

FUNDAMENTALS OF CONCRETE



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PREFACE

This e-book contains about concrete materials and mixture. The word “concrete” comes from the latin word “concretus” which means to grow together. Concrete is made up of three basic components that can influence the quality of concrete mixture. Good concrete depends on good materials, design and workmanship. The ratio of the ingredients changes the properties of the final product, which allows the engineer to design concrete that meets their specific needs.

The concrete plays a very important role in all branches of civil engineering. It is used in the construction of building structures and in a wide variety applications. Concrete is a popular material for many construction applications, and it is widely used because of its strength, durability, reflectivity, and versatility. The various properties in concrete make it a suitable and most popular construction material.

Reinforced concrete is a formation resulting from a combination of different properties on concrete and steel. There is many differences Properties of Concrete and Reinforcement. However, there are still have the advantages and disadvantages handling and associated with it such as the relationship between formwork and reinforced concrete.

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CONCRETE MATERIALS AND MIXTURE

This topic deals with the component of concrete, concrete mixture and concrete works at the construction site.

1.0 Introduction Of Concrete

The word “concrete” from the Latin word “concretus” which means to grow together. Concrete is the product of cement, aggregate (crushed rock gravel or), sand, water and admixture. Water, coarse granular material, which is the coarse and fine aggregate contained in a hard matrix of material that fills the space between the aggregate particles and binds them together, make up this composite material.

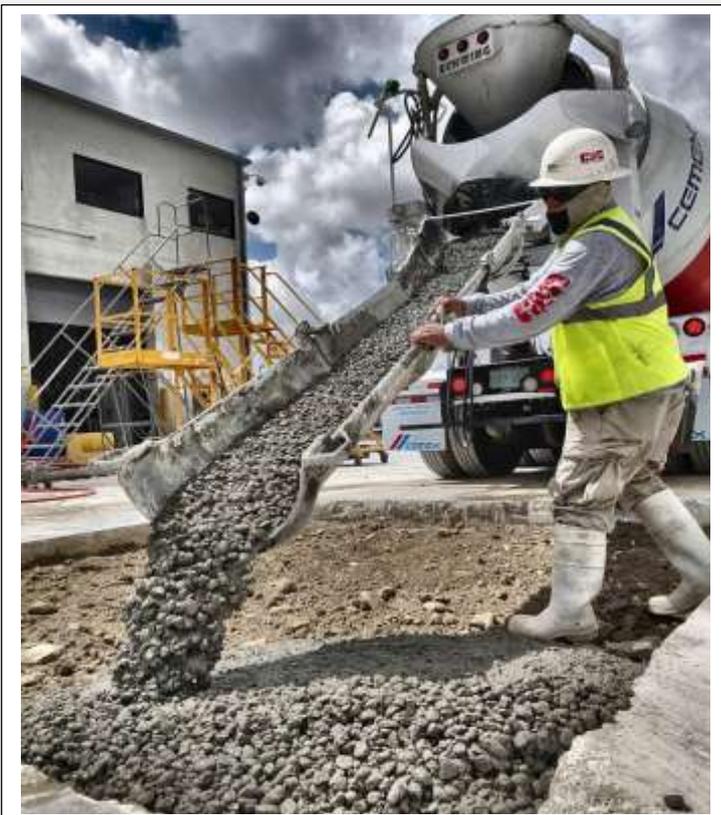


Figure 1.1 Concrete in construction

These materials are combined in accordance with their design specifications or proportion desired and let to harden to form a structural member. It is a strong and versatile construction material as it can be moulded to take up the shapes for various structural forms.

1.1 Concrete as a Construction Material

Good concrete depends on good materials, design and workmanship and also satisfactory in the hardened state and satisfactory while transported and placed in the formwork.

The quality of concrete depends on :

- a) The quality of the materials used in the mix.
- b) Concrete mix ratio.
- c) The use of grading of aggregate.
- d) Amount of water used.
- e) Method of mixing concrete.
- f) Concrete compacting method.
- g) Preservation or curing process after hardening.
- h) Mould/formwork quality used.

1.1.1 Materials in Concrete

Aggregate (sand, rock, or gravel), Portland cement, and water are the three main components of concrete. Cement, usually in powder form, acts as a binding agent when mixed with water and aggregates. The ratio of materials affects the final product's properties, allowing the engineer to create concrete that satisfies their unique requirements. Admixtures are added to adjust the concrete mixture for specific performance criteria. This concrete mixture will be poured and hardened into the hard material we're all familiar with. Concrete mixture constitutes of the following materials such as cement coarse aggregate and fine aggregate also water.



Figure 1.2 Concrete ingredients water, cement, coarse and fine aggregate, and admixture

Table 1.1 Concrete Mixed Ratio and Their Applications

Mixed Ratio	Usage	Strength (N/mm ²)	
		7 Days	28Days
1 : 1 : 2	Base of wall or embankment for hard ground/soil drainage	20	30
1 : 3 : 6	Concrete floor, mass concrete, etc	11	15
1 : 2 : 4	Reinforced concrete for column, beam, etc	14	20
1 : 1 ½ : 3	Pre-stressed concrete, tank, etc	17	25

Source: Malaysian Polytechnic Guide Notes (Concrete Technology)

1.1.2

Advantages and disadvantages of concrete

Concrete plays very important role in all branches of civil engineering. Concrete is the combination of inert material termed aggregates which are from sand, stone chip, brick chips, gravels and shells. Although concrete has become the best way to complete many construction jobs, there are still advantages and disadvantages to work with it.

ADVANTAGES

- Make the structure stable
- Resistance to high and low temperatures, sulphates and chlorides when proper specifications are being implemented.
- Easily available material
- Concrete can be formed into a variety of shapes and sizes
- Durable and economical
- Its non-combustible properties make it a better fire-resistant material.
- Its properties can be altered to requirement job.
- Can carry high loads and maintain its shape under loading
- Non absorption
- Do not shrink and brittle
- Concrete is recyclable and serves as aggregate material in new concrete.

DISADVANTAGES

- Cracks easily and low tensile strength. Steel reinforcement is required to sustain tensile stress.
- Fresh concrete shrinks on drying and hardened concrete expand on wetting
- Concrete expand with change in temperature hence expansion joints are provided
- Contains soluble salt, which may produce efflorescence, and is not completely water resistant.
- Liable to disintegrated by alkali and sulphate attack
- While concrete becomes stronger and more resilient with time, water can seep into fractures and cause damage.
- Low ductility
- Low strength to weight ratio

1.1.3

Concrete structure

Concrete applications in the construction of building structures :

- Column
- Beam
- Floor slab
- Footing
- Foundation

1.1.4

Application of concrete

Concrete is a versatile material that is widely used in a range of applications. It is a common choice for many building projects. Its strength, durability, reflectivity, and adaptability are all factors. These excellent properties have made concrete a reliable and long-lasting choice of construction. The following are the example of concrete structure in the world.

		
<p>(a) Petronas Twin Towers Kuala Lumpur, Malaysia</p>	<p>(b) The Three Gorges Dam on the Yangtze River, China.</p>	<p>(c) The Pentagon, Washington DC</p>

Figure 1.3 Concrete structure in the world

1.1.5

Properties of Concrete

The various properties of the concrete make it a suitable and popular construction material. There are different types and qualities of concrete are available on the market. The properties of concrete that make it extremely important in construction are:

- i. Strength
- ii. Durability
- iii. Versatility
- iv. Environmental Importance of Concrete

1.1.6

Cement as a Concrete materials

Cement is a substance with adhesive and cohesive qualities that allows mineral fragments to be bonded together into a compact whole. Cement is a mixture of materials that hydrate and harden quickly when mixed with water, binding gravel and sand together into a solid mass.

