction project, the scheduled meeting is an appropriate venue and suitable time for the project participants to discuss any issues related to the project. Problems in design could be discussed and finalised during the meeting, which could lead to a reduction in design errors during the construction stage.

Unscheduled meetings in the design process

An unscheduled meeting would be held if there was any urgent need to solve current issues related to design. This type of meeting normally takes over from a scheduled meeting in the design process when work has started onsite or between the intervals of scheduled meetings. Problems arising onsite, such as discrepancies in drawings that need to be solved urgently, are typical situations when an unscheduled meeting would be called. However, the need to attend unscheduled meetings requires the participants in refurbishment projects to be flexible and responsive (Rahmat, 1997). They may need to forgo their routine activities in order to attend unscheduled meetings for refurbishment projects. The allocation of time and overhead cost for refurbishment design works tends to increase if there are many unscheduled meetings during the construction stage. The need for unscheduled meetings increases during the construction stage, as many unknown items start to be discovered. The unscheduled meeting is probably suitable to cater to the uncertainty of design information in refurbishment projects. The unscheduled meeting would be least important if there were no urgent decisions to be confirmed. Minor design problems that arise could be discussed at the next scheduled meeting of the project.

Site clearance

Site clearance involves the removal of walls, hedges, ditches, and trees, other vegetation and services from the site. It can also involve the clearance of fly-tipped materials.

Carbon reduction and business efficiency

- Buying sustainable goods & services

Emergency response

- Environmental Damage
- Spills at construction sites

Land: Construction

- Archaeology at construction sites
- Nature conservation and affecting public rights of way in construction
- Site investigation and sampling to assess contamination
- Soils and soil stripping at construction sites

Land: General

- Contaminated Land
- Japanese knotweed, giant hogweed and other invasive weeds

Materials and equipment: Construction

- Generators at construction sites
- Plant maintenance at construction sites
- Road sweepers at construction sites

Materials and equipment: Hazardous

- Chemical storage
- Fuelling and fuel storage
- Oil storage

Nuisances

- Dust from construction sites
- Noise from construction sites
- Noise, odour and all nuisances

Permits and licences

- Permits and licences - an overview

Trade associations and BSOs

- Construction trade associations

Transport

- Vehicle movements and deliveries at construction sites

Useful links

- Construction resources

Waste: Storage handling and transport

- Duty of care – your waste responsibilities
- Site waste management plans
- Waste storage and transport

Waste: Waste materials

- Asbestos
- Fly-tipped material
- Hazardous/special waste
- Tyres
- Waste oil

Waste: Waste treatment

- Burning construction and demolition wastes
- Chipping wood and other plant material
- Crushing bricks, tiles, concrete and other materials
- Recycling construction materials

Water

- Bunds at construction sites
- Controlling surface water run-off
- Dewatering during construction
- Discharges to water and sewer
- Settlement tanks
- Trade effluent – discharges to sewers
- Water use and abstraction
- Wheel washing at construction sites
- Working close to rivers - const

What is setting out?

A definition of setting out, often used, is that it is the reverse of surveying. Whereas surveying is a process for forming maps and plans of a particular site or area, setting out begins with plans and ends with the various elements of a particular plan correctly positioned on site.

However most techniques and equipment used in surveying are also used in setting out i.e. while surveying may be the opposite of setting out, the processes and instruments are almost identical.

The International Organisation for Standardisation (ISO) define setting out as:

Setting out is the establishment of the marks and lines to define the position and level of the elements for the construction work so that works may proceed with reference to them. This

process may be contrasted with the purpose of surveying which is to determine by measurement the position of existing features. Setting out is one application of surveying

-Most of the techniques and equipment used in surveying are also used in setting out

-Mistakes in setting out can be costly -For setting out to be undertaken successfully good work practices should be employed

-There are three parties involved in the construction procedures: the employer, the engineer and the contractor -Although the engineer checks the work, the setting out is the responsibility of the contractor

-The cost of correcting any errors in the setting out has to be paid for by the Contractor, provided the engineer has supplies reliable information in writing

Earthworks are engineering works created through the moving or processing of parts of the earth's surface involving quantities of soil or unformed rock. The earth may be moved to another location and formed into a desired shape for a purpose. Much of earthworks involves machine excavation and fill or backfill

Types of excavation

Excavation may be classified by type of material:

- Topsoil excavation
- Earth excavation
- Rock excavation
- Muck excavation - this usually contains excess water and unsuitable soil
- Unclassified excavation - this is any combination of material types

Excavation may be classified by the purpose:

- Stripping
- Roadway excavation
- Drainage or structure excavation
- Bridge excavation
- Channel excavation
- Footing excavation
- Borrow excavation
- Dredge excavation
- Underground Excavation

Masonry:

It is the building of structures from individual units laid in and bound together by mortar; the term *masonry* can also refer to the units themselves. The common materials of masonry construction are brick, stone, marble, granite, travertine, limestone, cast stone, concrete block,

glass block, stucco, tile, and cob. Masonry is generally a highly durable form of construction. However, the materials used, the quality of the mortar and workmanship, and the pattern in which the units are assembled can significantly affect the durability of the overall masonry construction. A person who constructs masonry is called a **mason** or **bricklayer**.

Applications

Masonry is commonly used for the walls of buildings, retaining walls and buildings. Brick and concrete block are the most common types of masonry in use in industrialized nations and may be either weight-bearing or a veneer. Concrete blocks, especially those with hollow cores, offer various possibilities in masonry construction. They generally provide great compressive strength, and are best suited to structures with light transverse loading when the cores remain unfilled. Filling some or all of the cores with concrete or concrete with steel reinforcement (typically rebar) offers much greater tensile and lateral strength to structures.

Advantages

- The use of material such as bricks and stones can increase the thermal mass of a building and can protect the building from fire.
- Most types of masonry typically will not require painting and so can provide a structure with reduced life-cycle costs.
- Masonry is non-combustible product.
- Masonry walls are more resistant to projectiles, such as debris from hurricanes or tornadoes.
- Masonry structures built in compression preferably with lime mortar can have a useful life of more than 500 years as compared to 30 to 100 for structures of steel or reinforced concrete.[*citation needed*]

Disadvantages

- Extreme weather, under certain circumstances, can cause degradation of masonry wall surfaces due to frost damage.
- Masonry tends to be heavy and must be built upon a strong foundation, such as reinforced concrete, to avoid settling and cracking.
- Other than concrete, masonry construction does not lend itself well to mechanization, and requires more skilled labor than stick-framing.
- Masonry consists of loose components and has a low tolerance to oscillation as compared to other materials such as reinforced concrete, plastics, wood, or metals.

Stone Masonry and brick stone masonry

Definition:

The art of building a structure in stone with any suitable masonry is called stone masonry.

Types of Stone Masonry:

Stone masonry may be broadly classified into the following two types:

1. Rubble Masonry
2. Ashlar Masonry

1. Rubble Masonry:

The stone masonry in which either undressed or roughly dressed stone are laid in a suitable mortar is called rubble masonry. In this masonry the joints are not of uniform thickness. Rubble masonry is further sub-divided into the following three types:

1. **Random rubble masonry**
2. **Squared rubble masonry**
3. **Dry rubble masonry**

1. **Random rubble masonry:** The rubble masonry in which either undressed or hammer dressed stones are used is called random rubble masonry. Further random rubble masonry is also divided into the following three types:
   a. **Un coursed random rubble masonry:** The random rubble masonry in which stones are laid without forming courses is known as un coursed random rubble masonry. This is the roughest and cheapest type of masonry and is of varying appearance. The stones used in this masonry are of different sizes and shapes. before lying, all projecting corners of stones are slightly knocked off. Vertical joints are not plumbed, joints are filled and flushed. Large stones are used at corners and at jambs to increase their strength. Once "through stone" is used for every square meter of the face area for joining faces and backing. **Suitability:** Used for construction of walls of low height in case of ordinary buildings.
   b. **Coursed random rubble masonry:** The random rubble masonry in which stones are laid in layers of equal height is called random rubble masonry. In this masonry, the stones are laid in somewhat level courses. Headers of one coursed height are placed at certain intervals. The stones are hammer dressed. **Suitability:** Used for construction of residential buildings, go downs, boundary walls etc.

1. Squared rubble masonry: The rubble masonry in which the face stones are squared on all joints and beds by hammer dressing or chisel dressing before their actual laying, is called squared rubble masonry.
2. There are two types of squared rubble masonry.

3. Coursed Square rubble masonry: The square rubble masonry in which chisel dressed stones laid in courses is called coarse square rubble masonry. This is a superior variety of rubble masonry. It consists of stones, which are squared on all joints and laid in courses. The stones are to be laid in courses of equal layers. and the joints should also be uniform.

4. Suitability: Used for construction of public buildings, hospitals, schools, markets, modern residential buildings etc and in hilly areas where good quality of stone is easily available.

Squared rubble masonry: The rubble masonry in which the face stones are squared on all joints and beds by hammer dressing or chisel dressing before their actual laying, is called squared rubble masonry.

There are two types of squared rubble masonry.

Coursed Square rubble masonry: The square rubble masonry in which chisel dressed stones laid in courses is called coarse square rubble masonry. This is a superior variety of rubble masonry. It consists of stones, which are squared on all joints and laid in courses. The stones are to be laid in courses of equal layers. and the joints should also be uniform.

Suitability: Used for construction of public buildings, hospitals, schools, markets, modern residential buildings etc and in hilly areas where good quality of stone is easily available.

In brick masonry, there are many techniques to stack bricks. These different arrangements are known as bricks bonds. Each bond has its own characteristics. Following are the commonly used bricks bonds.

1. Stretcher Bond
2. English Bond
3. Flemish Bond
4. Common/American/English Garden Wall Bond
5. Flemish Garden Wall Bond
6. Herringbone Bond
7. and there are many other brick bonds which a designer can design for custom requirements

1. Stretcher Bond

- Easiest bond to lay & it minimizes the amount of cutting required.
- Originally used for single brick walls.
- It is used for cavity walls as less cutting is required.
- Walls are half brick wide.
- No two adjacent vertical joints should be in line.

2. English Bond

- Alternative courses of headers and stretchers.
- One header placed centrally above each stretcher.

- This is a very strong bond when the wall is 1 brick thick (or more thicker).
- One of the strongest brickwork patterns.

3. Flemish Bond

- Alternate bricks are placed as header and stretcher in every course.
- Each header is placed centrally between the stretcher immediately above and below. This is not as strong as the English bond at 1 brick thick .
- It can be successfully applied in cavity wall.

4. Common/American/English Garden Wall Bond

- A pattern made like Stretcher bond but with a row of headers replacing every nth course (n is usually odd).

5. Flemish Garden Wall Bond

- In this variant of Flemish bond, one header is placed at every third stretcher.

6. Herringbone Bond

- It is a purely decorative bond. It is used in floor and wall panels

Concrete Masonry Blocks

Concrete masonry blocks have been in existence for centuries. Revolutionary changes in manufacturing technology and material sciences have made multi sized, shaped, colours and textured blocks a reality. They are used as both structural and non-structural components and have been the preferred building blocks in the western world. They are fast replacing traditional bricks and other masonry products in India too.

Concrete Masonry Blocks can either be

- Hollow or Solid
- Load Bearing or Non-load Bearing
- Light weight or Dense

Shieeld concrete blocks are used in low and high rise buildings, for basements, exterior and interior walls and partitions.

Applications

- Shopping Malls, Multiplexes
- Multifunctional Complexes such as IT Parks
- Institutional Building
- Independent Residences
- Farmhouses, Villas
- Residential Complexes
- Hotels, Resorts

- Schools, Colleges
- Hospitals
- Ports, Airports, Mass Transport Stations
- Factory Buildings
- Warehouses
- Sports Stadiums

SHIEELD - CONCRETE PRE – ENGINEERED HOLLOW BLOCKS

BOTTOM OPEN TYPE
SIZE IN MM
390 x 190 x 190
400 x 100x 200

BOTTOM CLOSE TYPE
SIZE IN MM
390 x 190 x 190
390 x 125 x 190
390 x 90 x 190

ISOLATION BLOCKS
SIZE IN MM
400 x 200 x 200

SHIEELD - CONCRETE PRE – ENGINEERED SOLID BLOCKS

SIZE IN MM
390 x 190 x 190
390 x 140 x 190
390 x 90 x 190
400 x 200 x 200
230 x 74 x 109

LINTEL BLOCK (U CHANNEL)

SIZE IN MM
390 X 190 X 190

Shieeld Concrete Blocks advantage

Precision	Protection	Economy

• Excellent Dimensional Tolerance Modular • Range of Architectural Forms • Excellent Finish • Even Textures	• High Compressive Strength High Flexural Strength • High Lateral Modulus of Rupture High Bond Strength • Earthquake Resistant	• Ease and Speed of Construction • Low Onsite Wastage • Low Labour Cost • Consumes Less Cement • Low/ No Plastering Cost • Low/ No Painting Cost
• Variety of Structural Forms • Control on Bonding Dimensions and Quality • High Precision Moulds from Rampf Germany	Durable • Excellent Fire Rating Good Thermal Insulation • Good Acoustic Insulation High Weathering Resistance • Low Water Absorption Low Permeability • Low Coefficient of Expansion Low Coefficient of Contraction • Negligible Efflorescence High Abrasion Resistance • Resistant to Salt Attack	• Low Maintenance Cost • Minimal Steel Reinforcement in case of Load Bearing Structure • Additional Floor Space

Concrete Flooring & floor finishes

Concrete floor finishes are typically only used in basements and garages. The floor should slope down to a floor drain in basements and other areas where water may accumulate.

In modern construction, a four to six inch gravel base below the 3-inch thick floor slab allows water below the slab to drain away. Moisture barriers (plastic sheets) may also be provided under the slab, and in energy efficient construction or slab-on-grade construction, rigid insulation may be used below the floor. In older construction, concrete floor slabs were as thin as 1/2 inch. These are prone to impact damage, heaving and break-up.

This is a cosmetic issue and may be a trip hazard. Most concrete floors are not part of the structure. Basement floors are typically installed after the home is completed, and their main function is to keep our feet out of the mud.

Concrete basement floors can be overlaid with finished flooring. Since almost every house with a basement has water on the basement floor at some point, water-resistant floors make sense. In

slab-on-grade construction, the concrete floors provide a substrate for floor finishes. - Citation: Carson Dunlop Associates, *Home Reference Book* , quoted with permission.

Concrete Floor details are in these articles

- FLOOR, CERAMIC TILE
- FLOOR, CONCRETE SLAB CHOICES
- FLOOR DAMAGE DIAGNOSIS
- FLOOR, ENGINEERED WOOD, LAMINATES INSTALL
- FLOOR FRAMING & SUBFLOOR for TILE
- FLOOR, KITCHEN & BATH OPTIONS

- FLOOR, LAMINATE PLASTIC
- FLOOR, CONCRETE POURED FINISH

Cork Flooring - Details about cork flooring are at these articles

- CORK FLOORING & FLOOR TILES
- FLOORING COMPANIES

FLOOR TILE HISTORY & INGREDIENTS - history, dates, and description of the production process and ingredients in asphalt floor tiles, asphalt-asbestos floor tiles, & vinyl-asbestos floor tiles 1900 to present.

- FLOORING MATERIALS, Age, Types - Age of Building Flooring Materials - A Guide to Estimating Building Age, This article describes types and ingredients in flooring materials: Asphalt floor tile, Cork floor tile or planks, Laminate flooring (modern), Linoleum & older sheet flooring (painted canvas), Vinyl-asbestos floor tiles, Wood flooring.

FLOOR TYPES & DEFECTS - Asphalt floor tiles, asphalt-saturated asbestos felt, carpeting, cork floor tiles & planks, laminate flooring (modern), linoleum (sheet flooring) & earlier painted fabric floor coverings, vinyl-asbestos tile floors, wood flooring.

- Resilient Floor List
  - Asphalt Tile
  - Cork Flooring Tiles
  - LINOLEUM & Other Sheet Flooring
  - Sheet Flooring Materials
  - Vinyl Asbestos Tiles
- Non-Resilient Floor Coverings
  - Carpeting

- Laminate Flooring Products
- Tile Floors
- Wood Flooring

- Properties of Flooring Types, Table of

Hardwood Flooring, the Basics

Hardwood floors are traditionally oak, although other woods such as cherry, walnut, birch, beech, mahogany, elm and maple, are also used. Bamboo is not technically wood, but is also used as flooring. Hardwood flooring may be in the form of strips or parquet, which often consist of six inch squares with each square made up of six one-inch strips. The squares are laid with the grain in adjoining squares at right angles, giving a checkerboard effect. Parquet flooring may be nailed or glued down. There are several different types and installation techniques. Parquet flooring can also be made up of a combination of rectangles, triangles and lozenges and can be very decorative and very expensive.

Strip flooring is typically tongue and groove, secured with nails driven diagonally through the tongues into the subfloor. Hardwood flooring in modern construction is typically 3/8 inch to 3/4 inch thick and may be pre-finished or finished on site. Hardwood flooring is a high quality and durable floor system. It can be mechanically damaged, attacked by termites, rot and fire, or damaged by water.

Wood flooring is not ideally suited to kitchen and bathroom areas, since it is susceptible to water damage. Nonetheless, hardwood flooring is regularly found in kitchens. Individual boards can be replaced, but matching can be tricky. Worn 3/8 inch thick hardwood flooring can be sanded once to provide a new wood surface. 3/4 inch hardwood flooring can be sanded several times before the tongues are exposed. Wood flooring can be covered with carpeting or other flooring materials. - Citation: Carson Dunlop Associates, *Home Reference Book* , quoted with permission.

Kitchen & Bath Floor Options - Table comparing properties of different flooring materials
See
FLOOR, KITCHEN & BATH OPTIONS

Laminate Flooring, (Plastic Laminate Floors and Engineered Wood floors)

In recent years, laminate flooring has become very popular, especially among do-it-yourselfers. Laminate floor planks (or tiles) have several layers. The top layer is generally a clear laminate that is bonded to a decorative layer below, often creating the look of a wood floor. These layers are bonded to a wood- or fiber-based core. The bottom layer may be a paper or melamine backing. The product is similar to resilient countertops. A complete floor is created by either snapping planks together with specially-designed fasteners along the edges, or by gluing planks together along traditional tongue and groove edges.

Laminate flooring is not secured to the subfloor beneath it. Instead, it is installed as a floating floor, allowing it to expand and contract. A sheet of cushioning foam is installed between the laminate flooring and the subfloor. There may also be a sheet of plastic below the foam to act as a moisture barrier and to allow the floor to slide as it expands. A gap is required between the flooring and the walls to allow for expansion. This gap is covered by trim. Laminate flooring cannot be sanded, stained, or otherwise refinished, although damaged planks can be replaced.

Laminate flooring is resistant to small amounts of water, such as quickly wiped-up spills, but

precautions should be taken in kitchens or bathrooms including applying a sealant around the perimeter. This is not visible during a home inspection. Laminate flooring should not be installed in damp basement areas. - Citation: Carson Dunlop Associates, *Home Reference Book* , quoted with permission.

See these detailed articles on laminate floor materials:

- LAMINATE PLASTIC FLOORING
- LAMINATE WOOD & Other Laminate Floors
- WOOD FLOORING & Engineered Wood Floors

Linoleum Flooring articles

- LINOLEUM & Other Sheet Flooring shown at left, Congoleum sheet flooring
- also see Congoleum Flooring History

Mold on or hidden in flooring

- FLOOR & SUBFLOOR MOLD, HIDDEN

Non-Resilient Floor Coverings - article list

- Non-Resilient Floor Coverings
- Laminate Flooring Products
- Wood Flooring
- Tile Floors
- Carpeting
- Properties of Flooring Types, Table of

- **Peel and Stick** / Self-Adhesive Floor Tiles - types of self-adhesive floor tiles and peel and stick tiles intended for consumer installation

Resilient Flooring - see details at FLOOR, RESILIENT VINYL or CORK

Resilient floor coverings include vinyl-asbestos, solid vinyl, vinyl faced, rubber, cork, asphalt and linoleum. It is installed in sheets or tiles. More expensive products include a cushioned backing material and a no-wax surface. In modern construction, these materials are typically applied over a 1/4 inch plywood underlayment. These thin, flexible materials will show through any irregularities in the floor surface. - Citation: Carson Dunlop Associates, *Home Reference Book*

Also see:

- Asphalt Tile
- Cork Flooring Tiles
- LINOLEUM & Other Sheet Flooring
- Vinyl Asbestos Tiles
- Resilient Floor List
- Sheet Flooring Materials

Sheet Flooring see sheet linoleum & vinyl flooring

- FLOOR TILE ASBESTOS IDENTIFICATION
- FLOOR TILE HISTORY & INGREDIENTS
- Sheet Flooring Materials

Stone Floors - Slate, Granite, Limestone, Marble

These are natural materials cut into flooring tiles. Terrazzo is made of marble chips set in concrete, usually laid in squares defined by lead beading. The surface is polished to give a smooth floor. Terrazzo is more common in commercial buildings, hospitals and schools than in homes.

Stone and terrazzo are good flooring materials because of their strength, appearance and durability. Installation considerations are similar to ceramic and quarry tile, in that the weight of the material itself may deflect conventional flooring systems. Joints on stone floors are grouted. - Citation: Carson Dunlop Associates, *Home Reference Book*

Tile Flooring - ceramic

Generally considered high quality, ceramic or quarry tiles are hard, fired-clay products that may be glazed or unglazed. These materials stand up well to heat, water and normal wear and tear, and have good resistance to stains and cuts. These brittle floor systems will crack if not well supported.

A conventional wood flooring system often has too much flex to support ceramic or quarry tile. Better installations include a concrete base for the tile, typically one to five inches thick. Tiles may be pressed into the concrete while it is setting. Joints are then grouted. Tiles are typically 1/16-inch to 1-inch thick and are commonly from one inch by one inch to 24 inches by 24 inches. Many shapes, colors, patterns and finishes are available.

In modern construction, a thin mortar base or adhesive is used over a thick subfloor. If well

installed, this can be satisfactory. Again, joints have to be appropriately grouted. It is common for ceramic or quarry tile floors to be cracked where floor joists deflect, or in heavy traffic patterns. Tiles can be damaged by dropping tools, pots, pans or other heavy objects.

Traditionally, ceramic tile floors were used in bathrooms and vestibules, because of their natural resistance to moisture. Ceramic or quarry tile floors are used in kitchens, for the same reason, although they are unforgiving if one drops glass on them, and they are also more tiring to stand on because of their hard surface. Wet floors can be slippery. - Citation: Carson Dunlop Associates, *Home Reference Book*

See details about ceramic tiles at

- FLOOR, CERAMIC TILE
- CERAMIC TILE, ASBESTOS in?

Also see tile flooring discussed at FLOOR RADIANT HEAT Mistakes to Avoid|

Tile Flooring - resilient, vinyl, vinyl-asbestos

- FLOOR TILE HISTORY & INGREDIENTS

- **Vinyl Asbestos Flooring Information: Tiles & Sheet Flooring**
  - Vinyl Asbestos Floor Tile Age
  - Vinyl-Asbestos Floor Tile History
  - Vinyl Asbestos Floor Tile Packaging
  - Vinyl Asbestos Floor Thickness & Dimensions
  - Vinyl Asbestos Sheet Flooring

Wood Flooring & Engineered Wood Floors

- **Engineered wood flooring** is similar to laminate flooring, except the thin top layer is actually hardwood that is bonded to a base that may be hardwood, plywood, or high-density fiberboard. The hardwood layer is usually pre-finished. The floor may be sanded and refinished, depending on the thickness of the hardwood layer. Engineered wood flooring may be installed as a floating floor, or it may be glued, stapled, or nailed in place.
  - Citation: Carson Dunlop Associates, *Home Reference Book* , quoted with permission.
- **Softwood Wood Flooring**: Pine is the most common softwood flooring. Fir and cedar are also used. Pine floors were typically used as a subfloor or as finish flooring in a 1x4 tongue-and-groove configuration. When used as a subfloor below hardwood, the softwood was typically laid in 1x4 or 1x6 planks, perpendicular or diagonal to the floor joists. The boards were typically separated slightly to allow for expansion.

- Softwood subflooring used under linoleum or other thin kitchen floor coverings was usually tongue-and-groove and tightly fit to provide a smooth, continuous surface to support the flexible flooring system. Modern construction often includes 1/4 inch plywood underlayment between the subfloor and finish flooring to provide a smooth surface for the finishing material. - Citation: Carson Dunlop Associates, *Home Reference Book* ,
- Laminate Wood & Other Laminate Floors

- Also see Laminate Flooring where we describe plastic laminate floors in this article
- FLOOR WOOD AGE TYPES HISTORY
- FLOOR WOOD, DAMAGE DIAGNOSIS
- FLOOR, WOOD ENGINEERED, LAMINATE, INSTALL
- FLOOR, WOOD FINISHES
- FLOOR, WOOD INSTALLATION GUIDE
- FLOOR, WOOD MOISTURE
- FLOOR, WOOD RADIANT HEAT
- FLOOR, WOOD SOLID STRIP, PLANK
- FLOOR, WOOD TYPES
- Also see FLOOR TILE HISTORY & INGREDIENTS and
- see FLOOR, CONCRETE SLAB CHOICES,
- and SLAB INSULATION, PASSIVE SOLAR for examples of discussion of energy-efficient floor designs and passive solar floor systems.

Guide to Inspection & Diagnosis of Flooring Materials in buildings

List of Non-Resilient & Resilient Floor Coverings Used in buildings. Definitions of Non-resilient Flooring & Resilient Flooring

Non-resilient floor coverings used in buildings that can assist in determining the age of a structure include bamboo, brick, concrete, stone, slate, and a wide variety of wood products.

Definition of non-resilient flooring:

"Non-resilient" flooring is defined as hard surfaced flooring material such as stone, brick, slate, or ceramic tile.

Definition of resilient flooring

"Resilient flooring" is defined as materials softer than the non-resilient materials we just listed (stone, slate, brick, ceramic tile), and includes organic types of flooring: asphalt based floor tiles, cork floor tiles, cork floor planks, linoleum sheet flooring (antique & modern), plastic floor tiles, rubber floor tiles, vinyl-asbestos floor tiles.

So what's "wood flooring" ? After all, it is organic too. Is a wood floor non-resilient, resilient, or just "wood"?

Non-resilient.

See Asphalt & Vinyl Floor Tile History - history, dates, and description of the production process and ingredients in asphalt floor tiles, asphalt-asbestos floor tiles, & vinyl-asbestos floor tiles.

Asphalt Tile Flooring - 1920 - 1960 (est)

Asphalt floor tiles are 9" square (or other sized) tiles which used asphalt as the main binding material. the original asphalt tiles were produced only in dark colors because asphalt was a main ingredient.

The black tiles shown at left were not dated and may be a newer product, but in general, if you find very old black floor tiles they are probably an asphalt-asbestos product.

Rosato indicates that the first publicized asphalt tile installation was in 1920 in New York City's Western Union office. The product was very successful and by 1936 over four million square yards of asphalt floor tiles were being sold annually.

By 1940, 5% of floor coverings sold in the U.S. were asphalt tile. -- Rosato In 1920 asphalt roofing manufacturers, who had been using asphalt and fiber binders to make asphalt roofing shingles for some time, tried to develop a rigid product that could be a substitute for (more costly) slate roofing. The material did not perform acceptably as a roof covering, but it led to the development of asphalt floor tiles.

At AGE of a BUILDING - how to determine in our section titled Flooring Materials we discuss the eras during which various flooring materials were first used in modern buildings and how to use these to help identify the age of a building.

Asphalt Floor Tiles Pose an Asbestos Risk

Asphalt-asbestos floor tiles were produced at first in dark colors using a heavy asphalt binder combined with a very high percentage of asbestos filler fibers. It would be uncommon to find these floors still in use today, but if you encounter black or very dark asphalt floor tiles they are

probably very high in asbestos fibers. We discuss floor tiles as an asbestos fiber source in buildings in more detail at ASBESTOS FLOOR TILE IDENTIFICATION where we elaborate the concerns about asbestos used in the manufacture of asphalt-based floor tiles.

Colors & Composition of Asphalt Asbestos Floor Tiles

Asphalt -asbestos tiles manufactured early in their life (1920's) were either black, near black, brown, or a gray-brown tone. Brown asphalt-asbestos tiles were made by substituting gilsonite as a binder. In both cases the tiles were hardened by evaporating a solvent used in the fabrication process, or by cooling of hot asphalt used in the mixture.

Gilsonite could be used to produce a wider range of mixtures, but required some asphalt as a softener. Dark vinyl-asbestos tiles used, for example, a mixture of 40 parts asphalt or gilsonite, 60 parts asbestos floats, 30 parts powdered limestone, and pigments (parts by weight). Another typical mixture cited by Rosato contained 70% asbestos fiber.

See these articles on asphalt and vinyl-asbestos floor tile identification:

- ASBESTOS FLOOR TILE IDENTIFICATION - How to Identify Floor Tiles That May Contain Asbestos
- ASBESTOS FLOOR TILE IDENTIFICATION PHOTOS by YEAR - detailed photo guide to asphalt asbestos and vinyl asbestos floor tiles, 1900 -1986
- FLOOR TILE HISTORY & INGREDIENTS - history, dates, and description of the production process and ingredients in asphalt floor tiles, asphalt-asbestos floor tiles, & vinyl-asbestos floor tiles 1900 to present.
- FLOORING MATERIALS, Age, Types - Age of Building Flooring Materials - A Guide to Estimating Building Age, This article describes types and ingredients in flooring materials: Asphalt floor tile, Cork floor tile or planks, Laminate flooring (modern), Linoleum & older sheet flooring (painted canvas), Vinyl-asbestos floor tiles, Wood flooring.
- FLOOR TYPES & DEFECTS - Asphalt floor tiles, asphalt-saturated asbestos felt, carpeting, cork floor tiles & planks, laminate flooring (modern), linoleum (sheet flooring) & earlier painted fabric floor coverings, vinyl-asbestos tile floors, wood flooring.
- ASBESTOS FLOOR TILE LAB PROCEDURES - photos of how vinyl asbestos flooring is analyzed in the lab.

Cork Flooring Tiles

Cork floor tiles were considered a warm, quiet, but less durable resilient floor covering than some of its competitors. It was sold often for use in residential dens, family rooms, or other warm, low-traffic areas, and it may have been popular (research needed) for use in areas where

workers had to spend long periods standing - where it would have competed with rubber floor coverings. In 1952 cork flooring sales made up 2% of total floor tile sales. -- Rosato p88.

Details about cork flooring are at CORK FLOORING & FLOOR TILES

and also at FLOORING COMPANIES (see Armstrong Corporation).

Vinyl Asbestos Floor Tiles - 1930 - 1976 (est)

Vinyl floor tiles, including vinyl-asbestos floor tiles and homogenous vinyl floor tiles (non-asbestos product) are almost as old as asphalt floor tiles. By the early 1950's in the U.S. vinyl tile floor products were more popular than asphalt-based flooring. The reason is pretty obvious.

Asphalt-based flooring as it was originally produced used heavy asphalt products which meant that the floor tiles could be made in dark colors only. Soon after asphalt-asbestos floor tiles were marketed manufacturers heard from their buyers that consumers wanted lighter floor tiles and tiles of varying color and pattern.

Organic resin vinyl increased in popularity for this reason, but slowly. By 1952, the production of vinyl plastic floor tile sales in the U.S. was about half the volume of asphalt floor tiles, selling 35 million square yards.

We discuss vinyl-asbestos floor tiles as an asbestos fiber source in buildings in more detail at ASBESTOS FLOOR TILE IDENTIFICATION where we elaborate the concerns about asbestos used in the manufacture of vinyl based floor tiles that used high levels of asbestos fibers as a filler material and to provide other properties to that product. More photos of vinyl asbestos floor tiles, including microphotographs of vinyl-asbestos floor tiles can be seen at that article.

See these articles on asphalt and vinyl-asbestos floor tile identification:

- ASBESTOS FLOOR TILE IDENTIFICATION - How to Identify Floor Tiles That May Contain Asbestos
- ASBESTOS FLOOR TILE IDENTIFICATION PHOTOS by YEAR - detailed photo guide to asphalt asbestos and vinyl asbestos floor tiles, 1900 -1986

- FLOOR TILE HISTORY & INGREDIENTS - history, dates, and description of the production process and ingredients in asphalt floor tiles, asphalt-asbestos floor tiles, & vinyl-asbestos floor tiles 1900 to present.
- FLOORING MATERIALS, Age, Types - Age of Building Flooring Materials - A Guide to Estimating Building Age, This article describes types and ingredients in flooring materials: Asphalt floor tile, Cork floor tile or planks, Laminate flooring (modern), Linoleum & older sheet flooring (painted canvas), Vinyl-asbestos floor tiles, Wood flooring.

- FLOOR TILE / SHEET FLOORING PHOTO GUIDES - list of photo guides
- FLOOR TYPES & DEFECTS - Asphalt floor tiles, asphalt-saturated asbestos felt, carpeting, cork floor tiles & planks, laminate flooring (modern), linoleum (sheet flooring) & earlier painted fabric floor coverings, vinyl-asbestos tile floors, wood flooring.
- ASBESTOS FLOOR TILE LAB PROCEDURES - photos of how vinyl asbestos flooring is analyzed in the lab.

Sheet Flooring Materials That Indicate Age of a Building

Here is a photograph of an early (pre-vinyl) continuous floor covering, ca 1900, in an 1840 historic Vermont house.

Note the fabric backing of the flooring material. This article explains various common flooring materials (rough wood, finished wood, parquet, carpeting, linocrusta, sheet vinyl, and other items as they assist in determining the age of a house or other building.

Details about sheet flooring are at SHEET FLOORING MATERIALS

and at LINOLEUM & Other Sheet Flooring.

Linoleum Sheet Flooring As an Indicator of Building Age - 1890 - 1960 (est)

At LINOLEUM & Other Sheet Flooring we describe the history and properties of linoleum sheet flooring using the Congoleum-Nairn corporation history to obtain some useful dates on when different sheet flooring products were produced.

The resilient flooring product shown at left was made in the late 1990's and is not an asbestos concern, though in this case the flooring was damaged by water and movement of a cabinet.

According to Rosato, "The original resilient floor coverings were developed during the latter part of the Nineteenth Century by Frederick Walton.

The original covering was linoleum for use as a floor decking on British naval ships." The composition of the original products included asphaltic binders to which an asbestos filler was added by mixing on a rubber mill.

Details are at LINOLEUM & Other Sheet Flooring and at Congoleum Flooring History.

List of Non-Resilient Floor Coverings Used in buildings

Non-resilient floor coverings used in buildings that can assist in determining the age of a structure include bamboo, brick, concrete, stone, and a wide variety of wood products.

Laminate Wood & Plastic Flooring Products

The laminate wood flooring shown at left was buckled and destroyed by flooding caused by a leaky heating pipe. As we discussed with traditional wood flooring above, severe flooding or installation errors can lead to total loss of the finish floor system.

Contemporary snap-together flooring products that resemble wood or other surfaces, but are made of plastic, and other pre-finished and ready-to-assemble wood flooring products are a much more modern product.

Pergo (TM) laminate flooring, for example, was developed by Pergo AB, a Swedish company founded around 1890 as a vinegar manufacturer. Product development for Pergo laminate

flooring began in 1977 and was first brought to the market in 1984. Pergo laminate flooring was first sold in the U.S. in 1994.

It's safe to say that if you see a Pergo product in building in U.S. the flooring was installed no longer ago than 1994. But because this product is has been widely used as a renovation material installed atop older pre-existing finish floor surfaces, one should not presume that the product age is the same as the building age unless the floor was installed as original material - that is, unless it was not installed over an older floor covering.

Just seeing Pergo TM laminate flooring over a plywood subfloor is not sufficient data to conclude the age of a home. Older carpeting may have been removed to expose a plywood subfloor over which the laminate flooring was then installed.

Wood Flooring Inspection, Diagnosis, Repair

Wood flooring, one of the most warm and beautiful materials that can be placed in a home (OPINION-DF) needs to be installed following proper practices.

The gaps that appeared in the wood floor shown at left were caused by installation of the floor in a new home, over radiant heat tubing, and without allowing the flooring to reach a proper moisture level before it was nailed in place.

Extreme buckling can cause an upwards explosion of a wood floor when flooring is exposed to flooding or prolonged leaks.

This severe buckling wood floor damage can occur even at much smaller increases in interior moist sure if a tongue and groove wood floor is improperly installed - leaving inadequate free space margin around the floor perimeter.

See Wood Floor Types for a catalog of types and ages of wood flooring.

See WOOD FLOOR DAMAGE REPAIR for details of types of damage to wood flooring and for a description of wood floor repair approaches.

Tile Floor Inspection, Diagnosis, Repair

Cracked floor tiles like this can be diagnosed in order to decide if the cracking shows a serious structural problem, inadequate floor support, mechanical damage, or as in this case, damage from a loose, rocky toilet.

More Places to Look for Hidden Mold in buildingsincludes a discussion of how even a slight slope in a tile bathroom floor leads to bath leaks under and behind bathroom vanity cabinets and floor trim, and we discuss how to prevent this problem

Wall-to-wall Floor Carpeting Inspection, Diagnosis, Repair

See these articles about diagnosing stains, mold, and allergens in carpeting

- CARPET DUST IDENTIFICATION
- CARPET MOLD CONTAMINATION
- CARPET PADDING ASBESTOS, MOLD, ODORS
- CARPET STAIN DIAGNOSIS
- CARPET & other STAIN TESTS
- CARPET TEST PROCEDURE
- CABINETS & COUNTERTOPS
- CARPETING & INDOOR AIR QUALITY
- CARPETING, SELECTION & INSTALLATION
- Thermal Tracking: How to Diagnose Indoor Carpeting Stains Due To Building Air Leaks
- How to Find and Test for Moldy Carpeting in buildings
- Carpet Test for Mold: How to Collect Test Samples from Carpets & Soft Surfaces

Damp proofing in construction is a type of moisture control applied to building walls and floors to prevent moisture from passing into the interior spaces. Damp problems are one of the most frequent problems encountered in homes.

Different types of damp proof course

Damp proof courses (DPC‟s) are types of barriers designed to span across the length or width of your walls to prevent the onset of rising or penetrating damp; there are various options to choose from, including:

- **Solid DPC** – a solid DPC is made of some kind of waterproof material – such as bituminous felt, copper sheet or polythene – and is fitted either horizontally or vertically on the exterior or interior of the wall, at least six inches above ground level (in accordance with the *British Standard Code of Practice for Installation of Damp Proof Courses* BS 6576:1985). Solid DPC‟s are considered the most reliable form of preventing groundwater ingress, but are really only suitable for newly erected walls; fitting them onto already built walls adds the risk of cutting through pipe work or wiring, which could cost you more money later on.

- **Chemical DPC** – this involves drilling holes 10-12mm in diameter into the wall (also at least 6in above ground level), and injecting liquid silicone-based chemicals into the holes using a high pressure pump to create a water repelling layer in the wall. This often proves a more practical and less obtrusive DPC for home owners, but it can take a few months for results to emerge and the effectiveness will vary as the chemicals won‟t pass through the walls evenly. This method won‟t work on breeze block walls, as they are non-porous and thus won‟t allow the chemicals to permeate properly.

- **Porous tube DPC** – this DPC involves fitting small clay tubes into closely spaced rows along the wall, also into the mortar at least 6in above ground level; these tubes then allow moisture to locate an outlet that allows it to evaporate more freely and therefore limits the amount of water that can rise above them. This is a relatively simple and cheap method but it doesn‟t always produce effective results.

- **Electro osmotic DPC** – if you want a more scientific based DPC, electricity can even be utilised to help prevent the onset of damp. Titanium cathodes and anodes are fitted into the interior of the wall and power is drawn from the mains supply, usually by using a standard 13amp socket. The entire system is professionally earthed and the subsequent injected electricity creates an electric field, whereby the water molecules are naturally drawn downwards toward the negative electrodes and away from the bulk of the wall. The system is specifically designed to counteract the rising water that causes damp.

JOINTS IN CONCRETE CONSTRUCTION

Squared rubble masonry: The rubble masonry in which the face stones are squared on all joints and beds by hammer dressing or chisel dressing before their actual laying, is called squared rubble masonry.

There are two types of squared rubble masonry.

Coursed Square rubble masonry: The square rubble masonry in which chisel dressed stones laid in courses is called coarse square rubble masonry. This is a superior variety of

rubble masonry. It consists of stones, which are squared on all joints and laid in courses. The stones are to be laid in courses of equal layers. and the joints should also be uniform.

Suitability: Used for construction of public buildings, hospitals, schools, markets, modern residential buildings etc and in hilly areas where good quality of stone is easily available.

Why Precast?

Faster Construction

What do we mean by faster construction? We‟re not necessarily talking about how fast the pavement can be constructed, but rather how fast it can be opened to traffic. Conventional cast-in-place pavement requires several days of additional curing time after the concrete is placed before it is strong enough to withstand traffic loading. While “fast-setting” concrete mixtures have been developed for this purpose, these can be cost-prohibitive for large-scale pavement construction.

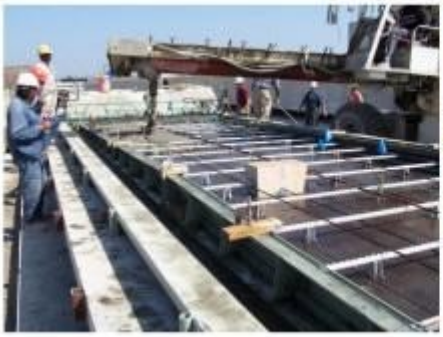
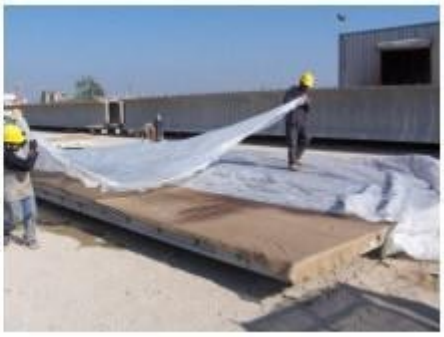
Reduced User Delay Costs

What are user delay costs? These are costs to the drivers of the roadway that are directly attributable to congestion caused by construction activities. Increased fuel consumption, lost work time, increased vehicle wear and tear, and increased air pollution are just a few of these costs. The savings in user delay costs realized through limiting construction to only off-peak

travel times (at night or over a weekend) can be substantial. This is where the primary economic benefit of precast pavement will be realized.

Improved Durability and Performance

Precast concrete has a proven track record as a durable high-performance product for bridge and commercial building construction. This is the result of a high degree of quality control that can be achieved at a precast fabrication plant. High strength, low permeability concrete mixtures with a low water-cement ratio and uniform aggregate gradation are used routinely by precast fabrication plants. At most plants concrete batching and quality control is done on-site and the concrete is transported only a short distance from the batch plant to the forms, minimizing changes in concrete properties between the mixing and placing operations. What‟s more, precast fabrication plants offer tremendous flexibility over the curing operation. Precast concrete elements can be fabricated indoors, they can be wet-mat cured, steam cured, and curing can be maintained as long as necessary after casting. Problems that can plague cast-in-place pavement construction such as surface strength loss, “built-in” curling, and inadequate air entrainment, can all be eliminated with precast concrete.

Why Prestressed Precast Pavement?

Prestressing has a proven track record for enhancing the performance and durability of concrete structures. And though it has seen very limited use in pavements, there are clearly benefits of prestressed concrete pavement, such as reduced cracking, reduced slab thickness, and bridging capability.

Reduced Cracking

While conventional pavements are “designed” to crack at specific locations (at sawcut joints for JCP) or at regular intervals (CRCP), in general cracking is not desirable. Cracks can spall, they can permit water to penetrate the underlying base, they can fault, and they can eventually lead to severe pavement failures such as punchouts. Prestressing helps to minimize or even eliminate cracking. By putting a pavement in compression there is less likelihood of cracking due to tensile stresses. What‟s more, the so-called “elasto-plastic” behavior of prestressed concrete will help keep any cracks that do form tightly closed.

Reduced Slab Thickness

While the underlying pavement structure is also a factor, the primary controlling factor in pavement thickness design is the magnitude and number of wheel load repetitions on the pavement over its expected design life. For a given pavement support structure and a given wheel load, tensile stresses in a thinner pavement will be higher than those in a thicker pavement. These higher stresses wear out or fatigue a concrete pavement faster. Prestressing can be used to reduce the tensile stresses in a thinner pavement slab to those of a much thicker pavement slab, increasing the design life of the pavement.

Why is this important? First is the savings in concrete material. Constructing an 8-inch thick pavement slab instead of a 12-inch-thick pavement slab will save more than 780 cubic yards of

concrete per lane-mile. Secondly, for removal and replacement it is generally necessary to match the existing slab thickness. Most existing pavements that are in need of replacement are on the order of 8-10 inches thick. Prestressing permits in-kind replacement of the existing pavement with a pavement slab that will have a design life of a much thicker slab. Finally, slab thickness can often times be governed by overhead clearance constraints. When replacing a pavement

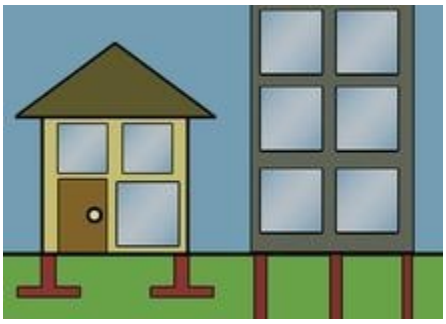
under a bridge overpass, for example, it is often not possible to construct a thicker pavement than what was in place already without having to excavate base material.

Bridging Capability

Prestressing gives the pavement a certain “bridging” capability that permits the pavement slab to span small voids and “soft” base materials beneath the pavement. This is critical for pavement removal and replacement operations that are limited to short (overnight) construction windows when it is often not possible to recondition or replace the underlying base material.

Foundation (engineering)

From Wikipedia, the free encyclopedia



Shallow foundations of a house versus the deep foundations of a skyscraper.

FOUNDATIONS

The foundations of the building transfer the weight of the building to the ground. While 'foundation' is a general word, normally, every building has a number of individual foundations, commonly called footings. Usually each column of the building will have its own footing.

Since the weight of the building rests on the soil (or rock), engineers have to study the properties of the soil very carefully to ensure that it can carry the loads imposed by the building. It is common for engineers to determine the ***safe bearing capacity*** of the soil after such study. As the name suggests, this is the amount of weight per unit area the soil can bear. For example, the safe bearing capacity(SBC) at a location could be 20 T/m2, or tonnes per square metre.

This capacity also changes at different depths of soil. In general, the deeper one digs, the greater the SBC, unless there are pockets of weak soil in the earth. To properly support a building, the soil must be very firm and strong. It is common for the soil near the surface of the earth to be loose and weak. If a building

is rested on this soil, it will sink into the earth like a ship in water. Building contractors will usually dig until they reach very firm, strong, soil that cannot be dug up easily before constructing a foundation.

To study the properties of the soil before designing foundations, engineers will ask for a ***soil***

investigation to be done. A soil investigation engineer will drill a 4" or 6" hollow pipe into the ground, and will remove samples of the earth while doing so. He will then send these samples to a lab to find out the detailed properties of the soil at every depth. Soil is usually composed of *strata*, or different layers, each with its own set of properties. Drilling technology today makes it easy and economical to drill to great depths, easily several hundred metres or more, even in hard rock.

The soil investigation team will then prepare a *soil investigation report* that lists the engineering properties of the soil at regular intervals, say every 2 meters. Based on this deport, engineers designing the structure can decide at what depth of soil to provide the foundations, the type of foundations they should provide, and the size of the foundations.

Every once in a while, engineers will find ***fill*** at a site. This occurs when humans have previously dug up the earth there, and then filled it back in. This happens if a quarry was dug or a building built there previously. Since fill is loose and soft and cannot support weight, engineers will dig to a depth below that of the fill, where strong soil is found, and construct foundations there.

TYPES OF FOUNDATIONS

Read our introduction to foundations if you have missed it.

In this article we will discuss the common types of foundations in buildings. Broadly speaking, all foundations are divided into two categories: shallow foundations and deep foundations. The words shallow and deep refer to the depth of soil in which the foundation is made. Shallow foundations can be made in depths of as little as 3ft (1m), while deep foundations can be made at depths of 60 - 200ft (20 - 65m). Shallow foundations are used for small, light buildings, while deep ones are for large, heavy buildings.