Cement is a powdery substance formed by oxidising lime and clay, then mixing it with water to make mortar, whereas concrete is made by mixing cement with sand, gravel, and water. There are many different types of cement that may be used to make concrete. Varying types of cement have different chemical compositions and toughness, which gives concrete different qualities.

a) Types Of Cement

i. Ordinary Portland Cement (OPC)

Ordinary Portland Cement (OPC) is a type of cement that is widely used around the world. Limestone and chalk or marl are combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore to make Portland cement. Cement is made by grinding and mixing raw materials in specific quantities, then burning them at temperatures ranging from 1425 to 1650 degrees Celsius in massive cylindrical steel rotary kilns lined with special firebrick.

Clinker is formed when the materials are converted into balls. The clinker emerges from the kiln in the form of a grey ball around the size of marbles. The cement companies crush the clinker once it has cooled and combine it with small amounts of gypsum to manage the setting period, and the cement is now ready to use. For the raw ingredients, mixing and grinding can be done under either water or dry conditions. The most prevalent technique of producing Portland cement is using a dry process.

ii. Rapid Hardening Portland Cement (RHPC)

This type of cement manufactured is similar to OPC. The composition of the chemical and the degree of burning and grinding is differs. RHPC contains more lime than OPC and gains strength quickly.

iii. Low Heat Portland Cement (LHPC)

Produces less heat than general purpose cement and Rapid Hardening cement . It gains strength more slowly. It is special to provide a lower heat hydration in concrete. It ideal for mass concrete pous where the rate of temperature rise must be controlled to reduce thermal cracking. It is ideal for mass concrete application, for example, construction of dams large raft slabs, footing and very high strength concrete.

iv. Sulphate Resisting Portland Cement (SRPC)

Sulfate-resisting Portland Cement (SRPC) is a special purpose cement used when concrete constructed with CEM I or CEM II is subjected to sulphate attack when it comes into contact with soil or water that contains high sulphates, such as seawater or near the shore. Sulfate resistance is obtained by altering the chemical composition of the SRPC to reduce the amount of C3A present.

v. Blast Furnace Portland Cement (BFCP)

Heat evaluation and strength development occur at a medium rate. It's ideal for large-scale concrete projects. It's made by combining granulated blast-furnace slag with conventional Portland (type I cement in a ratio of up to 25% to 70%. For thick walls, slabs, and mass-filled foundations, this is a great tool. This form of cement is more heat, acid, and seawater resistant.

vi. High Alumina Cement (HAC)

Unlike Portland cement, which is made up of calcium silicates, calcium aluminate cement (CAC) or aluminous cement is made up of calcium aluminates. Cement is made by melting a mixture of limestone or chalk with bauxite, which contains a significant amount of alumina. This refractory material is utilised in the construction of ships, furnaces, kilns, and boilers. HAC is a heat-resistant and long-lasting material.

1.1.7 Properties of cement in concrete mixture

a) Chemical Composition in cement

Raw materials used in the manufacture of cement are basically calcareous material such as limestone, chalk, silica, alumina and iron oxide and argillaceous materials like shale and clay. These oxides (Calcium Oxide CaO, Silican Oxide SiO₂, Al₂O₃, Fe₂O₃, MgO, SO₃ and Alkalies (K₂O, Na₂O) react with one other during burning process in the kiln, to form a more complex compound. The following are major mineral compounds in Portland cement:

- Tricalcium silicate (C₃S)
- Dicalcium silicate (C₂S)
- Tricalcium aluminate (C₃A)
- Tetracalcium aluminoferrite (C₄AF)
- Gypsum, (CSH₂)

Chemical Composition of Cement		
Variation in the proportion of these elements effects the properties of Cement.		
Ingredient	%age	Effect
Lime (CaO)	60-65	Controls strength and soundness
Sillica (SiO ₂)	20-25	Gives strength, excess quantity causes slow setting
Alumina (Al ₂ O ₃)	4-8	Quick setting, excess lowers strength
Iron Oxide (Fe ₂ O ₃)	2-4	Imparts color, helps in fusion of ingredients
Magnesium (MgO)	Oxide 1-3	Color and hardness, excess causes cracking
Na ₂ O	0.1-0.5	Controls residues, excess causes cracking
Sulphur Trioxide (SO ₃)	1-2	Makes cement sound

Figure 1.4 Component of chemical substances in cement

b) Function of cement ingredient

i) Lime

A lack of lime reduces the strength of cement, whereas too much free lime causes the cement to expand and disintegrate prematurely.

ii) Silica

The cement's strength is determined by this component. Excess silica gives the cement more strength, but it takes longer to set.

iii) Alumina

To give the cement setting qualities, alumina forms complicated compounds with silica and calcium. A larger amount of alumina quickens the setting time but weakens the cement.

iv) Iron Oxide

This component is primarily responsible for the cement's colour. It also contributes to the strength and hardness of the cement to some extent.

x) Magnesia

Magnesium oxide (magnesia) also imparts strength to the cement when mixed in a small quantity. Excess magnesia makes the cement unsound.

xi) Sulphur Trioxide

Excess quantity of sulphur trioxide also makes cement unsound.

xii) Alkalizes

A large quantity of alkalizes (sodium and potassium oxides) is carried away by flue gases during clinkering. However, a small quantity is left behind, excess of which causes efflorescence.

xiii) Gypsum

Gypsum slows the setting of cement, allowing more time for shipping and laying the concrete/mortar that the cement is used for.

c) **Quality and testing of cement**

The bad quality of cement reduces the strength of cement thereby affecting the service life of buildings. Construction with bad cement always leads to the waste of money and at times, it may also cost the safety of homeowners. The quality of cement on-site need to check to ensure the engineering qualities of cement.

The following are the quality of cement :

- i. The colour of cement is greenish grey
- ii. One feels cool by thrusting one's hand in the cement bag
- iii. When rubbed in between fingers it fell smooth
- iv. A handful of cement thrown into a pail of water should float at first, then sink after a few seconds.

The quality test of cement:

- i. Finess test
- ii. Consistency test or setting time test
- iii. Time setting test
- iv. Compressive strength test

1.1.8 Process of hydration in concrete

The hydration process refers to the chemical processes that occur between cement and water. The reaction produces a significant amount of heat. Heat of hydration is the term for this type of heat release. Because the individual cement grains vary in size and content, the hydration reactions between finely ground Portland cement and water are exceedingly complicated. The chemical composition and microstructural features of hydration products vary not only with time but also with their location inside the concrete. The basic characteristics of the Portland cement hydration process can be defined in the following steps.