SHALLOW FOUNDATIONS

Shallow foundations are also called spread footings or open footings. The 'open' refers to the fact that the foundations are made by first excavating all the earth till the bottom of the footing, and then constructing the footing. During the early stages of work, the entire footing is visible to the eye, and is therefore called an open foundation. The idea is that each footing takes the concentrated load of the column and spreads it out over

a large area, so that the actual weight on the soil does not exceed the safe bearing capacity of the soil.

There are several kinds of shallow footings: individual footings, strip footings and raft foundations.

In cold climates, shallow foundations must be protected from freezing. This is because water in the soil around the foundation can freeze and expand, thereby damaging the foundation. These foundations should be built below the *frost line*, which is the level in the ground above which freezing occurs. If they cannot be built below the frost line, they should be protected by insulation: normally a little heat from the building will permeate into the soil and prevent freezing.

individual footings

Individual footings awaiting concreting of the footing column.

Individual footings are one of the most simple and common types of foundations. These are used when the load of the building is carried by columns. Usually, each column will have its own footing. The footing is just a square or rectangular pad of concrete on which the column sits. To get a very rough idea of the size of the footing, the engineer will take the total load on the column and divide it by the safe bearing capacity (SBC) of the soil. For example, if a column has a vertical load of 10T, and the SBC of the soil is 10T/m2, then the area of the footing will be 1m2. In practice, the designer will look at many other factors before preparing a construction design for the footing.

Individual footings connected by a plinth beam. Note that the footings have been cast on top of beds of plain cement concrete (PCC), which has been done to create a level, firm base for the footing.

Individual footings are usually connected by a *plinth beam*, a horizontal beam that is built at ground or below ground level.

strip footings

Strip footings are commonly found in load-bearing masonry construction, and act as a long strip that supports the weight of an entire wall. These are used where the building loads are carried by entire walls rather than isolated columns, such as in older buildings made of masonry.

raft or mat foundations

Raft Foundations, also called Mat Foundations, are most often used when basements are to be constructed. In a raft, the entire basement floor slab acts as the foundation; the weight of the building is spread evenly over the entire footprint of the building. It is called a raft because the building is like a vessel that 'floats' in a sea of soil.

Mat Foundations are used where the soil is week, and therefore building loads have to be spread over a large area, or where columns are closely spaced, which means that if individual footings were used, they would touch each other.

DEEP FOUNDATIONS

---

pile foundations

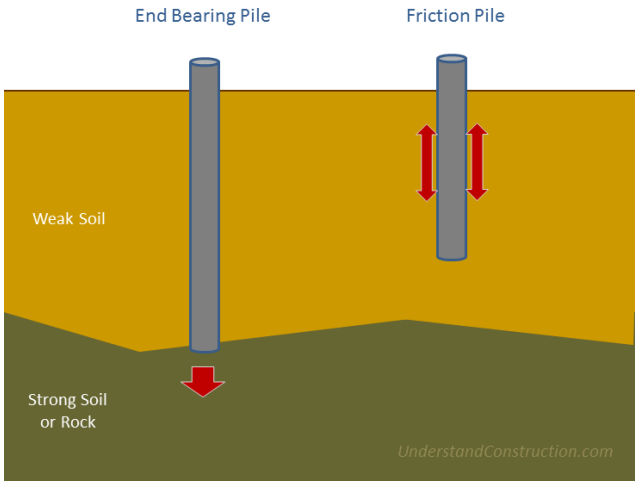
A pile is basically a long cylinder of a strong material such as concrete that is pushed into the ground so that structures can be supported on top of it.

Pile foundations are used in the following situations:

1. When there is a layer of weak soil at the surface. This layer cannot support the weight of the building, so the loads of the building have to bypass this layer and be transferred to the layer of stronger soil or rock that is below the weak layer.
2. When a building has very heavy, concentrated loads, such as in a high rise structure.

Pile foundations are capable of taking higher loads than spread footings.

There are two types of pile foundations, each of which works in its own way.



End Bearing Piles

In end bearing piles, the **bottom end of the pile rests on a layer of especially strong soil or rock**. The load of the building is transferred through the pile onto the strong layer. In a sense, this pile acts like a column. The key principle is that the bottom end rests on the surface which is the intersection of a weak and strong layer. The load therefore bypasses the weak layer and is safely transferred to the strong layer.

Friction Piles

Friction piles work on a different principle. The pile transfers the load of the building to the soil across the full height of the pile, by friction. In other words, the entire surface of the pile, which is cylindrical in shape, works to transfer the forces to the soil.

To visualise how this works, imagine you are pushing a solid metal rod of say 4mm diameter into a tub of frozen ice cream. Once you have pushed it in, it is strong enough to support some load. The greater the *embedment depth* in the ice cream, the more load it can support. This is very similar to how a friction pile works. In a friction pile, the amount of load a pile can support is directly proportionate to its length.

A **foundation** (or, more commonly, **foundations**) the element of an architectural structure which connects it to the ground, and transfers loads from the structure to the ground. Foundations are generally considered either shallow or deep.[1] Foundation engineering is the application of soil mechanics and rock mechanics (Geotechnical engineering) in the design of foundation elements of structures.

Basement

An unfinished basement used for storage and exercise

Chillon Castle (Château de Chillon) basement

Old Town medieval basements in Warsaw

A Stasi basement hallway

A **basement** or **cellar** is one or more floors of a building that are either completely or partially below the ground floor. Basements are generally used as a utility space for a building where such items as the boiler, water heater, breaker panel or fuse box, car park, and air-conditioning system are located; so also are amenities such as the electrical distribution system, and cable television distribution point. However in cities with high property prices such as London, basements are often fitted out to a high standard and used as living space.

Construction of basement in Top-Down method

Technology particulars:

- Top-down technology (downward) is the advanced method employed to substructure construction, other than the conventional method (upward).
- In this method, basement concrete slabs act as lateral bracing for the perimeter wall system. Ground level and first basement slabs are poured, with access holes left to allow excavation beneath. As each subsequent subgrade level is completed, the floors act as lateral bracing for the perimeter wall system.

Advantages:

- Working space and construction duration: it is not required a large working space for foundation excavation and saving cost by eliminating to construct the retaining wall. Especially for public transport works as traffic tunnels, this method helps to soon re-established trafffic road. And the top-down method of construction enables a high-rise superstructure and its sub-basement to be built simultaneously (popularly for civil works have basements) > accelerate construction.
- It is not required of the temporary strutting system (Bracsing System) to support the basement walls during excavation and construction of basement. That is cost-saving for constructiion. Temporary strut system is often very complex problems of space and very expensive construction.
- Construction schedules can be compressed by saving time in construction of substructures and high-rise superstructure at the same time (of course, we have increase the cost of strengthening

the lower part, and if the "savings" schedule can not cover the "cost" for safety strengthening, it's not necessary to do quick, top-down first and then the high-rise superstructuresthe as seen in Hanoi. After construction of the ground floor, we can separate completely superstructure and underground construction. You can construct simultaneously the basements and the superstructure.

- Foundation problems (the phenomenon of sludge, groundwater ...): attention that in dense urban areas of high-rise buildings, if open excavation (open cut) with diaphragm wall, deep foundation and water table to be lowered in the construction of the underground structures, adjacent buildings are not assured. (easily occur sliding roof excavation, subsidence, cracking ...), Top-down construction method to solve this problem.
- Construction of the basement with groud floor was constructed at first can partly reduce the impact of bad weather.

Construction of basement in Bottom-Up method

Technology particulars - Construction Sequence:

- Under this method, after the construction of pile and diaphragm wall, slurry pile or sheet pile surrounding the construction works, the contractor will conduct open-cut excavation to certain depth and then proceed installation of the strutting system (Bracsing System) to support the basement walls during excavation and construction of the basement. Depending on the depth of foundation mat, structure design may require one or more different layers of struts to ensure sufficient resistance against pressure of soil + ground water outside the project impact on the basement walls.
- After installation of strutting system is completed and ground is excavated to bottom level of foundation, the contractor will construct foundation,basement, superstructure of the building upward from the bottom in accordance with normal procedures.
- Strutting system can be used as hard core for structural beams / floor of the basement or will be removed after the basement floor shall afford all the pressure exerted on the basement walls.

Projects using Bottom-Up method in construction of basement: Using steel struts

- Oriental Hotel, No. 26-28 Tran Phu Str., Nha Trang; East Sea Tourism Company as real estate investor: Construction of 03 basement.
- Kinh Do Building, No. 93 Lo Duc, Ha Noi; Kinh Do Hotel Company Limited as investor: Construction of 03 basement.
- Business Center of Techcombank, No. 70-72 Ba Trieu Street, Hoan Kiem District, Hanoi; Viet Thanh Co Branch as investor: Construction of 02 basement.
- Treatment Building of central maternity hospital maternity; No. 43 Trang Thi Street, Hanoi, by central maternity hospital as investor: Construction of 02 basements with sheet piling and steel strut.

Temporary Shed

Temporary shed construction will be the first step before you bring your material near your site.

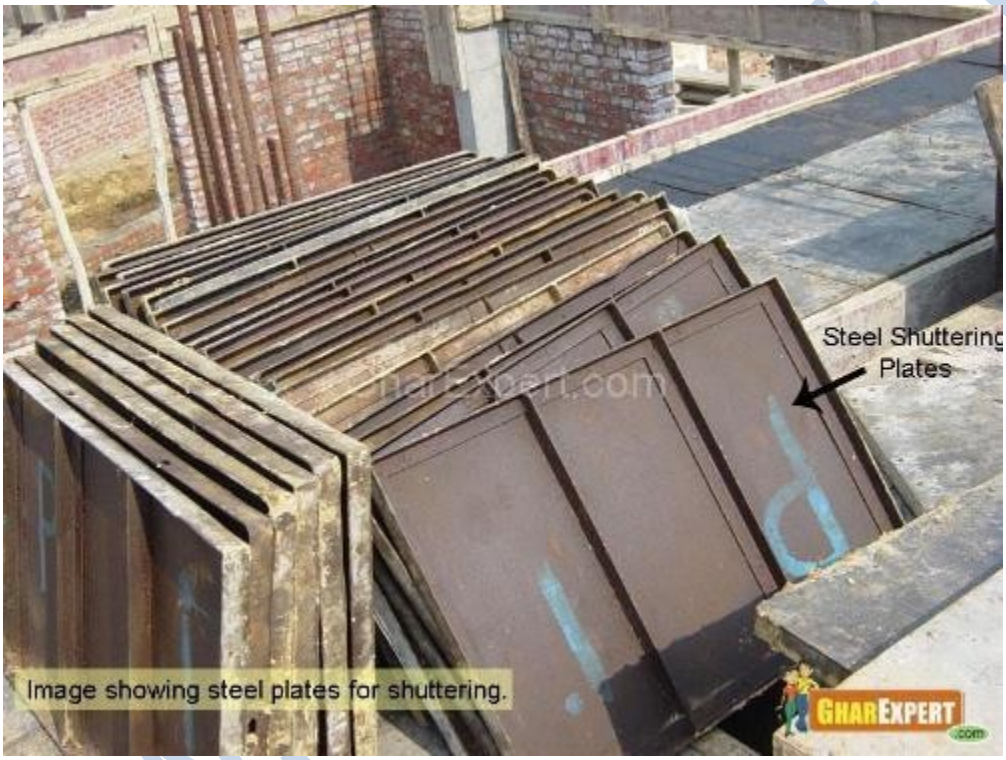
- You need to construct temporary Shed to keep your construction material and your watch men will stay there to look after your site and material
- You need to construct this in your neighbors site with their permission. So have a plan to contact them early
- Since it is temporary, you can consider using soil instead of cement.

Centering and Shuttering / Form Work

Shuttering or form work is the term used for temporary timber, plywood, metal or other material

used to provide support to wet concrete mix till it gets strength for self support. It provides supports to horizontal, vertical and inclined surfaces or also provides support to cast concrete according to required shape and size. The form work also produces desired finish concrete surface.

Shuttering or form work should be strong enough to support the weight of wet concrete mix and the pressure for placing and compacting concrete inside or on the top of form work/shuttering. It should be rigid to prevent any deflection in surface after laying cement concrete and be also sufficient tight to prevent loss of water and mortar form cement concrete. Shuttering should be easy in handling, erection at site and easy to remove when cement concrete is sufficient hard.



Steel plates for Steel Shuttering

Generally there are three types of shuttering.

- Steel Shuttering
- Wooden Planks Shuttering
- Temporary Brick Masonry Shuttering

Steel Shuttering

Steel shuttering plate is the best type of shuttering because this is water tight shuttering which can bear the load of cement concrete placed on it. This shuttering can be used for horizontal,

vertical or any other shape required for the work. It gives leveled surface which has good appearance. This shuttering gives good appearance and pattern work according to architectural drawings. If the plaster is required, the thickness of plaster will be less. Being water tight

shuttering, the strength of concrete with steel shuttering is comparatively higher.

Shuttering with the help of Steel Plates.

–

Note: As this is water tight shuttering, it is considered the best shuttering.

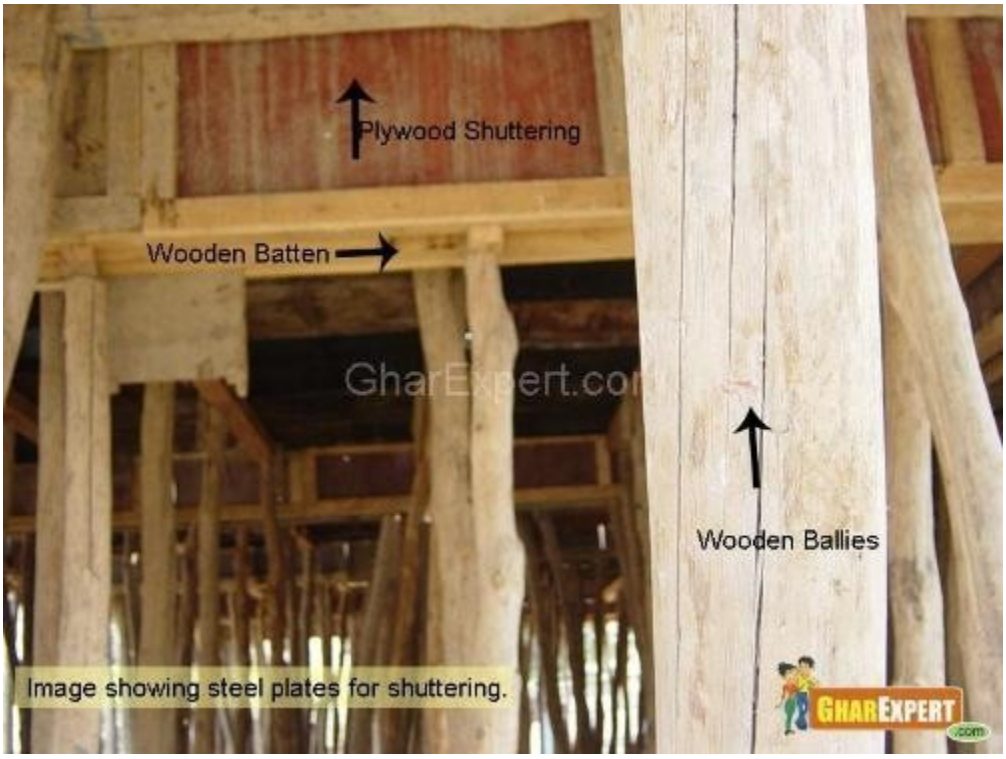
Wooden Plank Shuttering

Generally wooden planks shuttering is used by contractors because this shuttering is cheap and easily available. But this type of shuttering effects the strength of concrete and have some disadvantages which are given below.

Disadvantages

- This is not water tight shuttering as the size and thickness of planks differ and are not of same size. Due to this difference the water and cement flow to the ground from joints and reduce the strength of concrete.
- Bottom level of RCC slab is not in straight line and the surface being uneven, the thickness of plaster is more which remains weak.
- Due to leakage of cement slurry through joints, earth work below "'Ballies" may settle and create problems.

- In some cases wooden planks can not bear the weight of concrete. Due to low strength there is bending or deflection in wooden planks. Sometimes the planks may break.



Shuttering done with the help of wooden ballies and batten.

Temporary Brick Masonry Shuttering

In some cases labor contractor uses Temporary Brick Masonry in mud for vertical support of sides of beams, fascia etc. This shuttering should be avoided. This type of shuttering reduces the strength of cement concrete by soaking cement slurry. Also no proper compaction is made as this shuttering does not bear the pressure of vibrator. The surface of cement concrete given by this type of shuttering is uneven and the thickness of plaster is increased.

Precautions for Vertical Supports for RCC Beams, Slabs etc

- The "'Ballies" used for vertical support should not be less than 6" dia and these should be in one length without joints.
- Never allow bricks support of more than one or two bricks below a 'balli' to make required height.
- Cross Ballies or bracing should be done for better support to beam as well as slab.
- The wooden batten used below the plate should not be less than 5" in height.
- At the time of concreting one carpenter with helper having spare ballies, nails etc. should be deputed for watching any disturbances in ballies under shuttering.

Precautions for Cantilever slabs and Beams

- While doing shuttering of a cantilever part, outer edge of shuttering is 1” to 2" higher than inner edge with the wall.
- The bracing of vertical supports for cantilever portion should be tied to vertical supports of internal slab.
- The concrete should be laid on cantilever portion very gently.
- The shuttering should be removed after 28 days.

Recommended Period for Removal of Shuttering

- 48 hours for sides of foundations, columns, beams and walls.
- 7 days for underside of slab up to 4.5 meter span
- 14 days for underside of slab, beams, arches above 4.5 meter up to 6 meter span.
- 21 days for underside of beams arches above 6 meter span and up to 9 meter span.
- 28 days for underside of beams arches above 9 meter span.

Defects Found In Shuttering/Form Work

- The supports of form work are not in plumb and are not cross braced.
- The ground supports of ballies are poor and therefore settle the form work.
- There is insufficient thickness of shuttering plates/planks unable to bear lateral pressure imposed by wet concrete especially in columns.
- Shuttering plates are not cleaned and oiled or oiled with dirty oil.
- There are many insufficient and loose connections in centering and shuttering.
- The form work is removed before time. The work is not planned and designed properly.
- In case of beam shuttering proper provision for retaining side is not made. Hence the side of beam is not in proper line.
- The shuttering is poorly made with cracked and warped timber planks having lots of holes and knots.
- Through bolts for RCC walls form work for an underground tank is used. Later these holes made by bolts are not plugged.
- „Ballies“ are resting on bricks or brick pillars
- Ballies are not in one piece. Small ballies are used and these are not properly jointed. Also no additional cross bracing is provided at the joint.
- The supports under shuttering plates are not properly tight.
- The earth work under supports is not properly compacted before starting shuttering work.
- The bottom of „ballies“ are in wedge shape, not having proper base.

SLIPFORM CONSTRUCTION METHOD

Slipform construction is a method for building large towers or bridges from concrete. The name refers to the moving form the concrete is poured into, which moves along the project as the

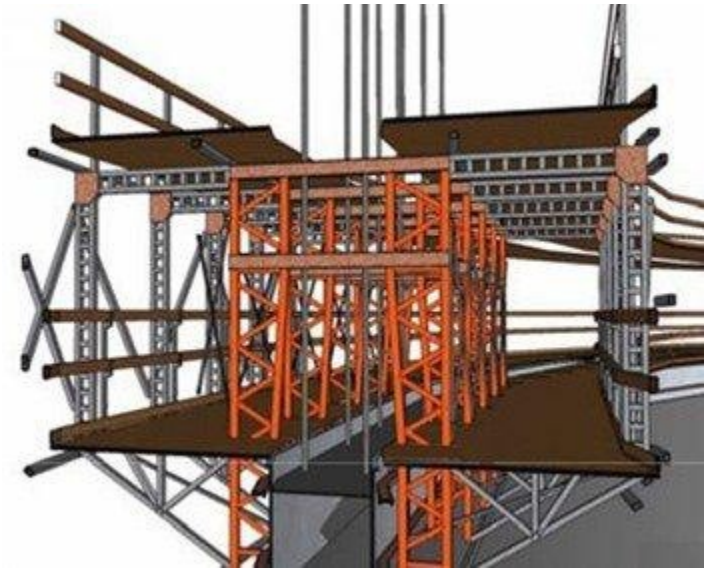
previously poured concrete hardens behind it. The technique has also been applied to road construction.

The technique was in use by the early 20th century for building silos and grain elevators.

Vertical slipform relies on the quick-setting properties of concrete requiring a balance between early strength gain and workability. Concrete needs to be workable enough to be placed to the formwork and strong enough to develop early strength so that the form can slip upwards without any disturbance to the freshly placed concrete.

A notable use of the method was the Skylon Tower in Niagara Falls, Ontario, which was completed in 1965. The technique was soon utilized to build the Inco Superstack in Sudbury, Ontario and the CN Tower in Toronto. It is the most common method for construction of tall buildings in Australia.

From foundation to rooftop of even the very tallest projects, with the system‟s hydraulic jacks, installing steel reinforcement and pouring concrete become much easier and faster, plus can be more efficiently controlled to assure the highest quality finished cement structure. SLIPFORM technology virtually eliminates unnecessary waste and hazards, making this construction system even more efficient and economical.



Benefits

- Careful planning of construction process can achieve high production rates
- Slip form does not require the crane to move upwards, minimising crane use.
- Since the formwork operates independently, formation of the core in advance of the rest of the structure takes it off the critical path – enhancing main structure stability.

- Availability of the different working platforms in the formwork system allows the exposed concrete at the bottom of the rising formwork to be finished, making it an integral part of the construction process.
- Certain formwork systems permit construction of tapered cores and towers.

- Slip form systems require a small but highly skilled workforce on site.

Safety

- Working platforms, guard rails, ladders and wind shields are normally built into the completed system.
- Less congested construction site due to minimal scaffolding and temporary works.
- Completed formwork assembly is robust.
- Strength of concrete in the wall below must be closely controlled to achieve stability during operation.
- Site operatives can quickly become familiar with health and safety aspects of their job
- High levels of planning and control mean that health and safety are normally addressed from the beginning of the work.

Other considerations

- This formwork is more economical for buildings more than seven storeys high.
- Little flexibility for change once continuous concreting has begun therefore extensive planning and special detailing are needed.
- Setting rate of the concrete had to be constantly monitored to ensure that it is matched with the speed at which the forms are raised.
- The structure being slipformed should have significant dimensions in both major axes to ensure stability of the system.
- Standby plant and equipment should be available though cold jointing may occasionally be necessary.

Scaffolding

Scaffolding, also called **scaffold** or **staging**, is a temporary structure used to support a work crew and materials to aid in the construction, maintenance and repair of buildings, bridges and all other man made structures. Scaffolding is also used in adapted forms for formwork and shoring, grandstand seating, concert stages, access/viewing towers, exhibition stands, ski ramps, half pipes and even art projects .

There are four main types of scaffolding used worldwide today. These are Tube and Coupler (fitting) components, prefabricated modular system scaffold components, H-frame / facade modular system scaffolds, and timber scaffolds. Each type is made from several components which often include:

- A base jack or plate which is a load bearing base for the scaffold.
- The standard which is the upright component with connector joins.
- The ledger (horizontal brace).
- The transom which is a horizontal cross section load bearing component which holds the batten, board or decking unit.

- Brace diagonal and/or cross section bracing component.
- Batten or board decking component used to make the working platform.
- Coupler a fitting used to join components together.
- Scaffold tie used to tie in the scaffold to structures.

- Brackets used to extend the width of working platforms.

Types Of Scaffolding And Their Uses

There is a surprising range of scaffolding types that can be used in construction and for other purposes. The general principle of a scaffolding construction, whether it is a static, rolling, or any other type of construction, remains the same – to provide a platform for workers and materials while work takes place.

Most often seen in construction projects, scaffolding structures and other constructs can be used for a variety of purposes. It is common to see scaffolding being used for repair work, to access high objects, for window cleaning tall buildings, and more. Choosing the most appropriate form of scaffold structure is an important stage in the project that you are undertaking.

Supported Scaffolding

This is the most commonly used form of scaffolding and is the type that you will see being used in construction work and on most other forms of work where elevation is required. Extra support may be required if the scaffolding will be long or required to take a lot of weight.

Supported scaffolding is built from the base upwards, and will normally be used wherever possible. It is considered the easiest, most convenient, safest, and most cost effective form of scaffolding construct. Different forms of supported scaffolding are available, and each will serve a very specific purpose and used in specific circumstances.

Suspended Scaffolding

Suspended scaffolding is typically suspended from a roof or other tall construct. It is most commonly used when it is not possible to construct a base, or where access to upper levels may be required, and the building of scaffolding from floor to the required level would be impractical.

This type of scaffolding is commonly used by window cleaners on tall buildings, but may also be seen where repairs are needed to the exterior of upper levels of similarly tall buildings. Supported scaffolding is usually preferred where possible.

Rolling Scaffolding

Rolling scaffolding is a similar type of construct to supported scaffolding, but rather than offering a stable base, it uses castor style wheels that enable the base to be moved. This is a

useful form of scaffolding when you need to complete work over a longer distance than a single scaffolding construction would permit.

The wheels should be locked when workers or materials are on the scaffolding, in order to ensure the safety of those using it, and those around it.

Mobile Scaffolding

There are a number of factors to consider when deciding whether to use static or mobile scaffolding. Ease of access is one such consideration, along with the amount of movement on the scaffolding itself. Where possible, you should rely on the use of a single scaffolding structure, or a number of structures, because mobile units, while perfectly safe when well-constructed and used properly, do pose more of a hazard than mobile constructs.

Most scaffolding is considered semi-permanent. Once used, it can be taken apart and moved to another location before it is constructed again. Fixed scaffolding can be left in position for longer periods of time, making it especially useful in those situations where permanent access may be needed to elevated positions.

Aerial Lifts

Aerial lifts should be used where workers need to be able to access a number of levels in order to be able to complete a construction. For example, if building work is being completed on the outside of a multi-storey property and both workers and materials will be needed to work outside two or more floors, at different times, then an aerial lift will make it easier and safer to lift even large amounts of material, and multiple workers to the levels required.

DESHUTTERING in simple means, the process of removing the shuttering (Formwork for Concrete).
Assuming standard conditions of workmanship and quality of materials, you can refer to the following time-frames for the removal of forms.

Walls/Columns & Vertical faces of structural members - 24 Hrs
Slab Spanning up to 4.5 m - 7 days
Slab Spanning more than 4.5 m - 14 days
Beams and arches spanning up to 6 m - 14 days
Beams and arches spanning more than 6 m - 21 days

SIMPLY SUPPORTED AND CONTINUOUS SPANS SHALL BE DESHUTTERED FROM MIDSPAN (CENTRE)

CANTILEVERS SHALL BE DESHUTTERED FROM FREE END TOWARDS SUPPORTS

*The above mentioned timeframe is excluding the day of casting

FABRICATION AND ERECTION OF STRUCTURAL STEELWORK

FABRICATION AND ERECTION OF STRUCTURAL STEELWORK

1.0INTRODUCTION

The steel-framed building derives most of its competitive advantage from the virtues of prefabricated components, which can be assembled speedily at site. Unlike concreting, which is usually a wet process conducted at site, steel is produced and subsequently fabricated within a controlled environment. This ensures high quality, manufacture offsite with improved precision and enhanced speed of construction at site. The efficiency of fabrication and erection in structural steelwork dictates the success of any project involving steel-intensive construction. Current practices of fabrication and erection of steel structures in India are generally antiquated and inefficient. Perhaps, this inadequate infrastructure for fabrication is unable to support a large growth of steel construction. In India, the fabrication and erection of structural steelwork has been out of the purview of the structural designer. Nevertheless, in the future emerging situation, the entire steel chain, i.e. the producer, client, designer, fabricator and contractor should be able to interact with each other and improve their efficiency and productivity for the success of the project involving structural steelwork. Hence it becomes imperative that structural designers also must acquaint themselves with all the aspects of the structural steel work including the "fabrication and erection," and that is the subject matter of the present chapter to briefly introduce good fabrication and erection practices.

2.1 FABRICATION PROCEDURE

Structural steel fabrication can be carried out in shop or at the construction site. Fabrication of steelwork carried out in shops is precise and of assured quality, whereas field fabrication is comparatively of inferior in quality. In India construction site fabrication is most common even in large projects due to inexpensive field labour, high cost of transportation, difficulty in the transportation of large members, higher excise duty on products from shop. Beneficial taxation for site work is a major financial incentive for site fabrication. The methods followed in site fabrication are similar but the level of sophistication of equipment at site and environmental control would be usually less. The skill of personnel at site also tends to be inferior and hence the quality of finished product tends to be relatively inferior. However, shop fabrication is efficient interms of cost, time and quality.

Structural steel passes through various operations during the course of its fabrication.Generally, the sequence of activities in fabricating shops is as shown in Table1. These quence and importance of shop operations will vary depending on the type of fabrication required. All these activities are explained briefly in the subsequent parts of the section.

FABRICATION AND ERECTION OF STRUCTURAL STEELWORK

Sequence of activities in fabricating shops

Sequence of Operation

Surface cleaning

Cutting and machining

Punching and drilling

Straightening, bending and rolling

Fitting and reaming

Fastening (bolting, riveting and welding)

Finishing

Quality control

Surface treatment

Transportation

2.2 Surface cleaning

Structural sections from the rolling mills may require surface cleaning to remove millscale prior to fabrication and painting. Hand preparation, such as wire brushing, does not normally conform to the requirements of modern paint or surface protection system. However in some applications manual cleaning is used and depending on the quality of the cleaned surface they are categorised into Grade St-2 and Grade St

-

3. 1. Squared rubble masonry: The rubble masonry in which the face stones are squared on all joints and beds by hammer dressing or chisel dressing before their actual laying, is called squared rubble masonry.

1. Squared rubble masonry: The rubble masonry in which the face stones are squared on all joints and beds by hammer dressing or chisel dressing before their actual laying, is called squared rubble masonry.

There are two types of squared rubble masonry.

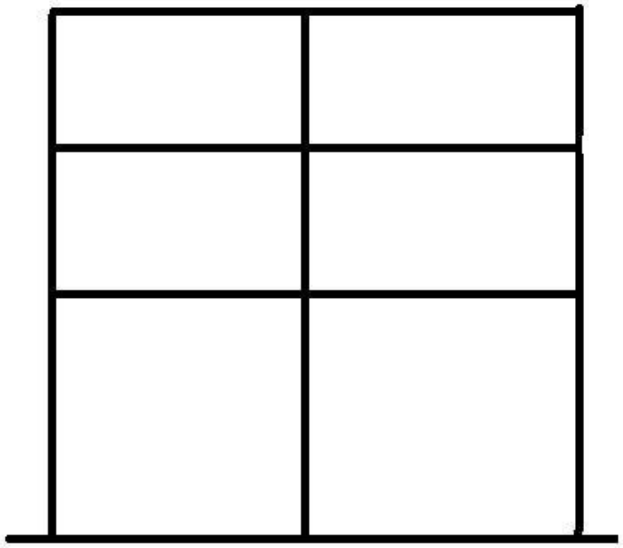
a. Coursed Square rubble masonry: The square rubble masonry in which chisel dressed stones laid in courses is called coarse square rubble masonry. This is a superior variety of rubble masonry. It consists of stones, which are squared on all joints and laid in courses. The stones are to be laid in courses of equal layers. and the joints should also be uniform.

Suitability: Used for construction of public buildings, hospitals, schools, markets, modern residential buildings etc and in hilly areas where good quality of stone is easily available.

Frame Structures - Types of Frame Structures

Frame structures are the structures having the combination of beam, column and slab to resist the lateral and gravity loads. These structures are usually used to overcome the large moments developing due to the applied loading.

Types of frame structures



Frames structures can be differentiated into:

1. Rigid frame structure

Which are further subdivided into:

- Pin ended

Fixed ended

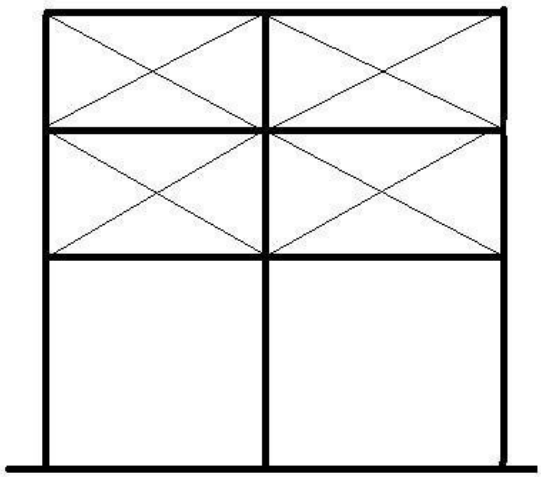
2. Braced frame structure

Which is further subdivided into:

Gabled frames
Portal frames

Rigid Structural Frame

The word rigid means ability to resist the deformation. Rigid frame structures can be defined as the structures in which beams & columns are made monolithically and act collectively to resist the moments which are generating due to applied load.



Rigid frame structures provide more stability. This type of frame structures resists the shear, moment and torsion more effectively than any other type of frame structures. That's why this frame system is used in world's most astonishing building Burj Al-Arab.

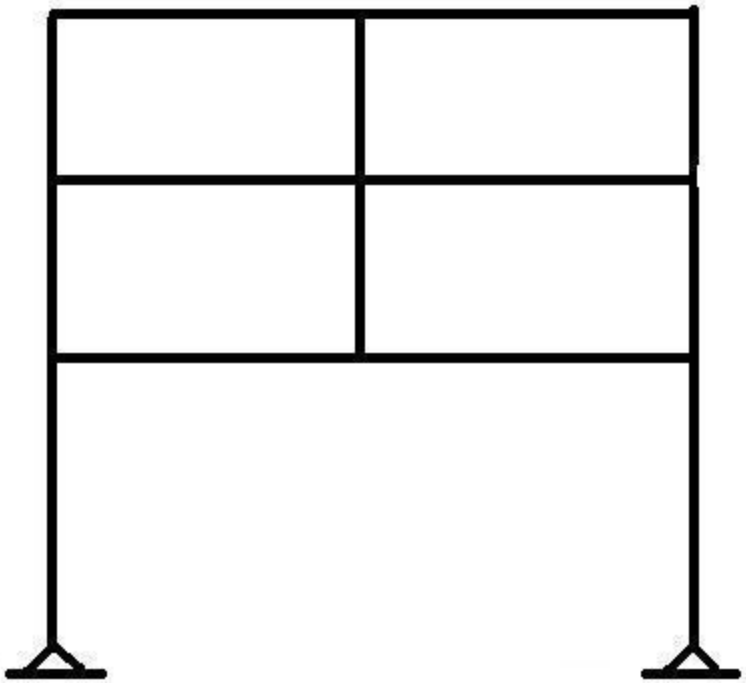
Braced Structural Frames

In this frame system, bracing are usually provided between beams and columns to increase their resistance against the lateral forces and side ways forces due to applied load. Bracing is usually done by placing the diagonal members between the beams and columns.

This frame system provides more efficient resistance against the earthquake and wind forces. This frame system is more effective than rigid frame system

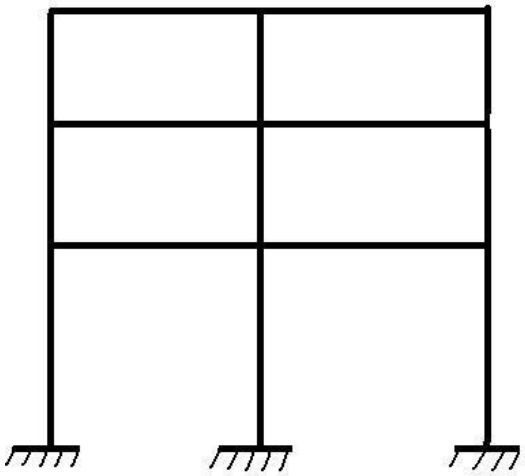
Pin Ended Rigid Structural Frames

A pinned ended rigid frame system usually has pins as their support conditions. This frame system is considered to be non rigid if its support conditions are removed.



Fix Ended Rigid Frame Structure:

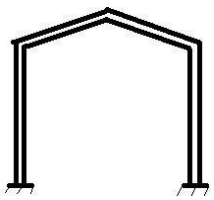
In this type of rigid frame systems end conditions are usually fixed.



<u>Gabeled Structural Frame:</u>

Gabled frame structures usually have the peak at their top. These frames systems are in use where there are possibilities of heavy rain and snow.

Portal Structural Frame

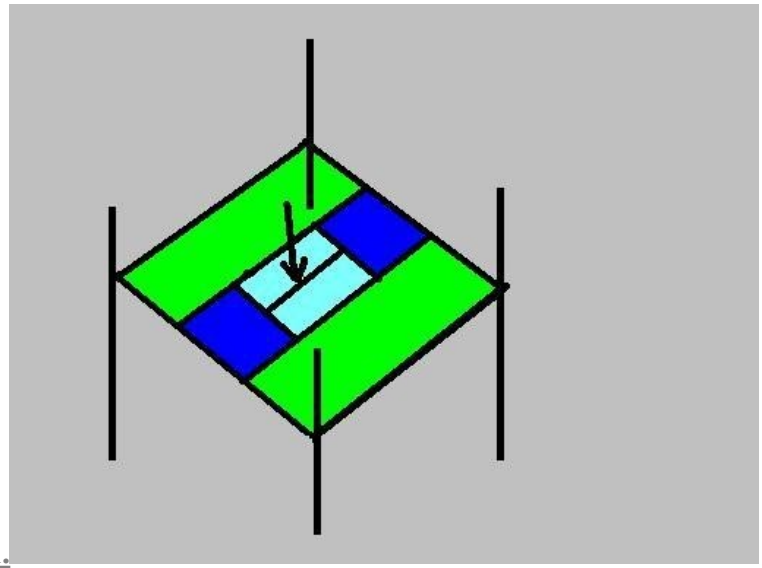


Portal structural frames usually look like a door. This frame system is very much in use for construction of industrial and commercial buildings

Load path in Frame Structure:

It is a path through which the load of a frame structure is transmitted to the foundations. In frame structures, usually the load path is:

Load first transfers from slab to beams then to from beam to columns, then from columns



it transfers to the foundation.

Advantages of Frame Structures

1. One of the best advantages of frame structures is their ease in construction. it is very east to teach the labor at the construction site.
2. Frame structures can be constructed rapidly.
3. Economy is also very important factor in the design of building systems. Frame structures have economical designs.

Disadvantages of Frames:

In frames structures, span lengths are usually restricted to 40 ft when normal reinforced concrete. Other wise spans greater than that, can cause lateral deflections.

Comparison of Frame structures with Normal Load bearing Traditional High Rise Building

Selection of frame structures for the high rise building is due to their versatility and advantages over the normal traditional load bearing structures. These include the following:

Actually the performance of load bearing structures is usually dependent on the mass of structures. To fulfill this requirement of load bearing structures, there is the need of increase in volume of structural elements (walls, slab).this increase in volume of the structural elements leads toward the construction of thick wall. Due to such a type of construction, labor and construction cost increases. in construction of thick wall there will be the need of great attention, which will further reduce the speed of construction.

If we make the contrast of load bearing structures with the framed structures, framed structures appear to be more flexible, economical and can carry the heavy loads. Frame structures can be rehabilitated at any time. Different services can be provided in frame structures. Thus the frame structures are flexible in use.

Braced domes may be fabricated in any of several common grid configurations. With different configurations, the dome performance varies considerably affecting both its competitiveness and suitability for specific applications. The study presented in this paper is an assessment of the most commonly adopted dome configurations and their effect on the dome characteristics such as the stiffness/weight value, member stress distribution, number of joints and members, degree of redundancy and cost. The study is parametric and covers wide variations of dome span/rise ratio and boundary conditions. The results of this study could be of significant value to the design of future braced dome structures.

How to Lay Brick

1. **Squared rubble masonry: The rubble masonry in which the face stones are squared on all joints and beds by hammer dressing or chisel dressing before their actual laying, is called squared rubble masonry.**
2. **There are two types of squared rubble masonry.**
3. **Coursed Square rubble masonry: The square rubble masonry in which chisel dressed stones laid in courses is called coarse square rubble masonry. This is a superior variety of rubble masonry. It consists of stones, which are squared on all joints and laid in courses. The stones are to be laid in courses of equal layers. and the joints should also be uniform.**
4. **Suitability: Used for construction of public buildings, hospitals, schools, markets, modern residential buildings etc and in hilly areas where good quality of stone is easily available.**

Step 1

Begin Laying Bricks

A mason's line acts as a guide for setting bricks in perfectly straight rows. It's made of two mason blocks with slots to hold a mason line.

Affix the blocks to either end of the row of bricks, with the line pulled tight. The top of each brick in the row should just touch the top of the line.

Step 2

Guide the Bricks

A story pole is a strip of wood that acts as a guide for laying bricks. Use a pencil to mark the height of each course of bricks, including the mortar joints, on the pole.

Step 3

Apply Mortar

Safety Tip: When working with mortar, always wear gloves and a mask or respirator.

Use a spade trowel to apply a generous amount of mortar to each layer of brick. Score a line through the center of the pile of mortar to allow it to spread. "Butter" the brick with mortar, spreading mortar on the sides that will affix to the bricks beside them. Use the handle of the trowel to knock each brick into place and to release any air bubbles that may be in the mortar underneath.

Add a Comment | 0 Comments

Step 4

Remove Excess Mortar

Using the sharp end of the trowel, scrape off any excess mortar that spreads beyond the joint. Finish cleaning off any other debris with a brush. Holding a spade trowel at a 30-degree angle, carve small lines between the bricks and the mortar. The lines will help protect the wall from the effects of precipitation.

Step 5

Cut Bricks

Most walls require smaller bricks at their ends. Before cutting a brick, place it in a bed of sand or dirt to absorb the shock of the blow. Place the sharp end of a brick chisel at the line where you want to cut. Use a hammer to tap the end of the chisel, scoring lines on all four sides where the brick must be cut.

After scoring the lines, hold the chisel on one of them, slightly angled toward the side of the brick that will be kept and used on the wall. With your other hand, strike the handle of the chisel with a hammer. The blow should break the brick cleanly in two.

Top tips to optimally use conventional waterproofing techniques

While the first part of this two-part series examines conventional waterproofing systems and offers tips to use them for optimum effect, the second part will discuss modern waterproofing techniques.

Construction chemicals providing strength to construction industry

- Waterproofing begins to fight weak monsoon
- Chettinad Cement to acquire AP-based Anjani Portland Cement
- Cement firms remain pessimistic after bad Q2 run
- BASF to build centre for flooring and waterproofing systems in Germany

Waterproofing of building to prevent the ingress of water is an activity, which, perhaps is practiced in one form or the other, ever since the first building was built on earth. The methodology has been changing with the changes in the architectural designs and with the availability different building materials in construction.

In the initial stages when stone was the main building construction material placed in position with mud or lime mortar the emphasis used to be to make the construction in such a way that the rainwater does not collect on the roofs. Hence old architecture relied mainly on dome structures or slanting roofs. The slow speed of such construction and unaffordability of common man to build such structures for their own dwelling, made constant evolution and development in the construction material technology.

With these developments the concepts of waterproofing also changed. Now in present day construction wherein the ordinary portland cement and its blends with puzzolonic and slag materials has come to stay a lot of compatible alternatives are available for a builder to choose from various waterproofing systems. Some systems are old and conventional but still practiced successfully and some are modern systems designed taking the material and structural behaviour into consideration.

There are some compounds, which are used in plastic concrete to make it less permeable to water. These compounds are known as integral waterproofing compounds. They are based on plasticising and air-entrainment or water repellence principles. These are used as a good waterproofing precautions when other factors such as good mix-design, proper mixing/placing, compacting/curing etc are taken care of. This subject of integral waterproofing compounds requires in depth discussion hence will not be taken up here. Similarly there are some water proofing techniques for vertical surfaces. These techniques are also used for preserving heritage buildings by stopping/minimising the aging process of these buildings.

For solving water seepage problems, customers use both conventional as well as modern waterproofing techniques.

Some of the old and conventional waterproofing systems are as follows:

- Brick bat coba system or lime terracing
- Bituminous treatment
- Metallic sheet wrapping
- Polyurethane based waterproofing treatment
- Epoxy based waterproofing treatment
- Box-type waterproofing system

Brick bat coba system
This system was developed during the initial stages of flat roof construction with lime mortar burnt clay brick pieces. This system involved laying lightweight mortar on the roof and spreading it to give gentle slopes for draining away the rainwater immediately. The mortar consisted of lightweight brick pieces as aggregates and ground brick with lime as binding matrix.

During British rule this system became more popular not because of its waterproofing efficiency but because of its efficiency in keeping the interiors cool. Some applicators developed better skills in laying these systems, with neatly finished top with lines engraved on top of plastic mortar now known as IPS. Some practiced embedding broken tile or ceramic pieces in the plastic mortar and called it china mosaic.

This type of system remained most popular with multi-storeyed construction in all major cities. The system lasts up to 15 years if done by skilful applicators. This system may be considered more from its weather proofing abilities rather than its waterproofing qualities. Once water starts entering into the brickbat coba the brick pieces absorb too much of water and the roof becomes an invisible pond of water continuously causing leakage and increasing burden on the roof slab. It will be highly beneficial if brick-bat coba is laid on a flexible waterproofing membrane as water proofing as well as economical weather proofing can be achieved with this system.

Bituminous treatment
Discovery of petroleum and its products and by-products has given the construction industry an indispensable product in the form of bitumen. Bitumen is more commonly used in the form of felt or flexible membrane formed by sandwiching jute fabric or fibreglass/polypropylene mats with chemically modified bitumen. These membranes are laid on the roofing over a bitumen primer. There are two types of membranes one is cold applied and the other hot applied which means one needs to heat the edges of the felt with a torch so that they melt and stick to the second layer in the overlap area.

On the RCC flat roofs the bitumen felts have not been successful because of the unacceptable black appearance and inaccessibility of the terrace for other social uses. Technically it is not preferred because bitumen layer or felt on the terrace not only makes it watertight but also airtight. Concrete has the breathing property. It takes water/moisture and breathes out water vapour. Hindrance of this breathing property of concrete develops pore pressure, which causes blisters in the felt.

After a few seasons the blisters multiply and eventually delaminate the felt from the concrete surface. Hindrance of breathing property of concrete makes the concrete weak. But on the asbestos cement sheets and zinc sheets in factory roofs, this bitumen felt is the only dependable waterproofing system. Hence all factory roofs in India adopt this water proofing system.

Bitumen is very effective in waterproofing of basements from outside. Bitumen primers have very successfully been used as damp-proof course in earlier days. This practice is slowly discontinued for whatever reasons now very few engineers now believe that this was in practice once. As consequence of this absent DPC we have a lot of cases of rising dampness, which we tend to attribute to wrong reasons

such as the quality or salinity of sand etc. Bitumen still is the product of first choice where it is commonly recommended, in areas such as industrial roof waterproofing, basement waterproofing, and damp-proof

course. More over bitumen is the most economical product available for waterproofing.

Metallic sheet wrapping
Because of the non-existence of suitable expansion joint filling compounds before the discovery of poly-sulphides, a complex procedure used to be adopted to treat expansion joints, in concrete dams and such huge structures utilising thick copper sheets. An extension of this practice was to try thin foils of copper and aluminium for wrapping the concrete surfaces with nagging leakage problems.

Unavailability of common joining material for these metal foils and the concrete and mortar created weakness in the system at the joints. This discouraged the system in its infancy only. But there after the metal manufacturers have been trying to market this type of waterproofing system with improved adhesives as and when the metal market slumped.

Polyurethane based waterproofing treatment
Polyurethane consists of two liquid components one is called the base component and the other is called reactor or curing agent. Base is a polyol and the reactor is an isocyanide such as TDI or MDI. There are various grades of polyols and so also there are numerous isocyanides. The combination of these two ingredients results in a formation liquid applied rigid membrane or a foam depending upon the selection.

In waterproofing, this rigid liquid membrane was tried with fibreglass reinforcing mats. The systems failed because coefficients of thermal expansion of concrete and rigid PU membrane being different lateral movement or creep occurred with the passage on one working climatic cycle. When exposed to ultra violet rays or direct sunlight most polyurethane rigid membranes became brittle and crumbled.

Apart from this the application of polyurethane coating needed very rigorous surface preparation. The surface needed to be neutralised by removing alkalinity from the concrete surface through acid itching then washing and blowtorching to make the surface bone dry. This kind of surface preparation with acids angered the civil engineering community and the product ceased to be used as waterproofing material apart from its several failures. Never the less continuous research in the polyurethane technology gave the construction industry excellent sealant for glazing industry and foams for thermal insulations. The new generation polyurethanes, which are alkali stable and water-based, may find better applications in waterproofing industry.