- i. Phase a: Initial mixing reaction
- ii. Phase b: Dormancy
- iii. Phase c: Hardening or Strength acceleration
- iv. Phase d: Cooling or Speed reduction
- v. Phase e: Densification or Steady development

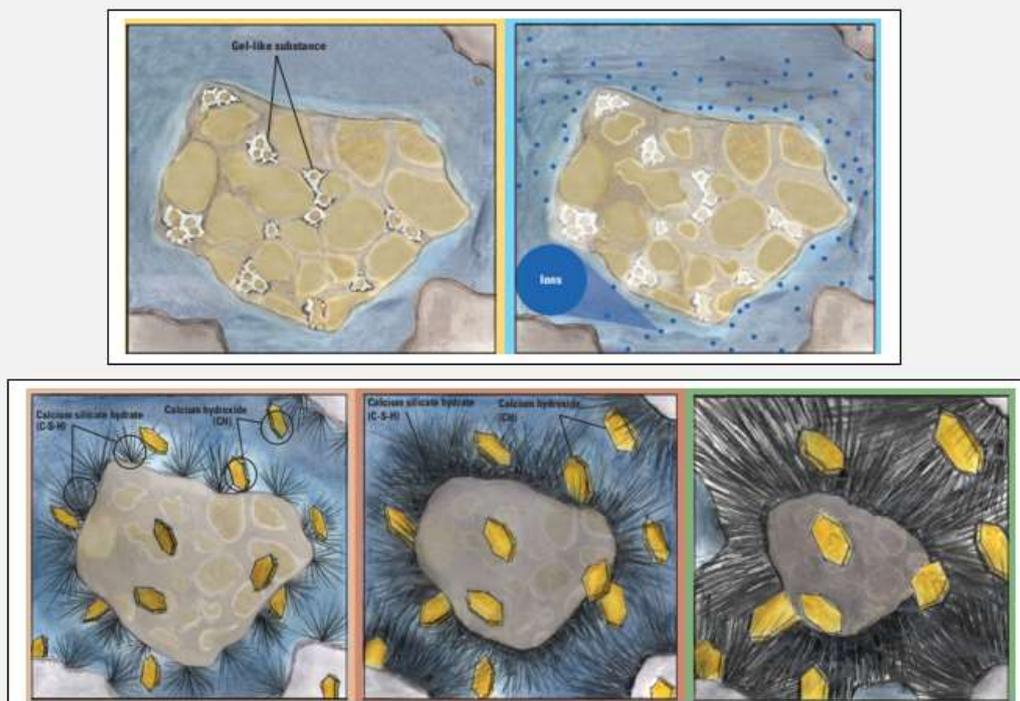


Figure 1.5 Hydration Process of cement concrete. (Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual, May 2019)

1.1.9 Storage method of cement

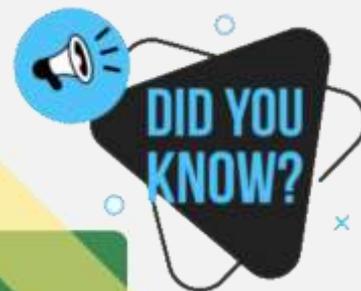
After the manufacturing process and before using cement on the construction site, proper precautions for cement storage are required, such as duration and storage location, arrangement, ambient moisture content, and so on. It is because cement absorbs moisture from the air quickly and hardens like stone, it cannot be utilised in construction. As a result, cement storage should be handled with caution.

The cement is delivered or transported to the job site and then waterproofed. The cement must be kept in a weatherproof cement storage store. The cement bags must not be placed on the ground or lay directly on the ground. There are various measures to keep in mind when storing cement.

PRECAUTION

There are some precautions to be considered in the storage of cement.

- 1. Atmospheric moisture content**
- 2. Cement storage period**
- 3. Storage Place**
- 4. Arrangement of cement bags**
- 5. Withdrawal of cement bags**



1.1.9.1 Cement storage procedure

- a) Cement shall be stored in a leak-proof storeroom. The storeroom should have the minimum window and close-fitting doors.
- b) Placed cement sacks on wooden boards with a 150-200mm clearance above the floor.
- c) A polythene membrane shall be there to cover the wooden planks on which cement will be stacked.
- d) Make sure there a space of 400mm to 600mm from the exterior walls and the stacks.
- e) Kept the cement close together to reduce the air circulation.
- f) Stacking shall not be more than ten bags.
- g) Each lot of cement shall be stacked separately with a minimum 400mm distance from the last lot stacked.
- h) Shall be stacked according to facilitate and use order, FIFO (First in First Out).
- i) Covered the cement bag with a waterproof membrane in case of unexpected weather.

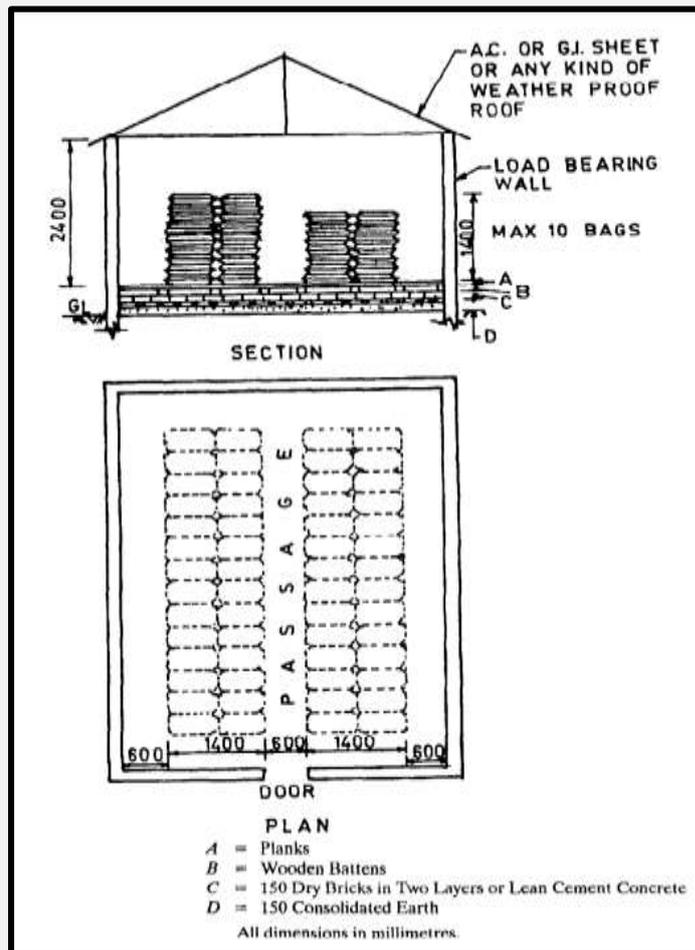


Figure 1.6 Typical arrangement in cement Godown (IS 4082:1996)

1.1.10 Aggregate

Fine aggregate and coarse aggregate are the two major types of aggregate used in concrete. The aggregate content in the concrete mix must be $\frac{3}{4}$ of the total volume of the concrete. As a result, aggregate is extremely important and can have a significant impact on the strength and toughness of concrete. The size of these aggregates should be classified. A fine aggregate is a mixture with a size of less than 5mm, while coarse aggregate particles ranging in size from 5mm to 50mm.

Aggregate can be obtained either from a river or quarry. The aggregate shape of the river is round, while of the quarry also sharply shaped. There are three (3) types of coarse aggregate; 10mm, 20mm, and 40mm. The most popular sizes is size 20mm for concrete 20 grade reinforcement or a mixture of 1: 2: 4 ratio. 10mm and 40mm sizes are rarely used unless available very close reinforcement construction or 20mm and 40mm sizes cannot fill a small space.

Coarse aggregates can be categories as the following.

- i. Uncrushed gravel
- ii. Crushed stone and crushed gravel

There are Three (3) varieties or types of fine aggregate.

a) Pit or quarry sand

It is discovered in the form of a soil deposit and must be excavated. It's often considered the best fine aggregate for concrete and mortar. The shapes is sharp or angular.

b) River Sand

Fine or coarse sand is collected from riverbanks and riverbeds. Typically, fine sand is mixed with silt and clay. It should be washed before use in concrete.

c) Sea sand

It's constituted of fine round grains with a brown colour that's collected from seashores or beaches. Sea sand may contain salts, which can cause efflorescence and damage to R.C.C reinforcement. When working with sea sand, washing is required.

1.1.10.1 Properties aggregate in concrete

Course Aggregates

1. Size of Coarse Aggregates

It is dependent on the intended application of the concrete. Grading curves, charts, tables, and other methods are used to calculate the ratio of each size. The maximum size that will be employed in the simple construction of residential or other buildings is 20 mm. The sizes 80 mm, 40 mm, and 20 mm are suitable for large - scale concrete projects that do not require sophisticated reinforcing.