Epoxy based waterproofing system
Like polyurethane is also a two-component system having a base resin and a reactor or curing agent. Base resin is obtained by dissolving bis-phenol A flakes in epichlorohydrin. This base is available in various viscosity ranges to suit different application conditions. The curing agent is an amine/polyamine aliphatic or aromatic, or an amine-adduct for general applications and polyamide or an amino-amide for coating purposes. After mixing base and reactor components the resultant viscous liquid or paste if some fillers are added to it can be brush applied like a paint or trowel applied like a mortar.

Here also epoxies not withstanding the alkalinity of concrete and the concrete needs to be acid washed and neutralised, which the civil engineers hated. Here again the coefficient of thermal expansion of concrete and epoxy being different the compatibility of epoxy in waterproofing exposed concrete surfaces

such as roofs became limited. Later the use of epoxy in waterproofing was discarded. But epoxies have come to stay in civil engineering industry as bonding agents, floor & wall coatings, coatings for food processing units, operation theatres and computer and pharmaceutical industries.

Box type waterproofing
This type of water proofing system is used only for basement waterproofing or waterproofing structures below the ground level from outside to prevent leakages of subsoil water into the basement.

In this method, limestone slabs (Shahabad Stones) are first laid in the excavated pit over blinding concrete in a staggered joint fashion to avoid the continuity of the mortar joints. The joints are effectively filled with rich mortar admixed with integral waterproofing compound and cured. Over this the raft is laid and shear/brick walls constructed. The limestone slabs are erected around the walls in a similar fashion leaving a gap of one to two inches between the external surface of the wall and the inner face of the stone surface. The joints again effectively sealed with rich admixed mortar and the same mortar is filled in the gap between the wall and the stones. This stonework is continued up to ground level. In this system the raft and the sidewalls are protected from direct exposure to sub soil water.

This system works on two principles of common sense. First, the area exposed to subsoil water is only the area of the joint where as the whole stone is impervious to water, hence only a fraction of area, that is, that of the joint is exposed to subsoil water, when the joint itself is filled with rich and quality mortar. Second, the path of water to reach the raft or the sidewall is elongated. This elongated path is through quality mortar. This system seeks to delay the occurrence of leakages in the basements. A lot of building structures are waterproofed by this system. A few notable successes are to its credit especially in five star hotels and of-course there are a few failures as well.

5 Types Of Roofs To Consider

Several **types of roofs** are available for residential construction. Different materials are chosen according to their various qualities, advantages and disadvantages. Roofing a house is quite a

cost-intensive affair and you need to be prepared with sound information prior to making your investment. Here‟s an overview of some of the most used types of roofing:

1. Wood Shingle Roofing

Wood shingles are also known as shakes and they are especially ideal if you appreciate naturally beautiful looks. They will gracefully age with your house while retaining their aesthetic appeal. Wood shingle roofing is quite expensive though it makes up for the cost with its durability. Most people have concerns with this type of roofing especially with issues like fire, splitting, rotting and molding. Always invest in shingles that have been treated with special protective glazes and finishes.

2. Slate Roofing

Another beautiful yet very costly roofing material is slate and is especially appropriate if your house is in the French or Colonial design style.

Slate roofing is ideally composed of thin layers of rock and as such the roof is bound to be quite heavy. For this reason it is advisable to first put in place adequate structural support. Laying this type of roof can be quite complicated for a DIY project and the installation is better off when done by a licensed contractor.

3. Tile Roofing

Tile roofing is an option that goes very well with your house if it is in the Spanish or Mediterranean design. There are two types of roofing tiles: clay tiles and concrete tiles.

Tiles are generally laid down on relatively new houses that have adequate structural support since tiles, like slates, are quite a heavy load. The services of a professional contractor will come in handy if you are not confident about taking on the task yourself.

Tile roofing is also quite costly but if properly maintained it can give proper service for up to 50 years.

4. Metal Roofing

Metal roofing options are fast gaining a good reputation in building circles despite their initially high costs. These roof types boast durability as well as low maintenance qualities that extend their life beyond other conventional roof types.

In terms of design and style you‟ll be glad to know that it‟s possible to get metal roofing that has been made to resemble different roofing types including slate, wood shingles and cedar.

5. Asphalt Roofing

Certainly the most affordable of roofing types has to be asphalt. Asphalt shingles that are made from the conventional highway asphalt are the least expensive. You can also invest in the costlier option that is known as architectural shingles.

Cheap asphalt shingles are not the best if you intend to have a stylish roof. They will also disappoint with their short lifespan. Architectural shingles are much more presentable.

Both of these options are quite prone to scarring and may also succumb to the occasional mildew depending on the weather. They are also not environmentally-friendly and upon replacing them you‟ll need to take the waste to a landfill.

Acoustic, Thermal, Fire and Safety

Acoustic, Thermal, Fire and Safety

Isover leads the way in terms of performance criteria in each of these three critical areas. Acoustic, Thermal, Fire and Safety.

Acoustic

Noise reduction is an increasing priority in both new build and renovation projects. Isover offers a range of high performance acoustic installation solutions.

Our Acoustic Partition Roll (APR 1200) is the only acoustic insulation product that forms part of the British Gypsum SpecSure® Lifetime Warranty.

Isover RD Party Wall Roll is a proprietary component of three masonry party wall Robust Details constructions, E-WM-17, E-WM-20 and E-WM-24.

Thermal

With an impressive array of products, in both roll and batt formats, to suit every conceivable application and a wide range of lambda values the Isover thermal insulation range is second to none.

Isover also leads the way in simplifying the identification and selection of the correct product for a given application. Our new packaging style incorporates a unique indicator of relative thermal performance without the need for a detailed understanding of lambda values. Simply select from

our three tier rating of standard, high and ultra thermal performance, which is clearly marked on each pack and also detailed in our new Packaging Guide.

Definition of lambda:
The ease by which heat energy travels through a material is measured by lambda. The lower the lambda value the more difficult it is for heat to flow through the insulation.

Fire & Safety

All of our glass mineral wool products are non-combustible, have the highest possible Euroclass A1 fire rating classification, and do not produce any toxic fumes in the event of fire.

Many are also fire rated, offering added protection against fire and providing vital time for building occupants to evacuate.

Isover provides fire safe insulation solutions to help protect your most precious resources and provide a safer building environment.

UNIT III

SUB STRUCTURE CONSTRUCTION

BOX JACKING

EXPLANATION

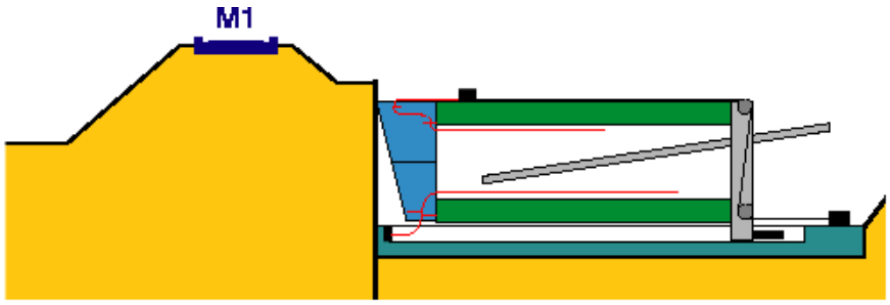
- •It is the process in which a pre-cast R.C.C box or a rigid box is pushed into the soil with the help of hydraulic jacks
- •It is non-intrusive method beneath the existing surface.
- •It is more often used when a subway or a aqueduct or a underground structure is to be constructed.
- •It enables the traffic flow without disruption.

R.C.C BOX JACKING

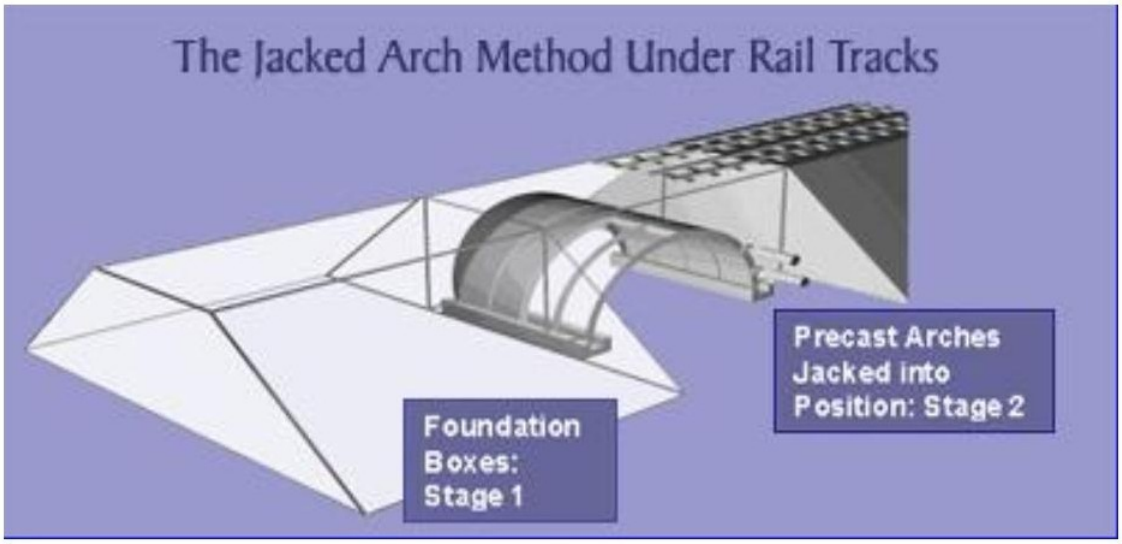
- •First the box section is designed and cast at the site or can be transported to the site according to the requirement.
- •The foundation boxes are jacked into the ground designed to carry the dead and the live loads.
- •Then the high capacity jacks are placed at the back and it pushes the box into the ground.
- •A purpose designed tunneling shield is provided in the front end.

- •Then the box is jacked carefully through the earth.
- •Excavation and jacking are done in small increments in advance.
- •Measures should be taken to prevent the soil being dragged towards the box.

R.C.C BOX JACKING



ARCHED JACKING



THRUST BORING METHOD

- •It is a process of simultaneously jacking the pipe through the earth while removing the earth inside the box by means of a rotating auger.
- •Unstable conditions- the end of auger is kept retracted inside the encasement so as not to cause voids.
- •Stable conditions- the auger can be successfully extended beyond the encasement.
- •This can be successfully used in any kind of soil conditions.

PROBLEMS ENCOUNTERED IN JACKING

- •Settlement of the above ground.
- •Seepage of ground water.
- •Caving in of soil etc.

FREEZING OF GROUND

- •This method is used when we encounter the problem of ground water seepage and settlement of ground.
- •In this method a brine solution is continuously passed through the pipes fixed in the soil.
- •The temperature of the brine would be -30°c.

- •So when this brine solution is circulated through these pipes it freezes the ground and the ground behaves like an ice block.

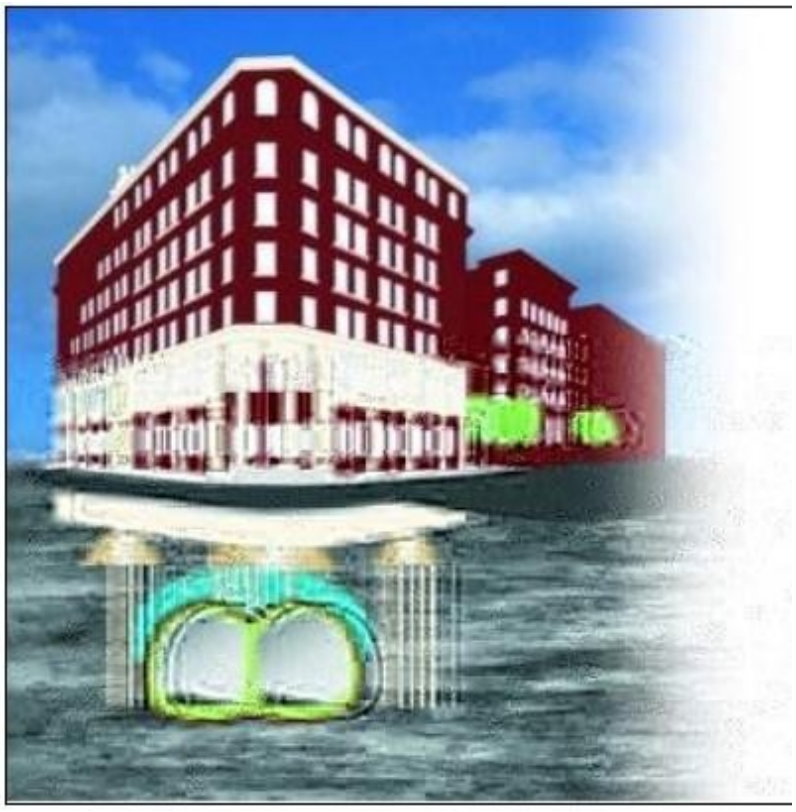
- •The spacing of the freezing pipes will vary according to the type of soil, its permeability and other factors.
- •Generally it is kept at a spacing of 1.2 m

PROBLEMS IN FREEZING

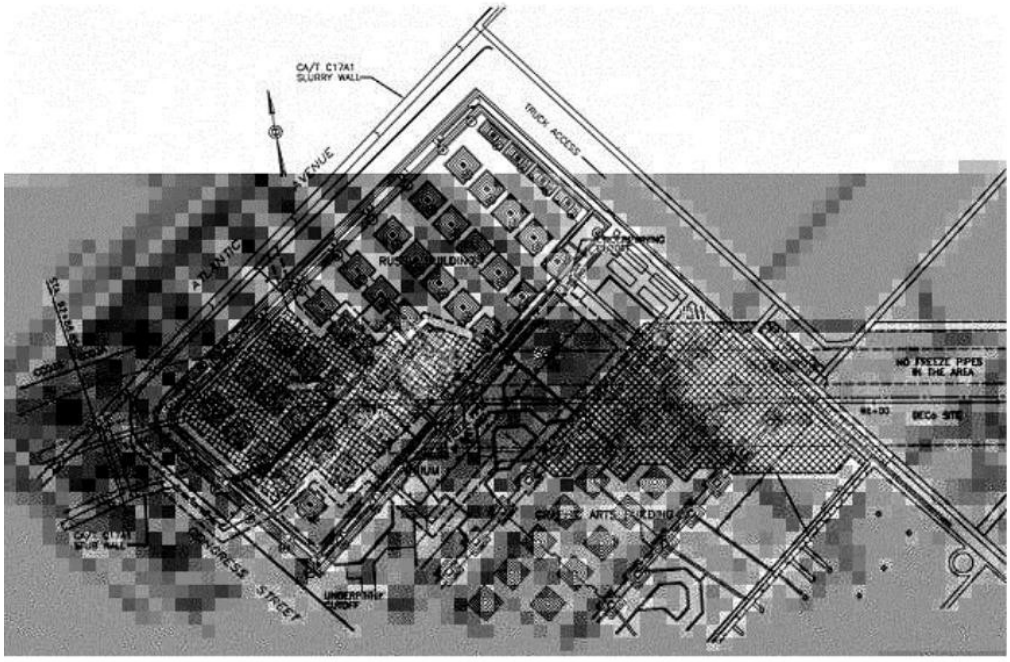
- •The main problem in the freezing method is the UPHEAVING of the above ground.
- •To avoid the upheavement problem we should be careful in the ground freezing process and the temperature of the brine solution.

CASE STUDY - SOUTHERN BOSTON PIERS TRANSIT WAY

- •The carriageway has to go beneath – a Russian building,100 year old
- •2m thick soil was frozen.
- •Under pinning was also done using mini piles.



PLAN OF THE RUSSIAN BUILDING



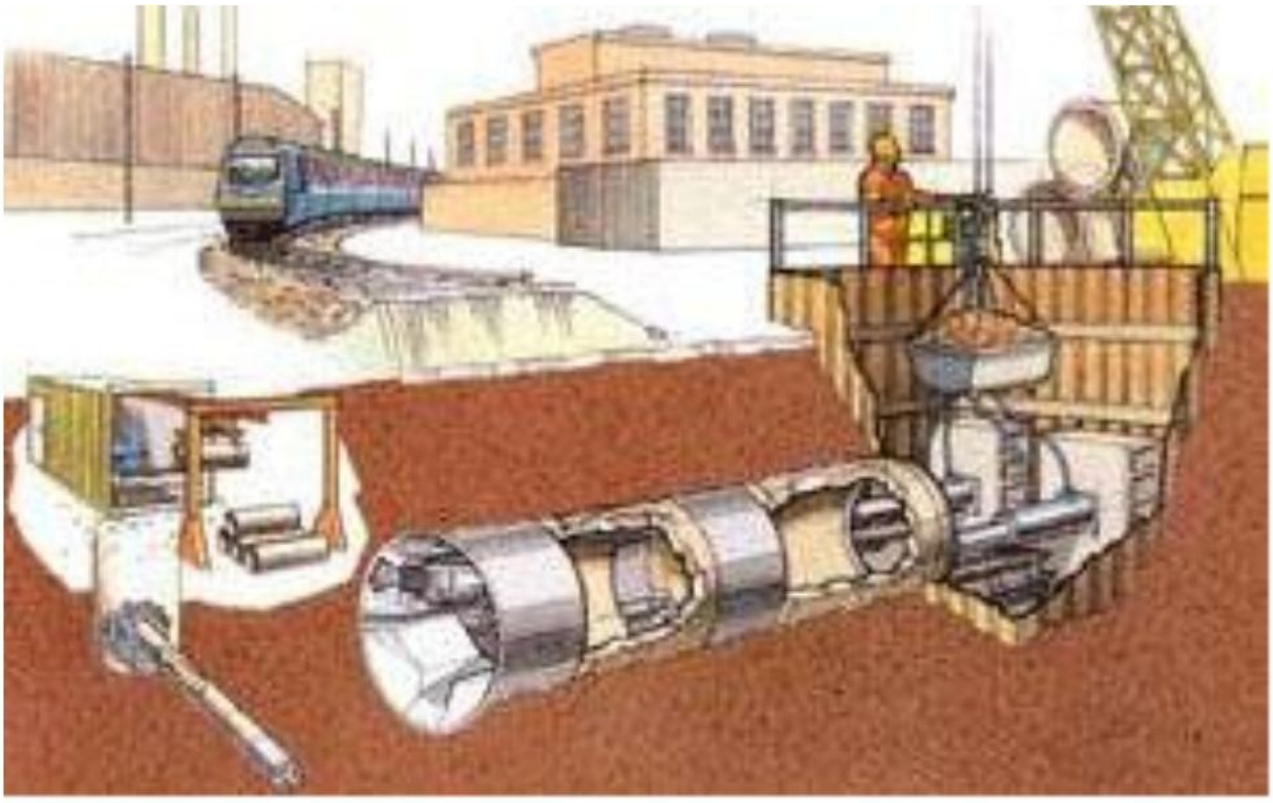
ADVANTAGES

- •Timely completion of project.
- •No disruption of traffic.
- •No need to divert the traffic.

DISADVANTAGES

- •Cost of project increases.
- •Skilled personnel required.
- •Safety precautions to be done properly.

PIPE JACKING



ABOUT THE TECHNIQUE

- •It is generally referred as “Micro tunneling”
- •Pipes are pushed through the ground behind the shield using powerful jacks.
- •Simultaneously excavation takes place within the shield.
- •This process is continued until the pipeline is completed.
- •The method provides a flexible, structural, watertight, finished pipeline as the tunnel is excavated.

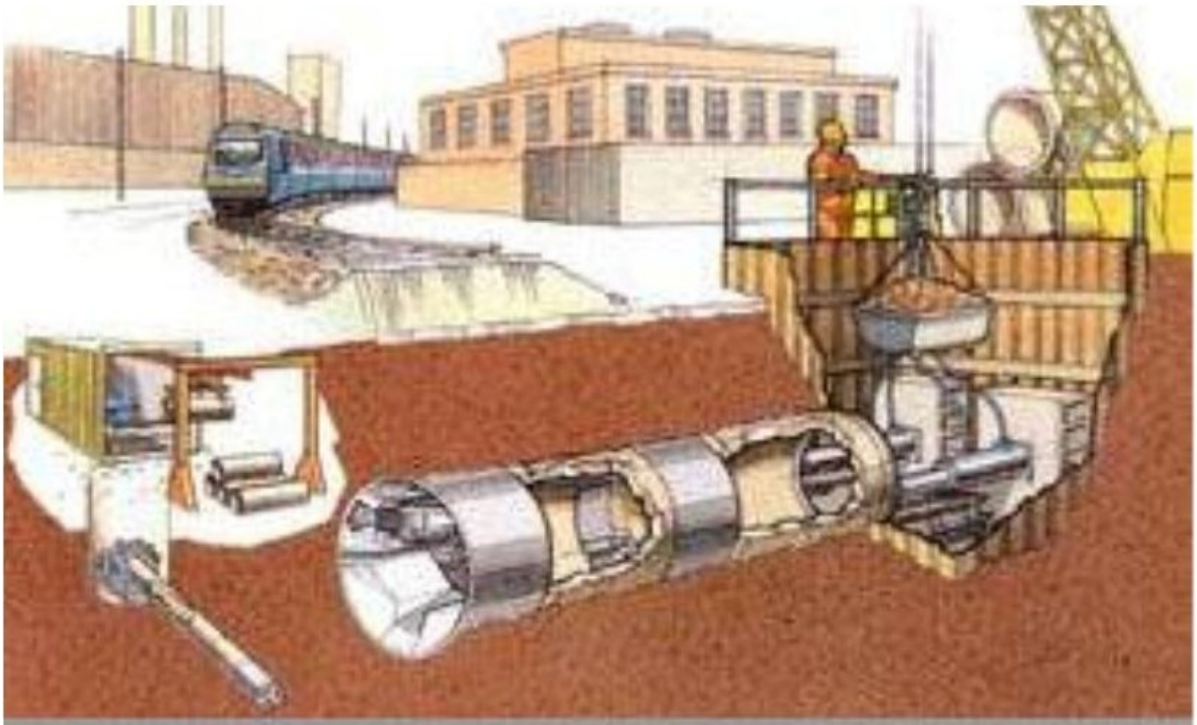
- •No theoretical limit to the length of individual pipelines.
- •Pipes range from 150mm to 3000mm diameter can be installed in straight line or in curvature.
- •Thrust wall is provided for the reaction of the jacks.
- •In case of poor soil, the thrust wall may punch inside the soil.
- •Then piles or ground anchoring methods can be used.

PROCEDURE

- •The thrust pit and the reception pit are excavated at the required places.
- •Then the thrust wall is set up in the thrust pit according to the requirement.
- •In case of mechanized excavations, a very large pit is required.
- •But in case of manual excavation, a small pit is enough.
- •Thrust ring is provided to ensure the even distribution of stress along the circumference of the pipe.

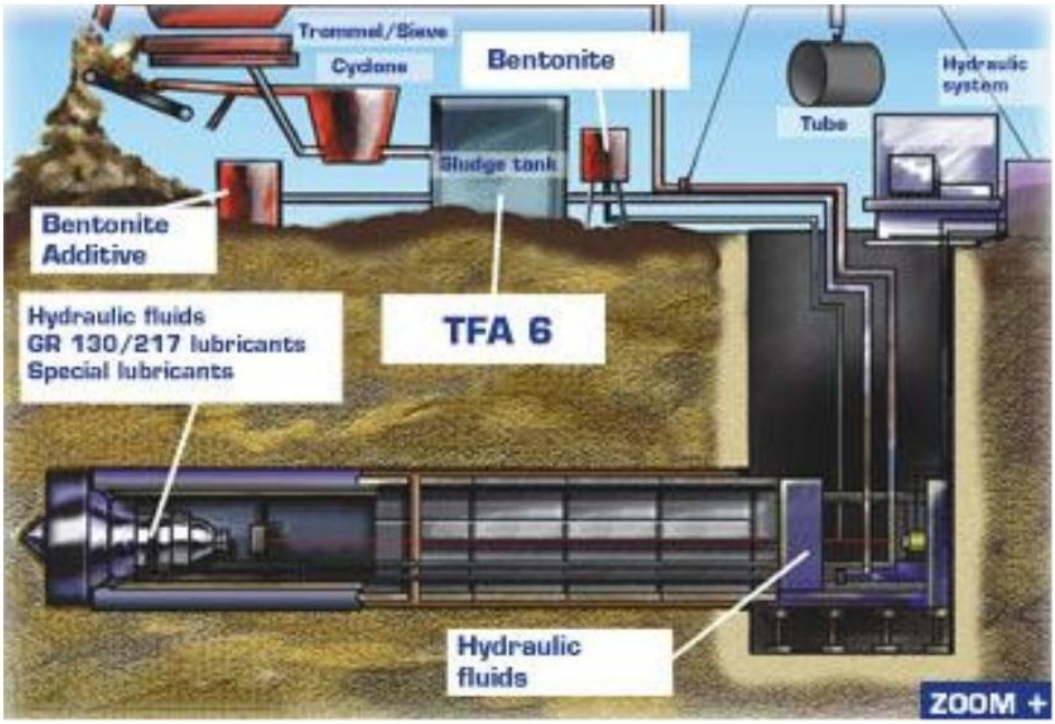
- •The number of jacks vary upon the frictional resistance of the soil, strength of pipes etc.,
- •The size of the reception pit is to be big enough to receive the jacking shield.
- •To maintain the accuracy of alignment a steer able shield is used during the pipe jacking.
- •In case of small and short distance excavations, ordinary survey method is sufficient.
- •But in case of long excavations, remote sensing and other techniques can be used.

GENERAL ARRANGEMENTS

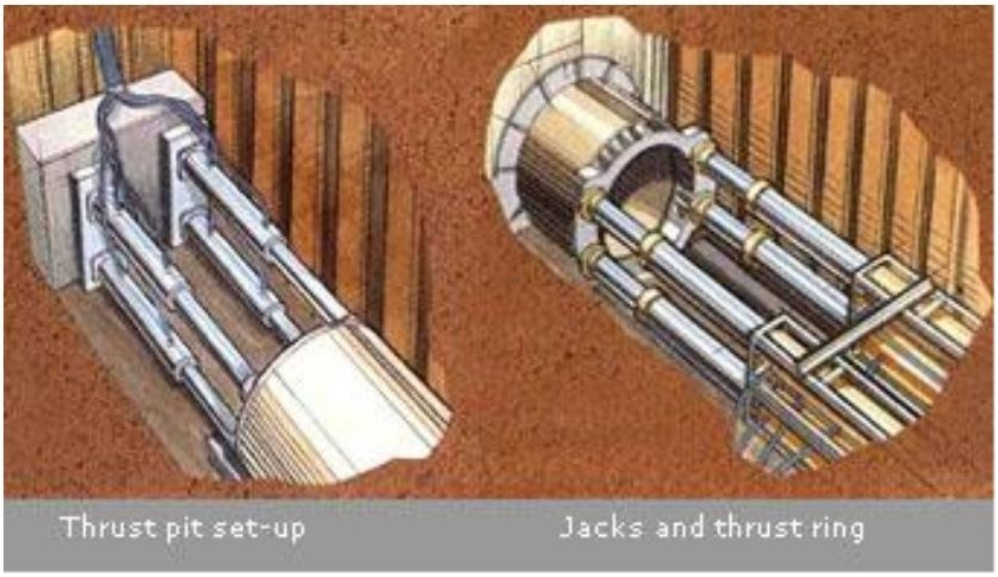


General arrangements of pipe jacking and microtunelling systems

PIPE JACKING SETUP



THRUST SETUP



Thrust pit set-up Jacks and thrust ring

COMPUTER GUIDANCE SYSTEM

- •The computer system enables us to control the work remotely.

Computer guidance system for microtunnelling

ADVANTAGES

- •It avoids the excavation of trenches. So it is also called as “Trench less Technique”.
- •There won’t be any leak problems in the future.
- •Timely finish of projects.

DISADVANTAGES

- •Very costly method.
- •Skilled personnel is required.

DIAPHRAGM WALL

Diaphragm wall are structure elements, which are constructed underground to prevent the seepage into the excavated area

Various methods adopted to construct a diaphragm wall

Slurry trench technique

1. Soil mixing method
2. RC continuous diaphragm wall
3. Precast diaphragm wall
4. Glass diaphragm walls

Slurry trench technique

- The technique involves excavating a narrow trench that is kept full of an engineered fluid or slurry
- The slurry exerts hydraulic pressure against the trench walls and acts as shoring to prevent collapse
- Slurry trench excavations can be performed in all types of soil even below ground water table

Soil mixing method

- This is the method used to make continuous walls by churning up piled soil using an auger, pouring in cement milk and marking soil mortar columns in the ground using the soil as aggregate
- This is an in situ mixing and churning method
- In the method after completing excavation of the groove wall using an excavator, soil cement is produced by mixing and churning excavated soil
- The excavated soil is classified and graded with cement milk after being put through a tremie
- Then the soil cement is poured into the groove wall, after which the steel material is built as the core material

RC continuous diaphragm wall

- This method of building a very long continuous diaphragm wall
- Excavate a given groove between the surface and under ground using a stabilizing liquid
- Insert a given steel bar pour in concrete, thereby building a reinforced concrete wall underground.

Precast diaphragm wall

- With this method, a continuous trench or longer panels are excavated under self-hardening cement- bentonite (CB) slurry.
- The precast concrete wall sections are lifted and positioned by a crane
- The CB slurry sets to form the final composite wall
- The trench is excavated under bentonite slurry, which is then displaced with CB slurry.

Glass diaphragm walls

- For contained enclosure, a diaphragm wall system consisting of special glass panels with a sealing made out of glass are used.
- The panels are 50cm wide and upto 15cm long

Common uses of diaphragm wall walls

- ✓ To provide structural support for the construction
- ✓ To provide retaining wall
- ✓ To provide deep diaphragms

Applications of diaphragm wall

- As permanent and temporary foundation wall foundation walls for deep foundation for deep basements
- In earth retention schemes for highway and tunnel projects
- As permanent walls for deep shafts for tunnel access
- As permanent cut - off walls through the core of earth dams
- In congested areas for retention systems and permanent foundation walls
- Deep groundwater barriers through and under dams

METHODS OF BOX JACKING

Box Jacking

- Non –intrusive method beneath existing surface infrastructure
- Frequently used where an existing road or rail tracks is an embankment and space exists for the structure to be cast at the side
- Enables traffic flows to be maintained disruption

Procedure

- It involves the advancement of a site-cast rectangular or other shaped box using high capacity hydraulic jacks.
- An open ended reinforced concrete box is cast on a jacking base.
- A purpose designed tunneling shield is provided at its leading end and thrust jacks are provided at its rear end reacting against a jacking slab
- The box is then jacked carefully through the ground
- Excavation and jacking take place in small increments of advance.
- Measure are taken to ensure stability of the tunnel face and to prevent the ground from being dragged forward by the advancing box
- When the box has reached its final position the shield and jacking equipment are removed.

R.C.C box jacking

- Is adopted where it is not possible to constructed in situ R.C.C boxes
- These boxes are used for canal siphon, road under bridge and culvert for conveying water/service pipes
- The R.C.C box is cast over the thrust bed which is provided with –pockets both in longitudinal and traverse jacks
- The box is provided with a shield in front in front called “Front shield” Which pierces through the soil by cutting

Throustboring method

- Is a process of simultaneously jacking pipe through the earth while removing the soil inside the encasement by means of a rotating auger.
- In unstable soil conditions, the end of the auger is kept retracted back inside the encasement so as not to cause voids.
- In stable conditions, the auger can be successfully extended beyond the end of the encasement.

TUNNEL BORING MACHINE

Tunnel boring machine (TBM) as mole recent developments in the tunnel driving technique. The function of TBM is to loosen the earth or break the rock continuously in the

entire section of the tunnel, in to cuttings and convey to the rear of the machine, where it can be loaded into muck cars or dumpers or on to conveyor belts for the transportation to the ultimate disposal site.

Working principle and construction features of TBM

These machines perform the boring operation through rotation of the front head against the rock face. The mole has circular cutter head in the front provided with fixed cutters of desired shape. The cutter head while rotating is pressed against the rock to cut or pulverize it. The cuttings while failing down is collected in the buckets provided around the cutter head periphery. These buckets discharge the muck into a hopper to feed it into the belt conveyor leading to the rear of the machine. This conveyor then discharges the muck either into the mine car or to another belt conveyor leading to the portal of the tunnel. The muck of cuttings can also be disposed off by using the slurry pipelines after mixing the fine muck into water to form slurry.

For driving through full- face on full-face TRMs number of cutter heads is mounted on a drum. The drum when rotates in one direction, the individually driven cutter heads having projected Tungsten carbide tipped tools can be rotated in another direction and the drum advances into the tunnel face, by providing a thrust with the help of hydraulic systems. The tips of the tools when worn out can be easily replaced. The tips are kept cooled by spraying a mixture of water and compressed air into the cutting area. This also suppress the dust formed during cutting.

Advantages of tunnel boring machines

- ✓ There is very less danger of fall outs in machine bored tunnels, since adjacent or surrounding rocks are undistributed as no blasting is done.
- ✓ Mucking is also safe and convenient, since muck is conveyed from the face to the rear of the machine and is loaded automatically by means to the rear of the machine and is loaded automatically by means of belt conveyors.
- ✓ Higher speed of excavation.
- ✓ Reduction in the tunnel supports requirement.

- ✓ Less manpower requirement.

Various types of tunneling technique

Tunneling techniques are

1. Drill jumbo
2. Loading and firing
3. Drilling

Drill Jumbo

Drill jumbos used in tunnels are also known as tunnel jumbos. A drill jumbo is a portable carriage having one more carriage having one or more working platforms equipped with columns, bars or booms to support and guide the drills, enabling the drills to perform drilling operation at any desired pattern. These platforms have arrangement for the supporting the compressed air pipes, water pipes. The booms are operated by hydraulic fluid or air and supports the drifters, and are equipped with control enabling the operator to spot a drill in any desired position conforming to the drilling pattern. The platforms are constructed as per the size of tunnel and can be raised or lowered so as to allow mockers or hauling equipment to pass under the jumbo several drill can be operated from each platform for speedy excavation

The jumbos either on rails on pneumatic tyres depending upon the type of work. The jumbo can be equipped with electricity feeding cables, pneumatic concrete placers etc. Mobile jumbos of modern design with four wheel drive and centrally articulated steering speeds production and reduces tunneling costs

Loading and firing

Drilling pattern when followed produces most economical and efficient breakage of rock for a given tunnel, and is determined by conducting tests using different patterns. Explosive selected for working in tunnels should have low fumes characteristics. Ammonium nitrate explosives are therefore preferred over dynamics due to less toxic fumes

Drilling

For driving a tunnel number of holes are drilled as per drilling pattern in size and depth as decided depending upon the size of the tunnel and its formation Drifters are generally used for

drilling in the tunnels where in water is used to remove the cuttings from the holes instead of compressed air to reduced the amount of dust in the air. Holes are drilled slightly deeper than the advance per round to taken care of loss in depth during blasting. Depth advanced due to drilling and blasting operation is called as one round.

Types of well point systems

1. Pumping from open sumps
2. Pumping from well points

   Well point systems are installed in two ways:

   a) Line system
   b) Ring system
3. Pumping from bored wells

Types of piles

(a) Driven piles – Timber, recast concrete,Prestressed concrete , steel H-section, Box and tube

(b) Driven and cast-in place piles

(c) Bored piles

(d) Composite piles

Use of H-piles

H-Piles are used in construction of bridges where they can be driven through existing construction in small spaces

They are used useful for driving close to existing structures since they cause little displacement of soil. It can be withstand large lateral forces.

They require less space for shipping and storing than wood, pipe or precast concrete piles

. They do not require special slings or special care in handling.

DEEP EXCAVATIONS

Problems normally developed during deep excavations

- To prevent the collapsing of sides of the trenches

- To prevent water oozing or coming out from the sides and bottom of the trenches

The remedial measures to avoid the problems deep excavation

- Providing shoring for the trenches
- Dewatering of the trenches

Line system

This system is employed when excavation area is long. The header is laid out along the sides of the excavation, and the pumping is continuously in progress in one length as further points are jetted ahead of the pumped down section and pulled up from the completed and back filled lengths and repeated till entire length is completed. For narrow excavation, like trenches, header is laid only on one laid, while for wide excavations, the header are required to be placed on both sides of the area.

Ring system

When excavation is done in area of appreciable width, line system is inadequate. The ring system is used in such condition and the header main surrounds the excavations completely. This system is used for rectangular excavations such as for piers or basements.

CAISSON

Caisson has come to mean a box like structure, round or rectangular, which is suck from the surface of either land or water to some desired depth. Caissons are of three types:

(a) Box caisson
(b) open caisson
(c) Pneumatic caissons

Box caisson

A box caisson is open at top and closed at the bottom and is made of timber, reinforced concrete or steel. This caisson is built on land, then launched and floated to pier site where is

suck in position. Such a type of caisson is used where bearing stratum is available at shallow depth, and where loads are not very heavy.

SHEET PILES

Sheet piles are thin piles, made of plates of concrete, timber or steel, driven into the ground for either separating members or for stopping seepage of water. They are not meant for carrying any vertical load. They are driven into ground with help of suitable pile driving equipment, and their height is increased while driving, by means of addition of successive instalments of sheets.

Functions of sheet piles

1. To enclose a site or part thereof to prevent the escape of loose subsoil, such as sand, and to safeguard against settlement.
2. To retain the sides of the trenches and general excavation.
3. To protect river banks.
4. To protect the foundations from scouring actions of nearby river, stream etc. To construct costal defence works

COFFERDAM

Types of cofferdam

1. Cantilever sheet pile cofferdam
2. Braced cofferdam
3. Embankment protected cofferdam
4. Double wall cofferdam
5. Cellular cofferdam

Grout anchors used in constructions

In most cases, however anchorages may be embedded below ground level, with backstays connecting them to adjacent towers, or they may constitute the end abutments of the end spans.

In addition to stability sliding, the anchorage structure must also be checked for stability against tilting and overturning.

Methods o f ground water control

Following methods of ground water control are adopted

1. Pumping from open sumps
2. pumping from well points
3. Pumping from bored wells

(1) Pumping from open sumps

This method is most commonly used where area is large enough for allowing excavation to be cut back to stable slopes and where there are no important structures close to the excavation to effect their stability by settlement resulting from erosion due to water flowing towards the sump. This method is also applicable for rock excavations.

This method costs comparatively low for installation and maintenance.In this method one or more sumps are made below the general level of the excavation.In order to keep the excavator area clear of standing water, a small grip or ditch is cut around the bottom of the excavation failing towards the sump.

For grater depths of excavation the pump is used or submersible deepwell pump suspended by chains and progressively lowered down.Pumps suitable for operating from open sumps are:

- Pneumatic sump pumps
- Self priming centrifugal pumps
- Monopump sinking pumps

Pumping is simple and less expansive, but has serious limitations. When fine sand or cohesion less soil lie below the water, this type of pumping removes the fine material from the surrounding soil and results in settlement of adjacent structures. To product it sumps lined with gravel filter are sometimes used.

(2) Pumping from wellpoints

This system comprises the installation of a number of filter wells generally 1m long, around the excavation. These filter wells are conducted by vertical riser pipes to a large dia header main at ground level which is under vacuum from a pumping unit. The water flows to the

filter well by gravity and then drawn by the vacuum upto the header main and discharged through the pump. This system has the advantage that the water is filleted as it removed from the ground and carries almost no soil with it once steady discharge conditions are attained. This system has the limitation of limited suction lift. Therefore for deeper excavations the well points are installed in two or more stages.

The filter wells or well points are usually 1m long and 60 to 75mm diameter gauge screen surrounding a central riser pipe. The capacity of a single we;; point with 50mm raiser is about 10 lit/min. Spacing between two well points depends on the permeability of the soil and on the time available to effect the drawdown. In fine coarse sand or sandy gravels a spacing of 0.75 to 1m is required, while in silty sands of low permeability a 1.5m spacing is sufficient .In permeable course gravels spacing should be as low as only 0.3m.A normal set of wellpoint system comprises 50 to 60 points to a single 150 or 200mm pump with a separate 100mm jetting pump.

(3) Pumping from bored wells

Pumping from wells, for draw-down depth of than the meters can be under taken by surface pumps with their suction pipes installed in bored wells. When dewatering is required to be undertaken from a considerable depth,electrity driven submersible pumps are installed in deep bore holes with rising main to the surface. Since heavy boring equipment is used, installation of wells can be done in all ground conditions including boulders and rocks. Due to higher costs of installation, this method is adopted where construction period is long and other methods of dewatering are not possible.Installation of bore well consists of sinking of a casting having a dia of about 20-30 cm larger than the inner well casting. The dia of inner well casting depends on the size of submersible pump. This inner well casing is inserted after complete sinking of borehole screen over the length where dewatering of the soil is required and it terminates in a 3-5 m length of unperforted pipe to act as a sump to collect any fine material which may be drawn through the filter mesh. Screen having slots are preferable to holes, since there is less risk of blockage from round stones.

Component parts of pipe jacking

Pipe jacking is specialist tunneling method for installing underground pipelines by assembling the pipes at the foot of an access shaft and pushing them through the ground with the minimum of surface disruption

Component parts of jacking systems

The pump unit has two distinct hydraulic systems

- A high pressure systems supplies oil for the main jacking cylinders and till intermediate jacking stations
- A low pressure system supplies oil, via hydraulic lines, for the boring head and conveyor. An auxiliary power pack may be easily installed to double the low pressure hydraulic flow. This may be necessary for larger and more powerful boring heads

Thrust yoke

The yoke is the frame that the main cylinders push against to advance the boring head and pipe. The ring provides a 360 degree surface against the pipe to minimize point pressure and reduce the chance of breakage.

Skid base

The skid base is the foundation of the pump unit and yoke. It also acts as a guide for launching the boring head and pipe into the ground.

Power packs

- Power packs with high and low pressure systems typically are matched with the multiple cylinder system.
- When tunneling, a lower pressure power pack may be selected to supply oil for the tunnel boring machine (TBM)
- Power required depend on the size and features of the boring head
- A mobile electric power pack may be positioned in the boring head/ TBM

Intermediate jacking stations

- Installing intermediate jacking stations is a simple economical way of adding and distributing thrust for pipe jacking

- The size and joint of the pipe, cost, length of push and versatility are important considerations that configure intermediate stations

Most popular design is effective with a variety of pipe sizes and design. Each design consists of ram segments. Each segment has 5 rams. All stations are supplied oil by one set of lines from the power pack and operated from one point in the jacking shaft.

Methods of providing shoring for the trenches

Methods for providing shoring for the trenches

1. Stay bracing
2. Box sheeting
3. Vertical sheeting
4. Runners
5. Sheet piling

(1) Stay bracing

- Carried out in moderately firm ground
- It is adopted when the depth does not exceed 2m
- The vertical sheets are placed opposite each other against the sides of the trench
- The vertical sheets are held in position by one or two rows of struts
- The sheets are placed at an interval of 3 to 4m and they extend to full depth of the excavation
- The normal sizes of
    - Polling boreds 200*40&200*50mm
    - Struts 100*100mm (For trench width upto 2m)
    - Structs 200*200 (For trench width more 2m)

2. Box sheeting

- Carried out in loose soil

- It is used when depth of excavation does not exceed 4m
- A box like structure is formed by providing sheeting,walls,structs and bracing

- In this arrangement, the vertical sheets are placed nearer and touching each other
- The sheets are kept in position by longitudinal rows of Wales, usually two and then,structs are provided across the wales

3. Vertcal sheeting

- Carried out in soft ground
- Adopted when the depth is about 10m
- This is similar to box sheeting except that the work is carried out in stages and at each stage, an offset is provided
- For each stage,vertical sheets,wales,structs and braces are provided as usual
- The offset is provided at a depth of 3 to 4m and it various from 30 to 60cm per stages
- Suitable for laying sewers or water pipes at considerable depths

4. Runners

- Carried out in extremely loose and soft ground which requires immediate support as the excavation progresses
- The runners which are long thick wooden sheets or planks are used in this arrangement
- One end of runner is made up of iron shoe
- These are driven by hammering about 30cm
- The wales and struts are provided as usual

5. Sheet piling

- Provided when large area is to be excavated for a depth grater than 10m
- Used when the soil is soft or loose
- Provided when the width of the trench is large
- It is also provided when the subsoil water is present

Large reservoir construction with membranes and earth system

- The main problem in reservoirs is the loss of water due to seepage

- So even if the capacity of the reservoir is large much water by lost due to it

- It can be made impermeable by construction of impervious membranes on the embankment
- The impervious membrane can be placed on
    1. The upstream face of the dam
    2. Core inside the embankment
- Most of the major earth dams constructed before 1925 were provided
- with central concrete core walls or concrete slabs on the upstream face
- The impervious advantages for the impervious membrane placement in
- the upstream side or core of the embankment

Concrete slab

- Concrete slab can be used successfully up to a height of 150ft
- The performance of concrete slab will directly on the quality of concrete
- Even trough the earth earth embankment is not required to act as a water barrier, it should be well compacted in order to minimize post-construction settlement of the upstream slope
- When single reinforced slab is adopted,some leakage will occur due to the hairline cracks so drains should be provided.

Steel plates

- Steel plate can be used where reinforced concrete is used
- The life is approximately the same as that of concrete
- It can be directly placed on the soil containing appreciable percentage of silt or clay
- It is expansive but it has two advantages
- It is watertight
- It is more flexible and can adapt to differential settlement in a better manner

Asphaltic concrete

- They are less costly than concrete or steel
- They are more flexible than reinforced concrete and can adapt to differential

settlement better

- They can be constructed quickly
- Under certain circumstances the leaks development are self-sealine
- The portion above the reservoir level are easy to repair than either concrete or steel

Advantages of upstream membrane

- When the membrane is on the upstream side optimum stability condition are produced ,so the volume of embankment can be reduced
- Since the upstream slab is exposed ,damage can be inspected and repaired easily
- The upstream membrane can be built after the embankment is completed
- Foundation grouting can be carried out while the dam is being built
- The membrane can serve a secondary function as wave protection

Internal impervious membrane

- Concrete is used mostly for internal membrane steel is used rarely
- Since it is not exposed for investigation very little reliable performance is available
- It is less influenced by embankment settlement and less likely to crack as a result

Advantages of internal membranes

- The area of the membrane is smaller than that of an upstream facing, so less material is required
- The surrounding embankment protects the internal membrane
- The core can be made almost watertight even if cracking develops, by placing thin layer of clay upstream
- A vertical extension of the core membrane below the base of the dam can be used through soil deposits in the foundation
- The length of the grout curtain in is shorter.

Well sinking operation procedures

1. **Laying the well curb**

If the river bed is dry, laying of well curb presents no difficulty. In such a case, excavation upto half a meter above subsoil water level is carried out and the well curb is laid. If, however, there is water in the river, suitable cofferdams are constructed around the site of the

well and is lands are made. The sizes of the island should be such to allow free working space necessary to operate tools and plane for movement of labour etc.When the island is made, the center point of the well is accurately marked and the cutting edge is placed in a level plane. It is desirable to insert wooden sleepers below the cutting edge at regular intervals so as to distribute the load and avoid setting of the cutting edge unevenly during concrete.

2. Masonry in well steining

The well steining should be built in initial short height of about 2m only. It is absolutely essential that the well steining is built in one straight line from the bottom to top. To ensure this steining must be built with straight edges preferably of angle iron. The lower portions of the straight edges must be kept butted with the masonry of the lower stage throughout the building of the fresh masonry. In no case should a plumb bob be used to built more than 5m at a time. The well masonry is fully cured for at least 48 hours before starting the loading or sinking operations.

3. Sinking operations

A well is ready to be set in after having cast the curb and having built first short stage of masonry over it. The well is suck by excavating material from inside under the curb. In the initial stage of sinking, the well is unsuitable and progress can be very rapid with only little material being excavated out. Great care should therefore be exercised during this stage, to see the well sinks to true position. To sink the well straight it should never be allowed to go out of plumb.

Excavation and scooping out of the soil inside the well can be done by sending down workers inside the well till such a stage that the depth of water inside becomes about 1m.As the well sinks deeper, the skin friction on the sides progressively increases. To overcome the increased skin friction and the loss in weight of the well due to buoyancy, additional loading known as kentedge is applied on the well.

Pumping out the water from inside the well is effective in sinking of well under certain conditions. Pumping should be discouraged in the initial stage. Unless the well has gone deep enough or has passed through a ring of clayey strata so that chances of tilts and shifts are

minimized during this process. Complete dewatering should not be allowed when the well has been sunk to about 10m depth.