2. Shape of Coarse Aggregates

The form of the aggregate is important since it influences the concrete's workability and strength.

3. Soundness of Coarse Aggregates

The resistance of coarse aggregates to any form of change is referred to as soundness. Temperature changes, alternate wetting and drying potable water, and alternate wetting and drying in seawater are all possibilities. Porous aggregates are unsound and much more liable to chemical attack. In addition, if these aggregates are exposed to alternate cold and heat, they will fracture.

The soundness of the aggregate is determined by soaking it in sodium or magnesium sulphate and dried it under specific conditions. If tested with sodium sulphate, the average weight loss after 10 cycles should not exceed 12%, and if tested with magnesium sulphate, it should not exceed 18%.

4. Water Absorption

Water absorption of coarse aggregates is measured by the percentage increase in weight of an oven-dried pattern after being immersed in water for 24 hours. It does not give an accurate picture and many times, the absorbance is measured for a period equal to the final setting time of the cement.

Water absorption will reduce the amount of water content in the concrete, it requires a greater water/ cement ratio. Greater water absorption will affect both the workability and durability of concrete.

5. Specific Gravity of Coarse Aggregates

It is the ratio of the dry weight of aggregate to the weight of an equal volume of water. The specific gravity of aggregate is determined along with the water absorption as specified in IS 2386 part III 1963.

Fine Aggregates

1. Size of fine aggregates

The largest size of fine aggregate produces the densest concrete, although a combination of various sizes is more desirable and cost-effective. When preparing cement mortar for building or plastering, very fine kinds of sand of uniform sized are used.

2. Strength

The aggregate's strength does not guarantee the concrete's strength.

It is more significant to consider the strength of coarse aggregates to ensure concrete achieve the strength.

3. Shape of fine aggregates

Sand with an irregular nodular shape is preferable than sand with a totally round grain. In coarse aggregates, the shape of the aggregate is more essential than in fine aggregates.

4. Specific Gravity

It's utilised in concrete mix design, and if it's not mentioned, the specific gravity is expected to be 2.7 because most aggregates from various sources have a specific gravity between 2.6 and 2.8.

5. Water Absorption

Because water absorption is usually low in sand, it is preferable to keep it to a minimum.

6. Soundness

It describes how aggregate expands and contracts as a result of temperature variations. A excellent sound aggregate is one that expands and contracts very little when the temperature changes.

1.1.10.2 Function of aggregate

a) Fine aggregates

1. It contributes in the formation of workability and consistency in the mixture.
2. It assists the cement paste hardens the coarse aggregate particles.
3. It helps to prevent possible segregation of paste and particularly coarse aggregate during the transport operation of concrete for a long distance.
4. Binding material shrinkage is reduced by fine aggregate.
5. It prevents a crack in the concrete.

6. It fills in the voids left by coarse aggregate. As a consequence, it contributes in the increase of concrete density.
7. It assists in the hardening of cement by allowing the penetration of water through its voids.

b) Coarse aggregates

1. With cement and sand, it creates a strong and hard concrete mass.
2. It provides bulk to the concrete.
3. It improves the concrete's crushing strength.
4. It lowers the cost of concrete by utilising cheaper materials.

1.1.10.3 Relationship of aggregate properties to the strength of concrete

- i. Shape
- ii. Size
- iii. Surface texture

Table 1.2 Grades of Coarse aggregate

Sieve size (BS410)	Percentage by mass passing BS410 sieve for nominal sizes					
	Graded Aggregates			Single-sized Aggregate		
	40 mm to 5 mm	20 mm to 5 mm	14 mm to 5 mm	40 mm	20 mm	10 mm
50.0 mm	100	-	-	100	-	-
37.5 mm	90 to 100	100	-	85 to 100	100	-
20.0 mm	35 to 70	90 to 100	100	0 to 25	85 to 100	-
14.0 mm	25 to 55	40 to 80	90 to 100	-	0 to 70	100
10.0 mm	10 to 40	30 to 60	50 to 85	0 to 5	0 to 25	85 to 100
5.0 mm	0 to 5	0 to 10	0 to 10	-	0 to 5	0 to 25
2.36 mm	-	-	-	-	-	0 to 5

Table 1.3 Grade of Fine aggregate

Sieve size (BS410)	Percentage by mass passing BS410 sieve			
	Overall Limits	Additional limits for grading		
		C	** M	F
10.0 mm	100	-	-	-
5.0 mm	80 to 100	-	-	-
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 µm	15 to 100	15 to 45	25 to 80	55 to 100
300 µm	5 to 70	5 to 40	5 to 48	5 to 70
150 µm	0 to 15*	-	-	-

Notes:

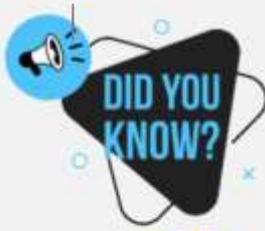
* Increase to 20% for crushed rock fines, except when they are used for heavy-duty floors.
 ** For prescribed concrete only Grading Limit M is applicable.

Individuals sands may comply with the requirements of more than one grading. Alternatively, some sands which satisfy the overall limits but may not fall within any one of the additional limit C, M or F may also be used provided that the supplier can satisfy the S.O that such materials can produce concrete of the required quality.

1.1.11 The Behavior of Water in A Concrete Mixture

Water is required for hydration in concrete. Water used in concrete mixing must be clean and fresh, and it must be free of impurities that may affect the concrete's properties such as suspension clay, organic acid, and other organic materials such as salt and alkali.

In addition, drinking water is suitable for use as a material in concrete mixing. While seawater should not be used to mix concrete, it will corrode steel bars in reinforced concrete. Besides that, industrial water, wastewater, and brackish water should not be used.



There are some important definitions of water, here we learn:

1. **Potable water:** Water that is suitable for consumption of human being.
2. **Recycled water:** Water that is treated up to an acceptable limit that is suitable for its intended use.
Duration of cement storage
3. **Blackish water:** Wastewater generated from toilets, urinals that are directly contaminated with human excreta.
4. **Gray water:** Waste water from wash basins, showers, laundries and kitchen.

1.1.12 Function of water

The quality of the water used in the preparation of concrete is important. Water impurities can interfere with the setting of the cement and reduce the strength and durability of the concrete. Water's chemical constituents may actively participate in chemical reactions, influencing the setting, hardening, and strength development of concrete.

i. Bonding

Water and cement are mixed together to form a binder in concrete mixed. Its functions include strengthening the bond between cement, coarse aggregate, sand, and admixture.

ii. Hydration

Water is also responsible for the hydration process, which leads to the hardening of concrete to form various structures.

iii. Workability

Water eases the ferrying and mixing of concrete to form the desired mixture. It can also be referred to as the concrete's fluidity. Water facilitates the workability of concrete, allowing it to be shaped into various shapes before it hardens.

iv. External and Internal Friction

Water helps to reduce external friction between the concrete and the mixing equipment. It also aids in the reduction of internal friction between the aggregate and the cement.

Every construction project that is undertaken necessarily requires the use of water in the preparation of concrete. Furthermore, one important point should be emphasised: excess water in concrete leads to improved workability. However, it can also cause swelling, staining, reinforcement corrosion, volume instability, and decreased durability.

1.1.13 Suitable Water Quality for Concrete

The water used to prepare the concrete must meet the following specifications.