4. Tilts and shifts

The primary aim in well sinking is to sink them straight and at the correct position. Suitable precautions should be taken to avoid tilts and shifts. The precautions to avoid tilts and shifts are as follows

1. The outer surface of the well curb and steinings should be as regular and smooth as possible.
2. The radius of the curb should be kept 2 to 4 cm larger than outside of well steining
3. The cutting edge of the curb should be of uniform thickness and sharpness since the sharper edge has a grater tendency of sinking than a blunt edge.
4. As soon as tilt exceeds 1 in 200, the sinking should be supervised with special care and rectifying measures should be immediately taken.

5. Completion of well

When the well bottom has reached the desired strata, further sinking of the well stopped .A concrete seal is provided at the bottom. The bottom plug is made bowl shaped so as to have inverted arch action. As generally under watering concerting as to done, no reinforcement can be provided. Under watering concreting is done the help of tremie.However if it is possible to dewater the well successfully, the concrete can be placed dry also.

After having plugged the well at its bottom, the interior space of the well is filled either with water or sand. It may even we kept empty. The well is capped at its top, with help of reinforced concrete slab. If however sand has been filled inside, top plug of lean concrete is interposed between the wall cap and sand filling as shown in fig.

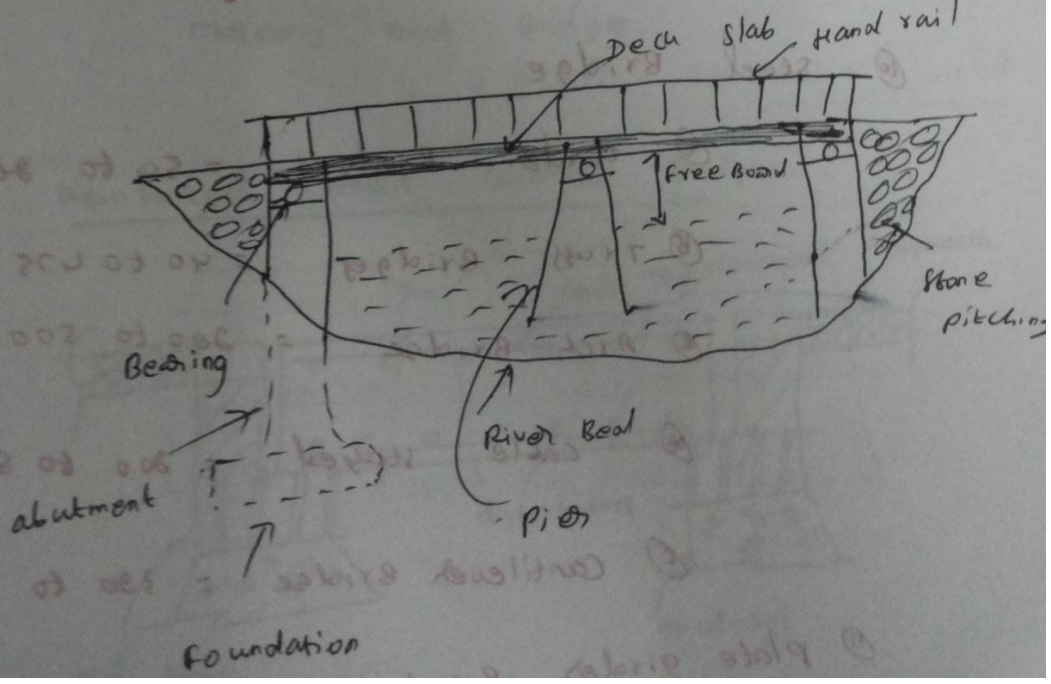
SUPER STRUCTURE CONSTRUCTION

Super structure :-

Structural members which are constructed above the ground which are used to fulfil certain facilities it is called as super structure.

Super structure of Bridge :-

A Bridge is a structure constructed to provide passage for a road (or) Railway over an obstacle such as river, valley, Road etc



Types of Bridge :-

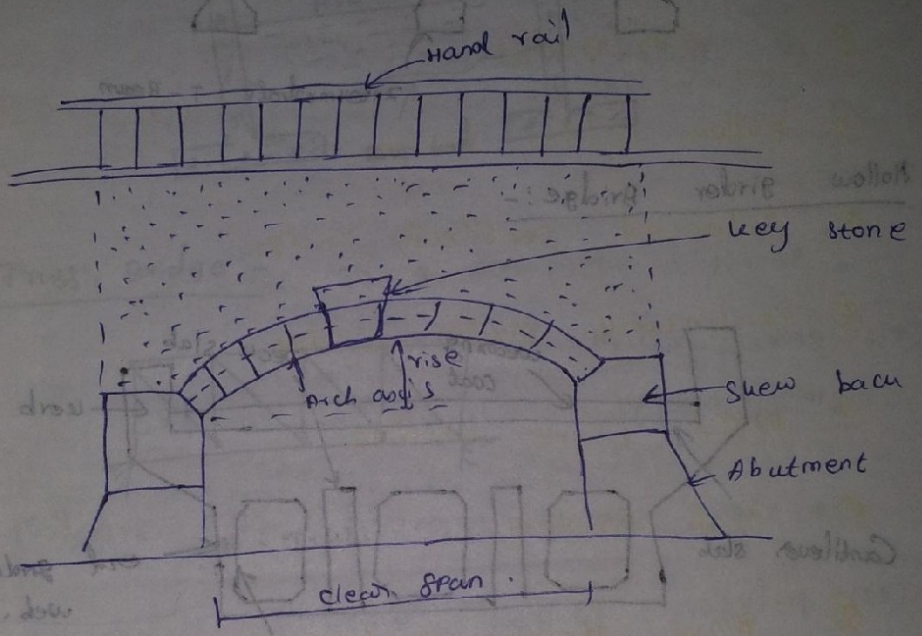
1. majonry Arch Bridge
2. slab Bridge
3. T- beam Bridge
4. Hollow Girder Bridge
5. Balanced Cantilever Bridge
6. Continuous girder Bridge.
7. Rigid frame Bridge
8. Arch Bridges
9. Bow string Girder Bridges
10. steel Bridge
    - (a) Girder Bridges = 50 to 260m
    - (b) Truss Bridges = 40 to 475 m
    - (c) Arch Bridge = 200 to 500 m
    - (d) Cable stayed = 200 to 500m
    - (e) Cantilever Bridge = 320 to 500m
11. plate girder Bridges

12. steel Arch Bridges

(14) Cable stayed Bridges

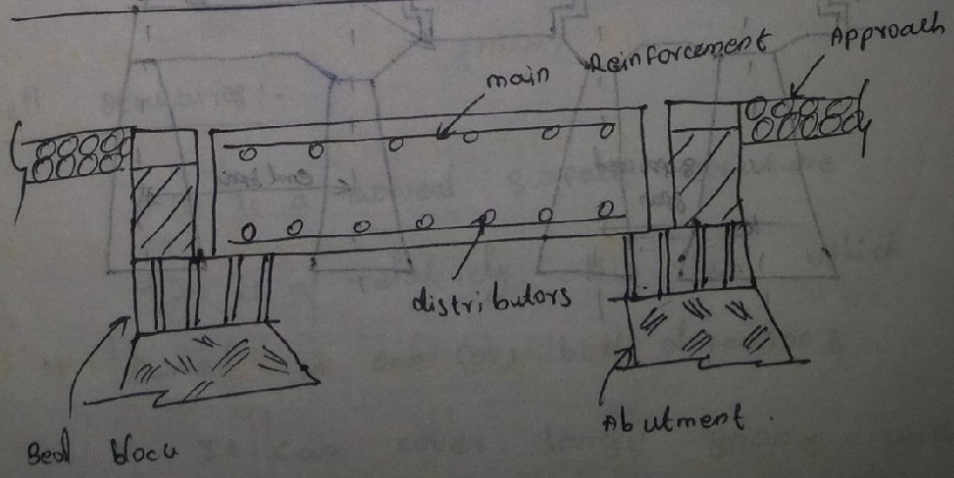
(15) Suspension Bridges

(16) Cantilever Bridges

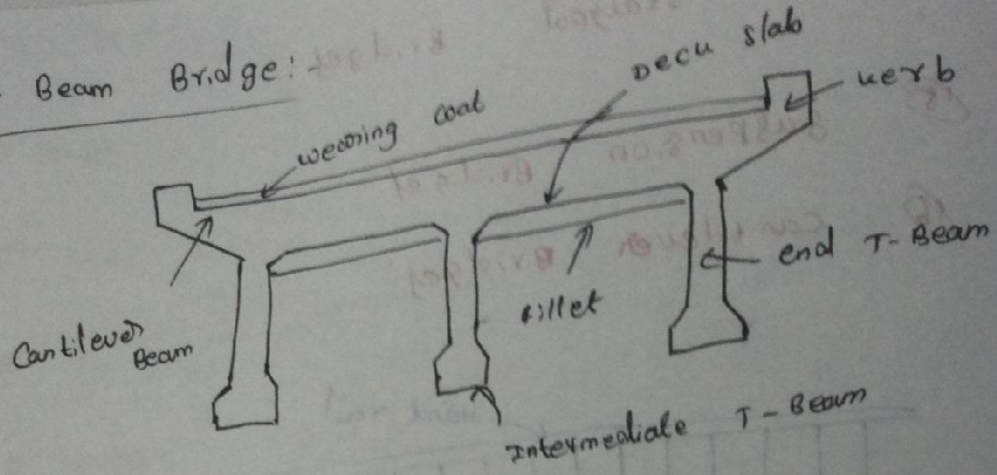


Masonry Arch Bridges.

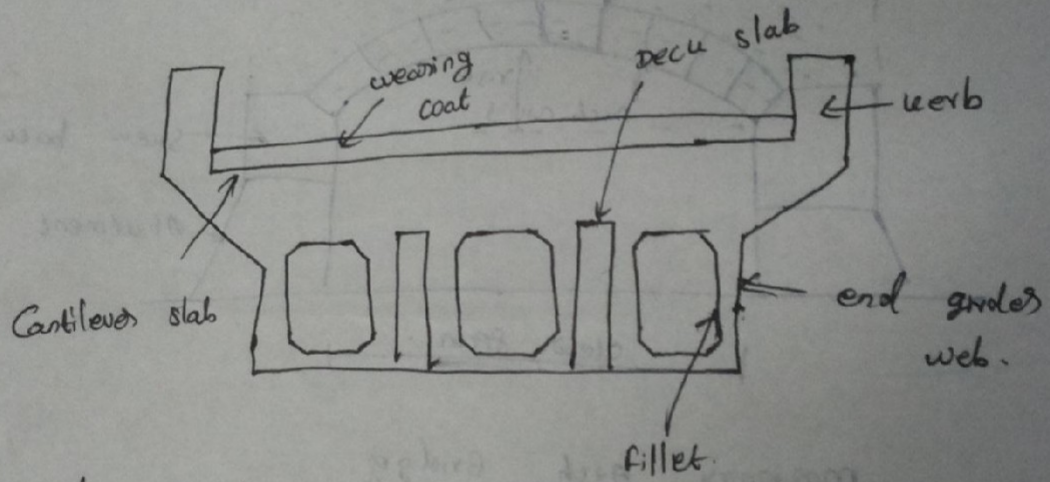
Reinforced Cement Concrete Bridge:-



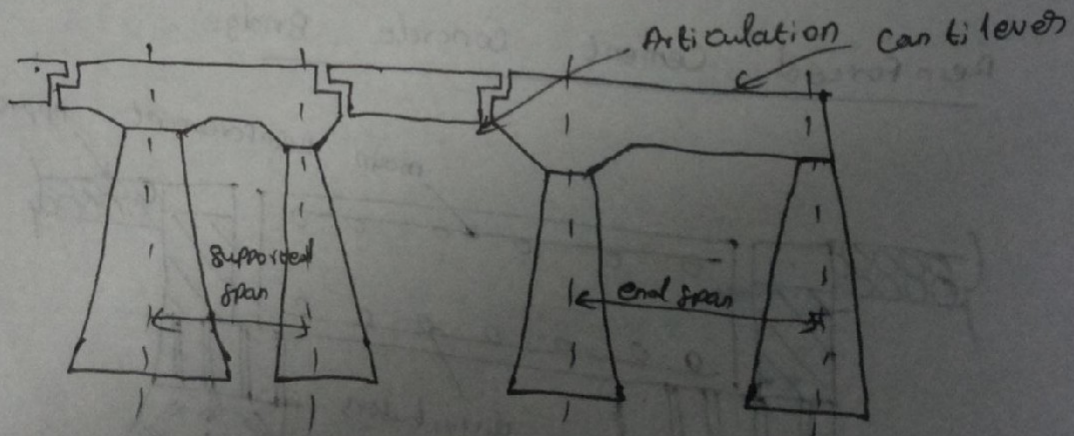
T- Beam Bridge:-



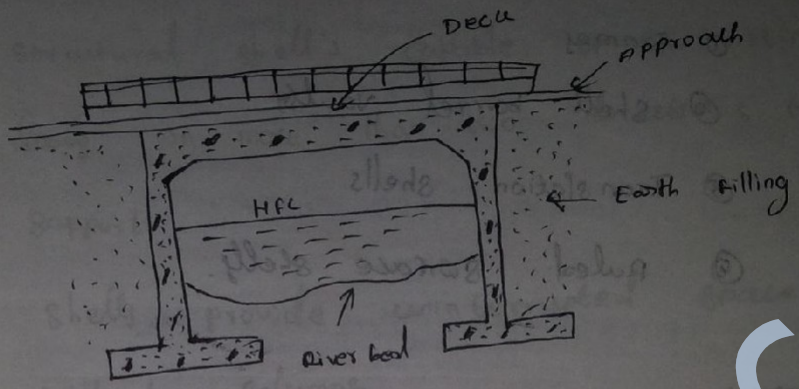
Hollow girder Bridge:-



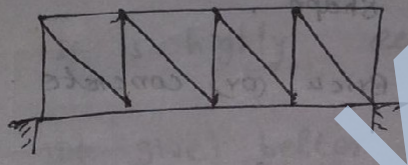
Balanced Cantilever Bridge:-



Rigid Frame Bridge:-



Truss Bridge:-



N - Truss

Curved Choral Plate truss

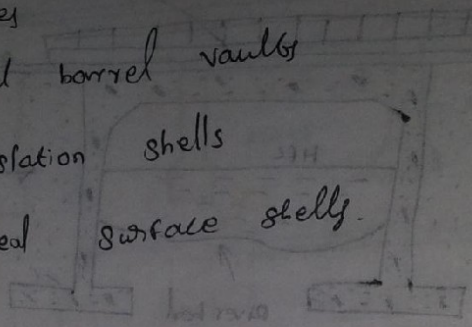
Shell structures:-

* It is a curved surface structure.
* It is a relatively thin slab which is curved in one (or) both directions.
* It can cover large spans with interruption of columns, shell roof.

CE6506 / CONSTRUCTION TECHNIQUES,EQUIPMENT AND PRACTICE V SEM/III YEAR

Types of Shell structures :-

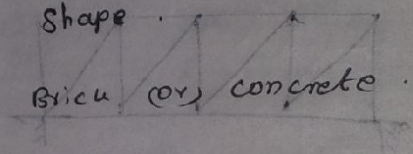
1. Domes
2. Shell barrel vaults
3. Translation shells
4. Ruled surface shells.



Domes :-

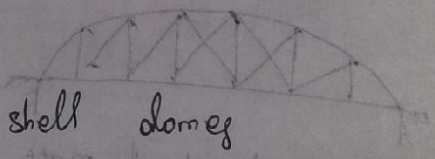
* It is a type of roof of semi spherical (or) semi elliptical shape.

* material used for stone, Brick (or) concrete.

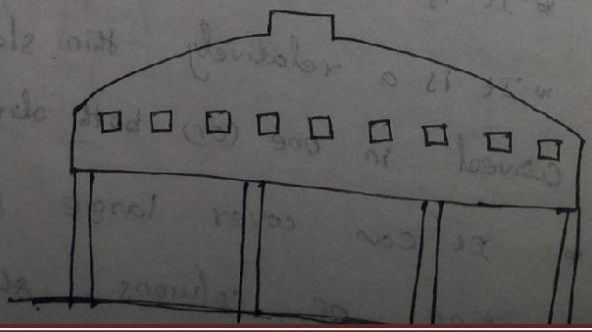


* They are supported on circular (or) polygon shaped walls.

Types :-



1. Smooth shell domes
2. Ribbed domes.



① Structural shell's capable of transmitting loads in more than two directions to support.

② Shells provide uninterrupted space without columns.

③ It have less dead weight

④ It is highly economical

⑤ It give better ventilation

⑥ It give better appearance and provide good reflecting surfaces.

⑦ Construction time is very low compare to other type of construction.

Demerits of Shell Roofs:-

① It can sustain only direct stresses and no bending is permissible.

② It can take only a negligible amou of shear stresses.

③ Any damaged caused to the shell roof can not be repaired easily.

④ Colour washing the shell roof needs special ladder (or) Temporary scaffolding.

IN SITU PRESTRESSED CONCRETE :-

* It give more tensile stress against the heavy load.

* This concrete is first set compressive stresses before the external loads are applied.

* It induing tensile stresses external loads are counteracted.

method of prestressing :-

① pre tensioned method

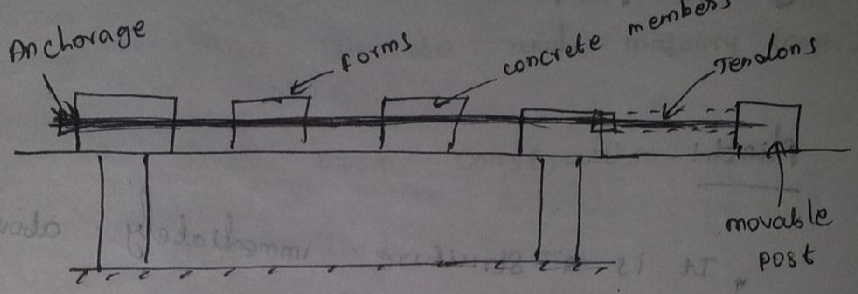
② post tensioned method.

pre tensioned method :-

* Steel wire (or) Tendons are stressed before placing of

Post tensioning method :-

Steel wire (or) Tendons are stressed after the hardening (or) after the placing of Concrete.



Prestressing beal.

Superstructure of Building :-

The above the ground level of Building structure is called as Super structure

Components of Superstructure :-

1. plinth
2. walls and piers
3. Basement

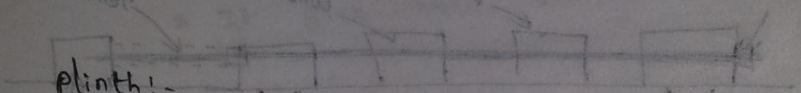
⑤ Door and window

⑥ Roofs

⑦ Steps and Stairs

⑧ Finishes

⑨ ~~Roof~~ parapet wall (or) parapet wall



Plinth :-

* It is a structure immediately above the ground

* Thickness of the plinth is based on the width of foundation and the Number of floors.

Wall :-

* It function as load bearing structure (or) as a space divider.

* The main wall take the loads and Partition walls separate the spaces

Steps and Stairs :-

* It is a combination of a tread

* It is used for move one floor to another floor.

Construction sequence of a Building

Excavation for foundation

↓

Base concrete and masonry construction

↓

Plinth beam construction and sand filling.

↓

Floor concrete and super structure construction.

↓

Preparation of Doors and windows

↓

Fixing Doors and windows

↓

Construction of lintels and sunshades

↓

Brick work up to ceiling and roof capping

↓

Fixing electrical points

Concreting.

Remove form work and

plastering

↓

Floor finishing

↓

painting and fixing fittings.

Tall Structures:-

It is a multi storeyed buildings, R.C.C Chimney, elevated water tanks, cooling towers.

Tall Building:-

* multi storeyed building is called as Tall Building

* If prohibitive land cost in urban areas and demand to meet large population in urban areas.

* 5 to 11 stories.

Advantages or of Tall Building:-

① Economy in use of less land for construction.

② Freedom from street noises

Provides a pleasant panoramic view of the city.

(4) Enables better day lighting and greater flow of air

Disadvantages of Tall Buildings:-

(1) Density of population is high in a small area.

(2) Prevention of congestion is difficult.

(3) Prevention of accidents due to fire, earthquake disasters.

(4) Poses a number of social and human problems.

ARTICULATED STRUCTURE:-

Articulated structure means the separation of a structure into two (or) more elements and join the entire structural elements such that functions as a single monolithic structure.

Conveyers :-

It is a transportation devices which function adopting the friction blw the materials being transported and the base of the conveyer called the belt.

Types of Conveyers :-

1. Belt Conveyers
2. Roller Conveyers
3. Chain (or) Cable Conveyers
4. pipe line Conveyers
5. Screw Conveyers
6. Elevating Conveyers.

Coffer dam :-

Deep excavation, River diversion works require some type of temporary (or) Permanent retaining structures is called as coffer dam.

Types of Cofferdam :-

1. Cantilever Sheet piles
2. Braced Coffer dams
3. Earth Embankment
4. Double wall Coffer dams
5. Cellular Coffer dam.

1

CONSTRUCTION EQUIPMENTS

The selection of t appropriate type and size of construction equipment often affects the required amount of‟ time and effort and thus the job-site productivity of a project. It is therefore important for site managers and constructions p1anners to be familiar with the characteristics of the major types of equipment most commonly used construction. Construction equipments can be classified based on applications under the following heads:

- Excavation an Earthmoving equipments
- Concreting equipments
- Material handling Erection equipments
- Dewatering and Pumping equipments

Typically, construction equipments are used to perform essentially repetitive operations, and can be broadly classified accord to two basic functions:

- Operators such as cranes, graders, etc. which stay within the con of the construction site
- Haulers such as dump trucks, ready mixed concrete truck, etc. which transport materials to and from the site

In order to increase job-site productivity, it is beneficial to select equipment with proper characteristics and a size most suitable for the work conditions at the construction site

Excavation and Earthmoving equipments

Factors that could affect the selection of excavators include:

- Size of the job larger volumes of excavation will require larger excavators, or smaller excavator in greater number
- Activity time constraints Shortage of time for excavation may force contractors to increase the size or numbers of equipment for activities related to excavation
- Availability of equipment - Productivity of excavation activities will diminish if the equipment used perform them is available but not the most adequate.

2

- Cost of transportation of equipment - This cost depends on the size of the job, the distance of transportation and the means of transportation.

Type of excavation - Principal types of excavation in building projects are cut and/or fill, excavation massive, and excavation for the elements of foundation

Soil characteristics The type and condition of the soil is important when choosing the most adequate equipment since each piece of equipment has different outputs for different soils.

Geometric characteristics of elements to be excavated - Functional characteristics of different types of equipment make such considerations necessary.

Space constraints - The performance of equipment is influenced by the spatial limitations for the movement of excavators.

Characteristics of haul units - The size of an excavator will depend on the haul units if there is a constraint on the size and/or number of these units.

Location of dumping areas - The distance between the construction site and dumping areas could be relevant not only for selecting the type and number of haulers, but also the type of excavators.

Normally there are three purposes of earth moving equipments,
Excavation of soil from below or above the track/wheel level of the equipment
Clearance of site at the track/wheel level of equipment

Hauling of spoil out of site

A few types of equipments under this head are:

Bull Dozers and Angle Dozers

Graders

Skimmers

Scrapers

Loaders

Face Shovels

3

Backacters

Draglines

Multipurpose excavators

BullDozers and Angle Dozers

These machines consist of a track or wheel mounted power unit with a blade at the front, which is usually controlled by hydraulic rams and sometimes by wire cable operation. Many bulldozers have the capacity to adjust the mould blade to from angle dozers and the capacity to tilt the mould blade about a central swivel point. .

Some bulldozers can also be fitted with rear attachments such as rollers and scarifies.

The main uses of a bulldozer are:

Shallow excavations up to 300 nun deep either on levee, ground or side hill cutting

Clearance of shrubs and small trees

Clearance of trees by using raised mould blade as a pusher arm

Acting as a towing tractor

Acting as a pusher to scraper machines

Bulldozers push earth in front of the mould blade with some side spillage whereas angle dozers pu and cast spoil to one side of the mould blade.