1. It must be fresh and clean.
2. It has to be free of organic impurities, harmful amounts of acids and alkalis, hygroscopic, greasy, and oily substances.
3. It should be free of iron, vegetable matter, and any other substance that could harm the concrete or reinforcement.
4. It should be suitable for drinking.
5. Generally, the PH value should be between 6 and 8.

Water quality for construction must be tested or monitored on a regular basis because it affects the overall strength of the concrete. The following are the permissible solids limits for plain and reinforced cement concrete:

Table 1.4 Permissible Limit for Solids in Water for Construction (As per IS 456)

Type of Solid in water	Permissible Limits for Construction
Organic matter	200 mg/l
Inorganic matter	3000 mg/l
Sulphates (SO ₄)	500 mg/l
Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l

1.2 Basic Knowledge of concrete mixture

Concrete mix design is the process of selecting appropriate concrete ingredients and their relative proportions to obtain a certain minimum strength and durability. The objectives or purpose of concrete mix are to ensure the optimum proportions of the materials and to adhere to the structure's requirements. On the other side, mixed design is purposefully created with the following objectives:

- i. To produce the required workability during the plastic stage
- ii. To achieve the required minimum strength in the hard stage
- iii. To produce the expected durability
- iv. To produce concrete at the lowest possible cost.

1.2.1 Differences types of concrete mixture

Concrete mixtures are classified into 3 types:

- Prescribed mix
- Designed mix
- Nominal mix



Prescribed

- The prescribed mix is appropriate for general building work such as foundations and floors.
- Used instead of traditional nominal volume ratios such as 1:3:6.
- The prescribed mixture, specified by dry weight of aggregate, used in conjunction with 100 kg of cement.
- Provide a more accurate method of measuring the cement-to-aggregate proportion, and because they are measured against the dry weight of the aggregate, they allow for close control of the water content and thus the strength of the concrete.
- The proportions of the mix indicate the strength of the concrete for most building purposes, except designed reinforced concrete work.
- Prescribed concrete is a mix for which the purchaser specifies the exact composition and constituents of the concrete in order to achieve the desired performance.
- The purchaser chooses the materials and proportions of the mix to meet the required strength and durability requirements but does not specify these parameters.

<p>➔ Designed</p>	<ul style="list-style-type: none"> • The process of selecting appropriate concrete components and determining their relative proportions. • The objective is to produce as much concrete strength and durability as possible while reducing cost. • A design mix is a mix in which all of the proportions of the mix are considered in terms of weight to reduce the cost of concrete. • It is a high-performance concrete. • It is for high-grade concrete, grade 25 and above, with quality control. • The water grade ratio is still based on concrete grade, 28-day compressive strength, and strength of concrete. • Plasticizers can also be used to improve the workability of concrete while it is being pumped through the batching plant. • The mixing time can be maintained, and the standard can be changed as needed due to temperature effects.
<p>➔ Nominal</p>	<ul style="list-style-type: none"> • Specification for determining the standard proportion of cement, sand, and aggregates. • The nominal mixture is a volume at which all volume ratios where the strength and cost of concrete vary are considered. • For ordinary concrete and concrete grades no higher than M-20. • There is no need for quality control. Concrete mix is typically used in small quantities or where the load is not particularly heavy. • The water-cement-to-stability ratio is determined by quality, experience, and practical tests. • The water content can be adjusted. • The concrete mixers must rotate at a minimum of 15 rpm. It takes about 2 minutes to make one batch of concrete.

Table 1.5 Proportions and Strength Requirements for Nominal Mixes

Nominal volume mix	BS 5328 Standard mixes	Uses
1:8 all-in } 1:3:6 }	ST1	Foundations
1:3:6 } 1:2:4 }	ST2 ST3	Concrete site
1:11/2:3	ST4	Reinforced concrete site

1.2.2 Ratio of proportions in concrete mixture

There are various concrete mix ratios. The mix ratio is determined by the type of construction structures and mix designs. The components of the Concrete Mix Ratio are cement, sand, coarse aggregates, and water. Concrete grades indicate its strength for the required construction. The letter "M" stands for mixture. For instance, if the concrete mix is M20 grade, the compressive strength will be 20 MPa. Tables 1.6 and 1.7 show the specification, which includes the formulation for the prescribed mix, and they are reproduced without modification.

For prescribed concrete it may be used for works involving a small quantity of concrete. Weight and volume batching are allowed. In this work only CEM 1 (Portland cement) cement is allowed with no admixtures.

Table 1.6 Weight Batching Prescribed Mixes Per Cubic Meter of Concrete

Grade of Concrete	28-day Strength of Concrete (N/mm ²)	Nominal Maximum Size of Aggregate 20 (mm)			Max free water cement ratio
		Workability	Medium	High	
		Consistence	25-75	75-125	
15P	15	CEM I (kg) Total aggregate (kg) *Fine aggregate (%)	280 1800 35-50	310 1750 35-50	0.60
20P	20	CEM I (kg) Total aggregate (kg) *Fine aggregate (%)	320 1800 25-40	350 1750 20-45	0.55
25P	25	CEM I (kg) Total aggregate (kg) *Fine aggregate (%)	360 1750 25-40	390 1700 30-45	0.50
30P	30	CEM I (kg) Total aggregate (kg) *Fine aggregate (%)	400 1700 25-40	430 1650 30-45	0.45

Note: Fine aggregate is crushed aggregate and is expressed as a percentage by weight to the total weight of the dry aggregate

Table 1.7 Prescribed Mixes by Volume Batching Proportions and Strength Requirements

Proportion (Grade)	Slump Limits (mm)	Cubic Meters of Aggregate Per 50 kg of CEM I		Max. Free Water: Cement Ratio	Quantity Of Water (Litres)	Strength of Concrete	
		Fine	Coarse (20 mm)			At 7 Days (N/mm ²)	At 28 days (N/mm ²)
1:1:2(30P)	25 - 50	0.035	0.07	0.45	22.5	20	30
1:1.5:3(25P)	25 - 50	0.05	0.1	0.5	25	17	25
1:2:4(20P)	25 - 50	0.07	0.14	0.55 – 0.6	27.5 – 30	14	20
1:3:6(15P)	25 - 50	0.10	0.20	0.6	30*	11	15

Note:

*or as approved by S.O.

1.2.3 Purpose of the Admixture

Concrete's properties can be altered by adding chemicals. Admixtures have an effect on the time it takes for concrete to harden as well as the workability of freshly mixed concrete. These chemical admixtures also lower construction costs. Modify the properties of hardened concrete and ensure its quality. The following are examples of chemical admixtures:

a) Catalyzing substances

To increase hardening of the concrete used for the purpose of mold boxes that need to be opened quickly used for leak patching work on tanks that still contain water concrete work in cold or chilly weather to compensate for the slowing effects of concrete due to low temperatures.

b) Retarding substances

Its functions are to slow the rate of cement hydration and to increase the initial setting time of concrete. It is especially useful in high-temperature zones where concrete must be set quickly and transported over long distances.

c) Water decreasing substance

Assist in improving the workability of concrete The strength of concrete, the bond between concrete and steel, prevents cracking, bleeding, segregation, honeycombing, and other defects, and reduces the amount of water required in a concrete mix.

d) Plasticizing substances

Water demand can be reduced by up to 10% with mid-range plasticizers, and by up to 15% with superplasticizers. Plasticizers such as calcium, sodium, and ammonium lignosulphonates are widely used.

e) Air trapping additive

The formation of tiny air bubbles in concrete is known as air entrainment. A concrete maker introduces bubbles into the mix by including an air-entraining agent, also known as a surfactant (surface-active substance).

In areas where the weather is unusual (rapidly changing), an air-entraining admixture is used to protect concrete from various weather actions. Concrete is very vulnerable to frost action, in which water penetrates and damages the concrete.