Graders

These machines are similar in concept to bulldozers in that they have a long slender adjustable mould blade, which is hung, under the center of the machine. A grader is used to finish or grade the upper surface of a large area usually as a follow up operation to scraping or bulldozing. They can produce a fine and accurate finish but do not have the power of bulldozer. Therefore they are not suitable for over site excavation work. The mould blade can be adjusted in both the horizontal and vertical planes through an angle of 360 the latter enabling it to be used for grading sloping banks as well.

4

Two basic types of graders are:

(i) Four Wheeled Graders

In this type of graders all wheels can be driven and steered. This facility gives the machine the ability to offset and crab along its direction of travel.

(ii) Six Wheeled Graders

Six Wheeled Graders have four wheels in tandem drive at the rear and two front tilting idler wheels giving it the ability to counteract side thrust.

Skimmers

These excavators are rigged using a universal power unit for surface stripping and shallow excavation work up to 300 mm deep where a high degree of accuracy is required They usually require attendant haulage vehicles to remove the spoil and need to be transported between sites

on a low loader. Because of their limitations and the availability of alternative machines, they are rarely used today.

Scrappers

Scrapers are multiple-units of tractor-truck and blade-bucket assemblies with various combinations to facilitate the loading and hauling of earthwork. Major types of scrapers include single engine two-axle or three aide scrapers, twin-engine all-wheel-drive scrapers, elevating scrapers, and push-pull scrapers. Each type has different characteristics of rolling resistance, maneuverability stability, and speed in operation.

These machines consist of a scraper bowl, which is lowered to cut, and collect soil where site stripping and leveling operations are required involving large volume of earth, When the scraper bowl is full, the apron at the cutting edge is closed to retain the earth and the bowl is raised to the disposal area. On arnval of disposal area, the bowl is lowered, the apron opened and the spoil pushed out by the tailgate as the machine moves forwards.

(i) Towed scrapers

It consists of a four wheeled scraper bowl with a power unit such as a crawler tractor. They tend to be slower than other forms of scrapers but are useful for small capacities with haul distances up to 300 m.

5

(ii) Two Axle scrapers

These have a two-wheeled scraper bowl with an attached two wheeled power unit. They are veiy maneuverable with low rolling resistance and veiy good fraction.

(iii) Three Axle scrapers

It consists of a two-wheeled scraper bowl that may have a rear engine to assist the four-wheeled traction engine. Generally, these machines have a greater capacity than other scrapers, are easier to control and have a faster cycle time.

(e) Loaders

These machines are sometimes called tractor shovels. They are used to scoop up loose materials in the front mounted bucket, elevate the bucket and maneuver into a position to deposit the loose material into an attendant transport vehicle. Tractor shovels are driven towards the heap of loose material with the bucket lowered. The speed and power of the machine will enable the bucket to be filled. To increase their versatility tractor shovels can be fitted with a 4 in 1 bucket enabling then to car out bulldozing as well.

Both crawler mounted and wheel mounted types are available. The tracked loader being more suitable for wet and uneven ground conditions than the wheeled one, which has greater speed, and maneuvering capacities.

Face Shovels

The primary function of face shovels is to excavate above its own track or wheel level. They are available as a universal power unit based machine or as a hydraulic purpose designed unit. These machines can usually excavate any type of soil except that which needs to be loosened, usually

by blasting, before excavation. Face shovels generally require attendant haulage vehicles for the removal of spoil and a low ladder transport lony for travel between sites. Most of these machines have a limited capacity of between 0.3 mand 0.4 m for excavation below their own track or wheel level.

Backacters

These machines are suitable for trench, foundation and basement excavations and are available as a Universal power unit base machine or Purpose designed hydraulic unit. They can be used

with or without attendant haulage vehicles since the soil can be placed alongside the excavation for the use in back filling. These machines will require a low loader transport vehicle to be transported from one site to another. Backacters used in trenching operations with a bucket width equal to the trench width can be vely accurate with a high output rating.

Draglines

Draglines are based on the universal power unit with basic crane rigging to which is attached a drag bucket.

The machine is primarily designed for bulk excavation in loose soils up to 3 m below its own track level by

swinging the bucket out to the excavation position and haunting or dragging it back towards the power unit.

Dragline machines can also be fitted with a grab or clamshell bucket for excavating in very soils.

Mu1tIpurpose Excavators

These machines are usually based on the agricultural tractor with 2 or 4 wheel drive and are intended mainly for use in conjunction with small excavation works such as foundation excavations, pipe laying and drainage trenches. Most multi-purpose excavators are fitted with a loading/excavating front bucket and a rear backwater hoe bucket both being hydraulically controlled. When in operation using the backwater bucket, the machine is raised off its axles by rear mounted hydraulic outriggers or jacks and In some models by placing the front bucket on the ground.

The choice of the type and size of haulers is based on the consideration that the number of haulers selected must be capable of disposing of the excavated materials expeditiously. Factors which affect this selection include:

1. Output of excavators - The size and characteristics of the excavators selected will determine the output volume excavated per day.

2. Distance to dump site - Sometimes part of the excavated materials nay be piled in a corner at the job site for use as backfill
3. Probable average speed - The average speed of the haulers to and from the dumping site will determine the cycle time for each hauling trip.
4. Volume of excavated materials - The volume of excavated materials including the part to be piled up should be hauled away as soon as possible.
5. Spatial and weight constraints - The size and weight of the haulers must be feasible at the job site and over the route from the construction site to the dumping area.

Concreting equipments

It is well known that the process of concreting involves batching, mixing, transporting, placing, compacting and curing. Accordingly common concreting equipments are,

- Concrete mixers
- Concrete Hauling Equipments

- Concrete pumps for placement in different conditions
- Concrete vibrators for compaction

Concrete mixers

These are generally related to their designed output performance. Machines are decided based upon what mixing and placing methods are to be employed to mix and place a certain amount of concrete in a given time period. Generally, a batch mixing time of 5 minutes per cycle of 12

batches per hour can be assumed as a reasonable basis for assessing mixer output.

(b) Concrete Hauling Equipments

(i) Wheel barrows

he usual means of transporting mixed concrete produced in a small capacity mixer is by wheelbarrow. The run between the mixing and placing positions should be kept to a minimum

8

and as smooth as possible by using planks or similar materials to prevent segregation of the mix within the wheelbarrow

(ii) Dumpers

These can be used for transporting mixed concrete from mixers up to 600-litre capacity and are available in two forms,

(iii) Ready Mix Concrete Mixers

These are used to transport mixed concrete from a mixing plant or depot to the site. Usual capacity range of ready mixed concrete trucks is 4 to 6 rn3. Discharge can be direct into placing position into some form of site transport such as dumpier, crane skip or concrete pump.

(d) Concrete pumps for placement in different conditions

These are used to transport large volumes of concrete in a short time (say up to 100 m3 per hour) in both the vertical and horizontal directions from the pump position to the point of placing. The pump is supplied

with pump able special concrete mix or with constant flow of ready mixed concrete lorries through out the pumping period. Concrete pumps are usually of a twin cylinder hydraulically driven form with a small bore pipeline (100 mm diameter) and can be trailer or lorry mounted. Pumping ranges may be up to 850.00 m vertically and 200 m horizontally depending on the pump model. It generally requires about 45 minutes to set up a concrete pump on site including coating the bore of the pipeline with a cement grout before pumping. After plumbing, the pipeline should be cleared and cleaned. Usually concrete pump and operator are hired for the period required

(e) Concrete vibrators for compaction

(i) Poker or Internal Vibrators

These consist of a hollow steel tube casting in which is a rotating impeller which generators vibrations as its head comes into contact with casing. Poker vibrators should be inserted vertically and allowed to penetrate 75mm into any previously vibrated concrete.

(ii) External Clamp or Tamping Board Vibrators

9

These vibrators operate by shaking the formwork. Clamp vibrators powered by either compressed air or electricity whereas tamping board vibrators are usually petrol driven. Formwork must be stronger than is traditional to withstand vibration.

MATERIAL HANDLING AND ERECTION EQUIPMENTS

Horizontal transportation
Vertical transportation
Upward only
Downward only
Upward and downward
Derricks are commonly used to lift equipment of materials in industrial or building construction
A derrick consists of a vertical mast and an inclined boom sprouting from the foot of the mast.
The mast is held in position by guys or stiff legs connected to a base while a topping lift links the

top of the mast and the top of the inclined boom. A hook in the road line hanging from the top of the inclined boom is used to lift loads. Guy derricks may easily be moved from one floor to the next in a building under construction while stiff leg derricks may be mounted on tracks for movement within a work area.

Tower cranes are used to lift loads to great heights and to facilitate the erection of steel building frames. Horizon boom type tower cranes are most common in high rise building construction. Inclined boom type tower cranes are also used for erecting steel structures

Forklift trucks are useful for horizontal and limited vertical transportation of materials. Hoists are used in two-way vertical transportation of materials and passengers, whereas rubble chutes are used in downward transportation of construction and demolition debris. Cranes are the most versatile material handling equipments that can be chosen or designed for any kind of movement.

(a) Forklift Trucks

Forklift trucks are used for horizontal and limited vertical transportation of packaged materials positioned on paflets or banded together such as brick packs.

10

They are generally suitable for construction sites where the building hieght does not exceed three dories. Although designed to negotiate rough terrain sites, forklift trucks have a higher productivity on firm and level soils.

Three types of forklift trucks with various height, reach and lifting capacities are in common use namely,

- Straight mast
- Overhead thicks
- Telescopic boom

(b) Hoists

Hoists are equipments used for transporting materials and passengers vertically. Common types of hoists are as follows:

(i) Material Hoists

These are designed for the vertical transportation of materials and under no circumstances should they be used to transport passengers. Most material hoists are mobile, can be dismantled, folded onto the chassis and moved to another position or site under their own power or towed by a haulage vehicle. When in use material hoists need to be stabilized and / or tied to the structure and enclosed with a protective screen.

(II) Passenger Hoists

These are designed to carry passengers although most are capable of transporting a combined load of materials and passengers within the lifting capacity of the hoist. A wide selection of hoists are available ranging from a single cage with rope suspension to twin cages with rack and pinion operation mounted on two sides of a static tower.

(c) Cranes

Cranes are machines designed to move materials vertically (raise by rope pulley operation) or horizontally. The range of cranes available is very wide, from gear wheel to a complex tower crane. Therefore, choice must be based on:

- The loads to be lifted

11

- Height of lifting
- Horizontal distance to be covered
- Time period of lifting operations

- Utilization factors and
- Degree of mobility required

However, it may be possible to place most cranes into one following groups

(i) Mobile Cranes

These are low-pivot cranes capable of horizontal motion, either by itself or mounting on crawler or truck. They are classified based on the type of mobility as:

Self propelled cranes with wheeled chassis

- Truck mounted hydraulic cranes
- Truck mounted lattice jib cranes
- Crawler mounted cranes

(ii) Static Cranes

These are either operating from affixed position on ground or is capable of longitudinal motion on rails

Depending on the height of pivot and operational ability , static cranes are of three types:

- Gantry Cranes which are not pivoted, and are cranes with pulley, rope and hook are hung from a portal frame
- Most Cranes which are similar to tower cranes are low pivot cranes
- Tower Cranes are high pivot cranes

Rubble Chutes

These are used in demolition, repair, maintenance and refurbishment. The concept involves connecting of several perforated dustbins vertically downwards for expedient and safe conveyance of materials. In customized forms the tapered cylinders are produced from reinforced rubber with chain linkage for continuity. Overall unit lengths are generally 1.1 m,

12

providing an effective length of 1 m. Hoppers and side entry units are made for special applications.

Dumpers

These are used for the horizontal transportation of materials on and off construction sites generally by means of an integral tipping skip.

A wide range of dumpers is available depending on their carrying capacities, discharge control (gravity or hydraulic discharge) and tipping facilities (front tipping, side tipping). Special dumpers fitted with flat platforms, rigs to carry materials, skips and rigs for concrete, skips for crane hosting are also available. Highway dumpers are of a similar but larger design and can be used to carry materials such as excavated soil along the roads.

PILE DRIVING EQUIPMENTS

13

Pile driving equipments are of three types

Impact type drivers which drive piles by impact of weight on or into piles

Vibration type drivers drive pile be vibrating the pile through the soil

Piling hammers combine the desirable effects of both impact and vibration driving.

Piling Hammers

Details of Piling Hammers

These are designed to deliver an impact to the pile to be driven. The hammer weight and drop height is chosen to suit the pile type and nature of subsoil through which it will be driven. There are four types of piling hammers depending on the mechanism of driving

Drop Hammers

Drop hammers are heavy iron blocks, which hammer the pile b free fall onto the pile top. Drop hammers require special arrangement on top of pile to ensure that impact is steady, vertical and correctly located. It also needs a winch to lift the wei2.ht and release it.

Single Acting Hammers

These hammers are raised by steam or compressed air and are lowered by free fall. Guide tugs or rollers are required on the piling frame leaders to maintain the hammer position but necessity of winches are eliminated.

Double Acting Hammers

These consist of a cast iron cylinder that remains stationary on top of the pile. Both up and down strokes are powered by steam or compressed air. This eliminates both winch arrangement and leader arrangements. However blow forces are lower in these hammers

Diesel hammers

These are self-contained hammers using free fall for down stroke, which in turn ignites diesel engine for upstroke. Hence, they do not require winches or leaders and deliver moderate impact energy.

Lifting and Erecting

14

Derricks are commonly used to lift equipment of materials in industrial or building construction. A derrick consists of a vertical mast and an inclined boom sprouting from the foot of the mast. The mast is held in position by guys or stiff legs connected to a base while a topping lift links the top of the mast and the top of the inclined boom. A hook in the road line hanging from the top of the inclined boom is used to lift loads. Guy derricks may easily be moved from one floor to the next in a building under construction while stiff legs derricks may be mounted on tracks for movement within a work area.

Tower cranes are used to lift loads to great heights and to facilitate the erection of steel building frames. Horizon boom type tower cranes are most common in high rise building construction. Inclined boom type tower cranes are also used for erecting steel structures.

Mixing and Paving

Basic types of e for paving" include machines for dispensing concrete and bituminous materials for pavement surfaces. Concrete mixers may also be used to mix

Portland cement, sand. Gravel and water in batches for other types of construction other thin paving.

A truck mixer refers to a concrete mixer mounted on a truck which is capable of transporting ready mixed concrete from a central batch plant to construction sites. A paving mixer is a self propelled concrete mixer equipped with a boom and a bucket to place concrete at any desired point within a roadway. It can be used as a stationary mixer or used to supply slip form payers that are capable of spreading, consolidating and finishing a concrete slab without the use of forms.

A bituminous distributor is a truck-mounted plant for generating liquid bituminous materials and applying them to road surfaces through a spray bar connected to the end of „ he truck Bituminous materials include both asphalt and tar which have similar properties except that tar is used when the pavement is likely to be heavily exposed to petroleum spills.

15

CONSTRUCTION TOOLS AND OTHER EQUIPMENT

Air compressors and pumps are wide! used as the power sources for construction tools and etc Common pneumatic construction tools include drills, hammers. grinders. saws, wrenches, staple

nuns. Sandblasting guns. And concrete vibrators. Pumps are used to supply water or to dewater at construction sites and to provide water jets for some types of construction.

Automation of Equipment

The introduction of new mechanized equipment in construction has had a profound effect on the cost and productivity of construction as well as the methods used for construction itself. An exciting example of innovation in this regard is the introduction of computer microprocessors on tools and equipment. As a result, the performance and activity of equipment can be continually monitored and adjusted for improvement. In many cases, automation of at least part of the construction process is possible and desirable. For example, wrenches that automatically monitor the elongation of bolts and the applied torque can be programmed to achieve the best bolt tightness. On grading projects, laser controlled scrapers can produce desired cuts faster and more precisely than ntholly manual methods. IIQJ Possibilities for automation and robotics in construction are. explored more fully in Chapter 16.

Concrete Hauling Equipments

Details of Concrete hauling equipments

Wheelbarrows

The usual means of transporting mixed concrete produced in a small capacity mixer is by wheelbarrow. The run between the mixing and placing positions should be kept to a minimum and as smooth as possible by using planks or similar materials to prevent senregat of the mix within the wheelbarrow

Dumpers

These can be used for transporting mixed concrete from mixers up to 600-litre capacity

Drop Hammers

16

Details of Drop hammers

Drop hammers are heavy iron blocks, which hammer the pile by free fall onto the pile top. Drop hammers require special arrangement on top of pile to ensure that impact is steady, vertical and correctly located. It also needs a winch to lift the weight ht and release it.

The major components of drop hammers are

- Block of iron which comprises the body of the hammer
- Rear lug that can be placed into the piling rig guides or leaders, so that the impact may be in position
- 3. A lifting eve at the top for attachment of the winch rope
- The number of blows that can be delivered with a free fall of 1.2 m to 1.5 m ranges from 10 to 20 per minute.
- The weight of the hammer should be not less than 50% of the concrete or steel pile
- weight and 1 to 1.5 times the weight of a timber pile.

Single Acting Hammers

Details of single acting hammers

Single Acting Hammers consist of a heavy falling cylinder raised by steam or

compressed air sliding up and down a fixed piston. Guide tugs or rollers are located in the piling frame leaders to maintain the hammer position relative to the pile head. The number of blows delivered ranges from 36 to 75 per minute with a total hammer weight range of 2 to 15 tones
Double Acting Hammers details of Double acting hammers

- Double Acting Hammers consist of a cast iron cylinder that remains stationary on

the pile head.

- A ram powered by steam or compressed air for both up and down strokes delivers a series of rapid blows that tends to keep the pile on the move durin2 driving. The blow delivered is a smaller force than that from a drop or single acting hammer.

17

- The number of blows delivered ranges from 95 to 300 per minute with a total hammer wei2ht range of 0.7 to 6.5 tonnes.
- Diesel powered double acting hammers are also available. Diesel Hammers

Details of diesel Hammers

These are self-contained hammers, which are located in the leaders of the pile. The driving action is started by raising the ram within the cylinder that activates the injection of a measured amount of fuel. The free falling ram compresses the fuel above the anvil. This causes the fuel to explode and expand resulting in a downward force on the anvil. It also generates an upward force that raises the ram to restart the cycle. The process repeats itself until the fuel is cut off

The number of blows delivered ranges from 40 to 60 per minute with a total hammer weight range of 1.0 to 4.5 tones..

Standard Type Dumper Crane Skip Dumper

Ready mixed Concrete Trucks

These are used to transport mixed concrete from a mixing plant or depot to the site. Usual capacity range of ready mixed concrete trucks is 4 to 6 m3. Discharge can he direct into placing position into some form of site transport such as dumpier, crane skip or concrete pump.

Concrete Pumps

Details of Concrete Pumps

These are used to transport large volumes of concrete in a short time (say up to 100 m3 per hour) in both the vertical and horizontal directions from the pump position to the point of placing. The pump is supplied with pump able special concrete mix or with constant flow of ready mixed concrete Lorries throughout the pumping period.

Bore pipeline (100 mm diameter) and can be trailer or lorry mounted.

Pumping ranges ma be up to 850.00 in vertically and 200 in horizontally depending on the pump model.

18

It generally requires about 45 minutes setting up a concrete pump on site including coaling the bore of the pipeline with a cement grout before pumping. After plumbing, the pipeline should be cleared and cleaned. Usually concrete pump and operator are hired for the period required.

Concrete Mixers

Details of Concrete mixers

Types of mixers are generally related to their designed output performance. Machines are decided based upon what mixing and placing methods are to be employed to mix and place a certain amount of concrete in a given time period. Generally, a batch mixing time of 5 minutes

per cycle of 12 batches per hour can be assumed as a reasonable basis for assessing mixer output. Small Batch Mixers have outputs up to 200 liters per batch with wheel barrow transportation on hourly placing rate of 2 to 3 m3 can be achieved. Most small batch mixers are of the tilting drum type. General. These mixers are hand loaded which makes the quality control of successive mixes difficult to regulate.

Medium Batch Mixers have output ranging from 200 to 750 liters. Low output machines are

available as tilting drum mixers and high output ones are available as non-tilting drum mixers. Non-tilting mixers are either reversing drum or chute discharge, the latter usually having a lower discharge height. Such mixers usually have integral weigh batching facility loading hoppers. scraper shovels and water tanks thus giving better quality control than the small batch mixers. Generally they are unsuitable for wheel barrow transportation because of their high output.

19

CONSTRUCTION EQUIPMENT

The selection of the appropriate type and size of construction equipment often affects the requirement amount of time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment most commonly used in construction. L

Excavation and Loading

One family of construction machines used for excavation is broadly classified as a crane-shove! as indicated by the variety of machines in Figure 4-3. The crane-shovel consists of three major components:

- A carrier or mounting which provides mobility and stability for the machine.
- A revolving deck or turntable which contains the power and control units.
- A front end attachment which serves the special functions in an operation.

The type of mounting for all machines in Figure 4-3 is referred to as crawler mounting which is particularly suitable for crawling over relatively rugged surface at a job site other types of mounting include truck mount1n and wheel mounting which provide 2reater mobility between job sites, but require better surfaces for their operation. The revolving deck includes a cab to house the person operating the mounting and “or the revolving deck The types of front end attachments in Figure 4-3 mi include a crane with hook, claim shell, dragline. Backhoe. Shovel and pile driver

20

A tractor consists of a crawler mounting and a non-revolving cab. When an earth moving blade is attached to the front end of a tractor, the assembly is called a bulldozer. When a bucket is attached to its front end, the assembly is known as a loader or bucket loader. There are different types of loaders designed to handle most efficiently materials of different weights and moisture contents.

Scrapers are multiple-units of tractor-truck and blade-bucket assemblies with various combinations to facilitate the loading and hauling of earthwork. Major types of scrapers include single engine two-axle or three axle scrapers, twin-engine all-wheel-drive scrapers, elevating scrapers. and push-pull scrapers. Each type has different characteristics of rolling resistance, maneuverability stability, and speed in operation.

Compaction and Grading

The function of compaction equipment is to produce higher density in soil mechanically. The basic forces used in compaction are static weight.. kneading, impact and vibration.
21
The de of compaction that may be achieved depends on the properties of soil, itsmoisture content, the thickness of the soil layer for compaction and the method of compaction. Some major types of compaction equipment are shown in Figure 4-4, which nr1iideq rn1ler with different operating characteriics.

Concrete Vibrators

Details of Concrete Vibrators

Poker or Internal Vibrators

These consist of a hollow steel tube casting in which is a rotating impeller which generators vibrations as its head comes into contact with casing. Poker vibrators should be inserted vertically and allowed to penetrate 75mm into any previously vibrated concrete.

External Clamp or Tamping Board Vibrators

These vibrators operate by shaking the formwork. Clamp vibrators powered by either compressed air or electricity whereas tamping board vibrators are usually petrol driven. Formwork must be stronger than is traditional to withstand vibration.

The function of grading equipment is to bring the earthwork to the desired shape and evasion. Major types of grading equipment include motor graders and grade trimmers.

Drilling and blasting

Rock excavation is an audacious task requiring special equipment and methods. The de of difficulty depends on physical characteristics of the rock type to be excavated such as grain size planes of weakness. Weathering. Brittleness and hardness.

The task of rock excavation includes loosening, loading, hauling and compacting. The loosening operation is specialized for rock excavation and is performed by drilling, blasting or ripping. Major types of drilling equipment are percussion drills, rotary drills- and rotary- percussion drills. A percussion drill penetrates and cuts rock by impact while it rotates without cutting on the upstroke. Common types of percussion drills include a jackhammer which is hand-held and others which are mounted on a fixed frame or on a wagon or crawl for mobility. A rotary drill

cuts by turning a bit against the rock surface. A rotary- percussion drill combines the two cutting movements to provide a faster penetration in rock.

Blasting requires the use of explosives, the most common of which is dynamite. Generally, electric blasting caps are connected in a circuit with insulated wires. Power sources may be power lines or blasting machines designed for firing electric cap circuits. Also available are nonelectrical

blasting systems which combine the precise timing and flexibility of electric blasting and the safely of non-electrical detonation.

Tractor-mounted rippers are capable of penetrating and prying loose most rock types. The blade or ripper is connected to an adjustable shank which controls the angle at the tip of the blade as it is raised or lowered. Automated ripper control may be installed to control ripping depth and tip angle.

In rock tunneling, special tunnel machines equipped with multiple cutter heads and capable of excavating full diameter of the tunnel are now available. Their use has increasing replaced the traditional methods of drilling and blasting.