Admixtures for air entraining Closely packed air voids protect concrete during severe conditions, and these voids provide water storage, which releases when pasting in the concrete freezes.

Each admixture has its own unique property and material composition. Before using any of them, it is critical to understand their applicability. When choosing them, it is advised to seek expert advice. The cost of these admixtures varies according to the quantity and type of admixture used. These will be added to the cost of concrete per cubic yard/meter.

1.2.4 Admixture Function

The following are some of the most important reasons for using admixtures: -

- Improve the workability of concrete.
- Improve concrete flowability (penetration) and pumpability.
- Accelerate and retard the initial set of concrete, accelerate the rate of strength development, or keep concrete workable for a longer period of time.
- Increases or decreases hydration heat liberation.
- Increase the strength of concrete by reducing its water content and densifying it.
- Increase the concrete's durability.
- Control the expansion of alkali aggregates or the reactivity of alkali-silica.
- Reduces water capillary flow through concrete while increasing its permeability to liquids.
- Reduces the weight of the concrete.
- Create non-slip wearing surfaces.
- Colored concrete or mortar can be made for coloured surfaces.
- Reduce segregation in grout and concrete mixtures.
- Produces concrete of fungicidal, germicidal and insecticidal properties.
- Enhance concrete bonding to the steel reinforcement and between old and new concrete surfaces
- Increase the resistance to chemical attack.

Table 1.8 Concrete Admixture and classification

Type of admixture	Desired effect	Material
Accelerators (ASTM C 494 and AASHTO M 194, Type C)	Accelerate setting and early-strength development	Calcium chloride (ASTM D 98 and AASHTO M 144) Triethanolamine, sodium thiocyanate, calcium formate, calcium nitrite, calcium nitrate
Air detrainers	Decrease air content	Tributyl phosphate, dibutyl phthalate, octyl alcohol, water-insoluble esters of carbonic and boric acid, silicones
Air-entraining admixtures (ASTM C 260 and AASHTO M 154)	Improve durability in freeze-thaw, deicer, sulfate, and alkali-reactive environments Improve workability	Salts of wood resins (Vinsol resin), some synthetic detergents, salts of sulfonated lignin, salts of petroleum acids, salts of proteinaceous material, fatty and resinous acids and their salts, alkylbenzene sulfonates, salts of sulfonated hydrocarbons
Alkali-aggregate reactivity inhibitors	Reduce alkali-aggregate reactivity expansion	Barium salts, lithium nitrate, lithium carbonate, lithium hydroxide
Antiwashout admixtures	Cohesive concrete for underwater placements	Cellulose, acrylic polymer
Bonding admixtures	Increase bond strength	Polyvinyl chloride, polyvinyl acetate, acrylics, butadiene-styrene copolymers
Coloring admixtures (ASTM C 979)	Colored concrete	Modified carbon black, iron oxide, phthalocyanine, umber, chromium oxide, titanium oxide, cobalt blue
Corrosion inhibitors	Reduce steel corrosion activity in a chloride-laden environment	Calcium nitrite, sodium nitrite, sodium benzoate, certain phosphates or fluosilicates, fluoaluminates, ester amines
Dampproofing admixtures	Retard moisture penetration into dry concrete	Soaps of calcium or ammonium stearate or oleate Butyl stearate Petroleum products
Foaming agents	Produce lightweight, foamed concrete with low density	Cationic and anionic surfactants Hydrolyzed protein
Fungicides, germicides, and insecticides	Inhibit or control bacterial and fungal growth	Polyhalogenated phenols Dieldrin emulsions Copper compounds
Gas formers	Cause expansion before setting	Aluminum powder
Grouting admixtures	Adjust grout properties for specific applications	See Air-entraining admixtures, Accelerators, Retarders, and Water reducers
Hydration control admixtures	Suspend and reactivate cement hydration with stabilizer and activator	Carboxylic acids Phosphorus-containing organic acid salts
Permeability reducers	Decrease permeability	Latex Calcium stearate
Pumping aids	Improve pumpability	Organic and synthetic polymers Organic flocculents Organic emulsions of paraffin, coal tar, asphalt, acrylics Bentonite and pyrogenic silicas Hydrated lime (ASTM C 141)
Retarders (ASTM C 494 and AASHTO M 194, Type B)	Retard setting time	Lignin Borax Sugars Tartaric acid and salts
Shrinkage reducers	Reduce drying shrinkage	Polyoxyalkylene alkyl ether Propylene glycol
Superplasticizers* (ASTM C 1017, Type 1)	Increase flowability of concrete Reduce water-cement ratio	Sulfonated melamine formaldehyde condensates Sulfonated naphthalene formaldehyde condensates Lignosulfonates Polycarboxylates

Table 1.9 Concrete Admixture and classification (continue)

Type of admixture	Desired effect	Material
Superplasticizer* and retarder (ASTM C 1017, Type 2)	Increase flowability with retarded set Reduce water–cement ratio	See superplasticizers and also water reducers
Water reducer (ASTM C 494 and AASHTO M 194, Type A)	Reduce water content at least 5%	Lignosulfonates Hydroxylated carboxylic acids Carbohydrates (Also tend to retard set so accelerator is often added)
Water reducer and accelerator (ASTM C 494 and AASHTO M 194, Type E)	Reduce water content (minimum 5%) and accelerate set	See water reducer, Type A (accelerator is added)
Water reducer and retarder (ASTM C 494 and AASHTO M 194, Type D)	Reduce water content (minimum 5%) and retard set	See water reducer, Type A (retarder is added)
Water reducer—high range (ASTM C 494 and AASHTO M 194, Type F)	Reduce water content (minimum 12%)	See superplasticizers
Water reducer—high range—and retarder (ASTM C 494 and AASHTO M 194, Type G)	Reduce water content (minimum 12%) and retard set	See superplasticizers and also water reducers
Water reducer—mid range	Reduce water content (between 6 and 12%) without retarding	Lignosulfonates Polycarboxylates

* Superplasticizers are also referred to as high-range water reducers or plasticizers. These admixtures often meet both ASTM C 494 (AASHTO M 194) and ASTM C 1017 specifications.

1.3 Basic Knowledge Of Concrete Mixture

1.3.1 The relationship between fresh concrete and the workability of concrete

a) Fresh Concrete

Water, cement, aggregate, and admixture are all components of fresh concrete.

The following are some of the properties of fresh concrete:

- i. The consistency or slump of concrete is determined by the wetness or dryness of the mixture.
- ii. Mix uniformity, which means that the concrete has been thoroughly mixed, has a uniform appearance, and that all ingredients are evenly distributed in the mix.
- iii. Fresh concrete workability, or the ease with which concrete can be placed and consolidated.

b) Workability of Concrete

- i. The workability of freshly mixed concrete is a purely physical property.
- ii. Concrete workability simply refers to the ability to work with concrete.
- iii. Fresh concrete is considered workable if it can be easily transported, placed, compacted, and finished without segregation.
- iv. Workability refers to the ease with which concrete can be placed, compacted, and finished in the desired manner.

c) Main Workability Characteristics

i. Consistency

The state of fluidity of a concrete mix, including the wettest and densest types, which are determined by the water content of the mix.

ii. Mobility

The ease with which concrete can flow into moulds and around steel, filling the mold/formwork and allowing it to be remoulded.

iii. Compactibility

The ease with which concrete mixes can be fully compacted and air voids removed.

iv. Stability

The concrete's ability to maintain its uniformity (during handling and vibrating without segregating)

1.3.2 Factors influencing Workability

i. Mix proportion

Water/Cement ratio \uparrow = Strength of concrete \downarrow = Workability \downarrow

Aggregate-cement ratio \downarrow = Strength of concrete \downarrow = Workability \uparrow

When the aggregate cement ratio is low, more cement paste is required to coat the aggregates and fill the voids between them in the concrete. Because it reduces friction between aggregates and allows for smooth movement, more cement paste makes the concrete relatively easy to mix, place, and compact. As a result, the workability of concrete improves.

When the aggregate cement ratio is higher, there will be less cement paste to coat aggregate surfaces and fill voids, making mixing, placing, and compacting concrete more difficult than in the previous case. It implies that the concrete's workability will be lower than in the previous case.

ii- Size, shape and surface texture of aggregates

Example:

Smooth aggregate = workability ↓ binding strength ↓

Rough aggregate = workability ↑ binding strength ↑

iii- Grading of aggregates

iv- Use of admixtures

v- Fineness of cement

1.3.3 Test on workability test

i- Slump Test

ii- Compacting Factor test

iii- Vee Bee Consistency test

1.3.4 Hard Concrete

Hardened concrete is concrete that must be strong enough to withstand structural and service loads, as well as durable enough to withstand the environmental exposure for which it is designed. Compression strength is high (high-compressive strength).

Normal concrete has a strength range of 25 to 40 MPa. The term High-Performance Concrete is used for concrete with a compressive strength greater than 50 MPa (50 MPa corresponds to a force of 50 tonnes acting on a square with sides of ten centimeters).

1.4 CONCRETE WORKS AT THE CONSTRUCTION SITE

1.4.1 Determine the cause and effects of segregation and bleeding on concrete.

1.4.1.1 Define Segregation and Bleeding

- i. **Segregation** can be defined as the separation of constituent materials of a concrete mix so that the mix is no longer in a homogeneous condition.

Segregation of concrete also defines as a separation of ingredients of concrete from each other. Separating coarse particles in a dry state terms as segregation.

- ii. **Bleeding** in fresh concrete is the process by which free water in the mix is pushed to the surface as a result of the settlement of heavier solid particles such as cement and water.

The tendency of water to rise to the surface of freshly placed concrete is referred to as bleed.

Bleeding causes the formation of porous, weak and non-durable top layer of concrete.

1.4.1.2 Causes Of Segregation And Bleeding Of Concrete

i. Causes of Concrete Segregation

- Concrete with a high water-cement ratio.
- Segregation is primarily caused by poorly graded aggregate and excessive water content.
- A poorly proportioned mixture that contains aggregates and lacks sufficient matrix to bind causes the aggregate to settle.
- Inadequately mixed concrete with an excess of water has a higher tendency for segregation.
- Poured too high during pouring work

ii. Methods for reducing bleeding in concrete include

- Lower the water content. Use a mix with a lower slump.
- Use finer cement
- Increase the proportion of fines in the sand
- Use additional cementitious materials.
- Make use of air-entraining admixtures.

1.4.1.3 Effects of Segregation and Bleeding On Quality of Concrete

a) **Concrete Segregation Effect**

i. Problems of leakage, corrosion, carbonations

Since segregation causes the formation of pores in the concrete there is water leakage or water permeability in the concrete causing leakage of water from the slab or column. Due to leaks in the columns, the reinforcement forms corrosion. Also, there will not be a bond between reinforcement and concrete in RCC, which directly affects the durability of the structure.

ii. Develops the crack in the concrete

Because of segregation, the strength of concrete in the slab, beam, or column is low, resulting in the formation of cracks in the structure.

iii. Concrete's lower strength

Segregation reduces the strength of the concrete by preventing compaction and bond formation.

b) Concrete Segregation Effects

- i. Concrete loses its homogeneity, resulting in brittle and porous concrete.
- ii. It permeates the concrete.
- iii. It causes a delay in the finishing of the pavement's surface.
- iv. Concrete bleed causes a high water-cement ratio at the top surface.
- v. The bond between two concrete layers deteriorates.
- vi. Concrete's pumping capacity is significantly reduced.

REINFORCED CONCRETE

This topic deals with the characteristics of reinforced concrete and the relationship between concrete and

2.0 Introduction to Reinforced Concrete

2.1 Definition of Reinforced Concrete

Reinforced concrete is a formation resulting from a combination of different properties in concrete and steel. This combination can produce a force to withstand compressive and tensile forces. These materials are strong and durable building materials to make it a building member. It can be moulded into varying shapes with varying sizes. For example, from a simple rectangular pillar to the shape of a dome that is slender and curved.

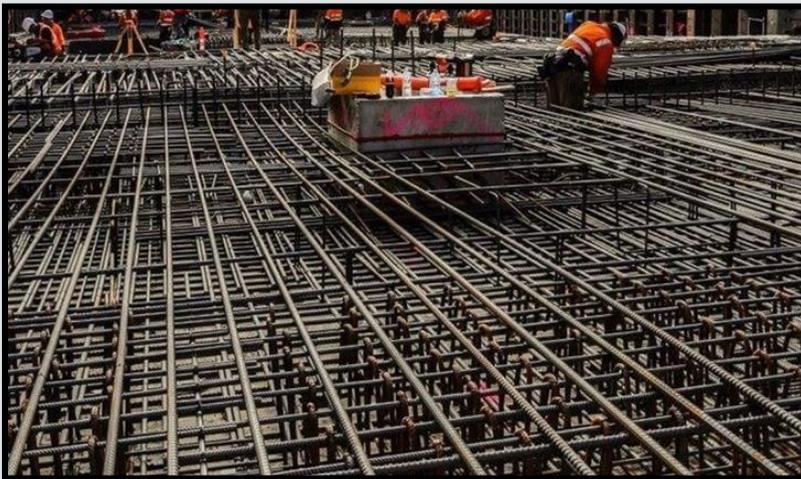


Figure 1.7 Construction using reinforced concrete

Examples of reinforced concrete structures are timbers, columns, walls, slabs, and piles. Meanwhile, examples of reinforced concrete structures are buildings, bridges, retaining walls, and others.

2.2 Properties of Reinforced Concrete

The characteristics of reinforced concrete are:

- a) The tensile strength of concrete is 10% of its compressive strength.
- b) The design of reinforced concrete is constructed on the assumption that concrete cannot overcome tensile force resistance.
- c) Reinforcement is designed to take the tensile forces transferred through the surface bonding of both materials i.e. concrete and reinforcement.
- d) If the bond (in) the surface adhesion of the two materials is insufficient, the reinforcement will slip from the concrete, and there will be no combined action of concrete and steel.
- e) During construction, concrete should be compressed/compacted around the reinforcement.
- f) Meanwhile, the reinforcement used should consist of twisted/overlapping surface parts to obtain additional mechanical grip (ribbed and twisted bars).

2.3 Determination of Materials

The materials used in reinforced concrete are:

- a) Cement

Consists of fresh cement. Clean of hardened lumps and stored in a water / weatherproof storebuilding with the floor raised above the ground.

- b) Aggregate

The material must be clean, sharp and have a good grade, such as river sand that is free from all impurities. For dirty sand (containing mud, silt and dead leaves), it must be washed first and preferably filtered.

c) Coarse aggregate

Must be sourced from a permitted quarry, such as gravel or limestone. It must be of good grade and uniform in size of 6 - 12 mm. This material must be free of silt, mud or all types of dirt.

d) Water

Must be clean and fresh (from the type of drinkable water). It is taken from a real water source.

2.3.1 Concrete

- a) Concrete is a mixed material composed of aggregate, cement, and water, and then when it acts between cement and water it will harden.
- b) Concrete is hard and brittle. Its strength depends on the rate of mixing, the age of maturity and many others.
- c) Concrete's apparent strength in the tensile force, which is about 1/10 of its compressive strength, is low.
- d) Concrete will increase its strength, especially in the early stages of a few weeks and it will continue slowly after that. On the 28 -day stage, the concrete has reached 3/4 of its maximum strength. The nature of this strength is that construction work can be carried out more advanced (progress) again.
- e) The quantity of water consumption is also important. If there is a lot of water, it will weaken the strength properties of the concrete, and if there is too little it will cause the concrete to be difficult to compress and combine.
- f) The amount of water needed is determined by the type of aggregate and the amount of cement used. However, it is frequently less than or equal to half of the total weight of the cement.

- g) For small works, cement can usually be purchased in 50 kg bags and with this bag of cement can be used as a mixing rate as follows:
- 50 kg of cement
 - 85 kg of sand
 - 160 kg of gravel
 - 28 kg of water
- h) For large works, cement is supplied in large batches of 1 cubic meter and this can also use as a mixing rate as follows:
- 360 kg of cement
 - 600 kg of sand
 - 1150 kg of gravel
 - 200 kg of water
- i) The mixture described above is known as the prescribed mix and from this mixture a 150 mm concrete cube is formed and left for 28 days. The average strength from the available cube test results is 33 N/mm² and usually none is less than 25 N/mm².
- j) If one has a strength of less than 21 N/mm², this indicates there is something outside of the cube preparation procedure i.e. cement, mortar and mixing rate or perhaps on the compression test method.
- k) Usually a 150 mm cube at the age of 28 days has a minimum strength of 25 N/mm² and it is named as grade 25 concrete and 25 N/mm² is the characteristic strength of the concrete (f_{cu}).
- l) Mix design is a mixture that requires the data related to the history of the materials used, the use of mixing machinery and supervisory system.

- m) Concrete is also graded according to the same system of grades 20, 30, 40 and others. Grade 20 concrete is typically used for columns for large-sized superstructures. Grade 40 concrete is typically used in certain circumstances, especially to avoid oversized for low-rise buildings or for high-rise structures.

- n) Grade 25 concrete is commonly used on structures that are frequently found today and its use of cement must be economical and the resulting cube results achieve the goal without causing difficulty.

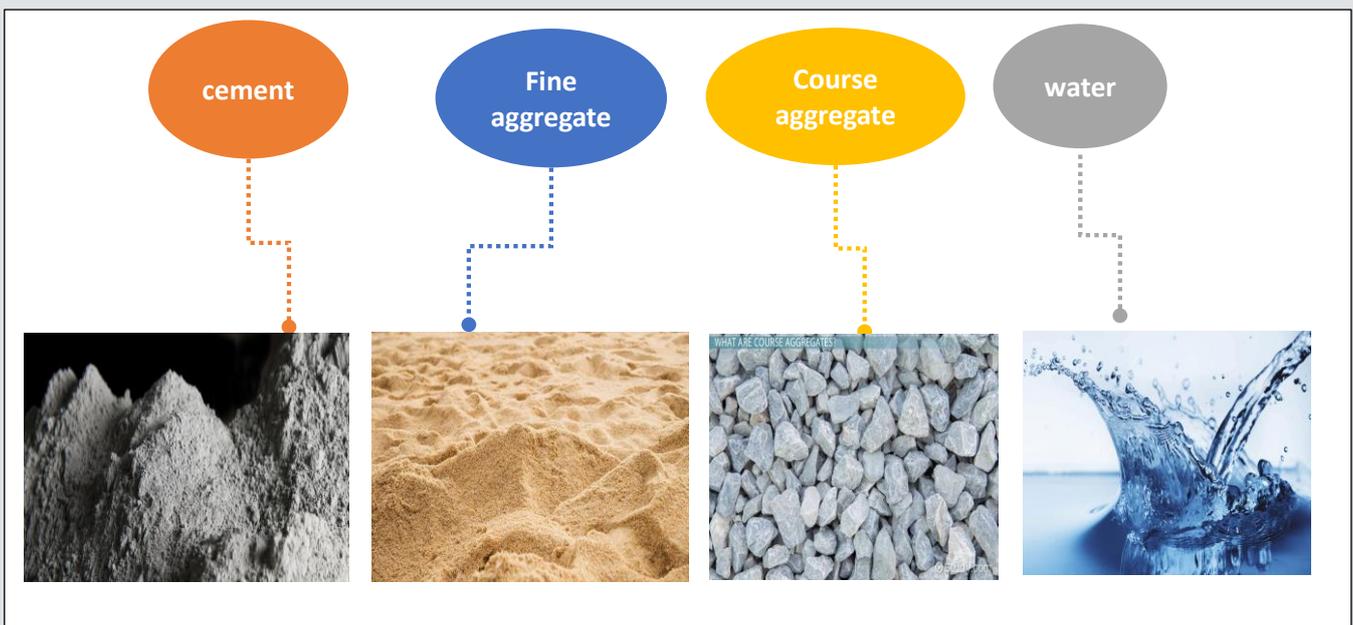


Figure 1.8 Material in concrete

There are **two (2)** factors where concrete should be reinforced for practical use other than its ability to compressive strength, namely:

i) Increased strength

The increase in the strength of concrete occurs as it ages, that is, it increases rapidly in the early stages and will decrease later. Typical changes in strength for Portland cement concrete allowed in CP 110 are:

Table 1.9 Typical change in strength of Portland Cement in CP 110

Age	7 day	1 month	2 month	3 month	6 month	1 year
Strength N/mm ²	16.5	16.5	16.5	16.5	16.5	6.5

ii) Durability characteristics of concrete

Concrete structures are designed and calculated for long periods of time and require little maintenance. The durable properties of concrete are influenced by:

- Conditions of exposure
- Quality of concrete
- Thick cover (concrete cover)
- The width of the crack surface

Structural exposure will affect the cement mix required; material consumption and water-cement ratio; minimum thickness of concrete cover as well as the use of cement types such as sulfate resistance cement.

The concrete cover is for the purpose of preventing the rusting agent from damaging the reinforcement, protecting the reinforcement from experiencing the rapid temperature rises as well as losing its strength during fire.

2.3.2 Steel / Reinforcement Bars

Steel is not the original metal as mild steel typically contains 90% iron and 10% of more than half the manganese, carbon and the remaining quarter is silicon, sulfur, and phosphorus. Of the minor content, carbon is the most important.

a) Type of Steel

- The surface of hot-rolled mild steel is usually smooth. Therefore, this type of steel is easy to bend and requires a small radius. For example, steel wire binding posts or small timber.
- Hot rolled high yield steels are steels that have a higher carbon content than ordinary mild steels. It is manufactured with an overlapping rough surface.
- High yield steel cold work surface is stacked rectangular-shaped spindles, also referred to as a "deformed bar" or bar-shaped.
- The standard shape of the bar and the method of tabulation of reinforcement are specified in BS 446. The type of reinforcement (steel) is indicated by the code, which ranges from R for mild steel to Y for high strength steel.
- Measurements of the strength of different types of steels are difficult to express in simple form because of the emergence of values of suitability for use but they are better known as:
 - i) The strength of hot-rolled mild steel is 250 N/mm² (FY)
 - ii) The strength of hot rolled high yield steel is 410 N/mm² (FY)
 - iii) Cold worked high yield steel has a tensile strength of 425 N/mm² (FY)

b) Properties of reinforcement / bars

Table 1.10 Reinforcement Properties (bars)

Steel Bars	Nominal Size (mm)	Characteristic strength (f_y) N/mm ²
1. Hot rolled mild steel (BS 4449)	All sizes	250
2. Hot rolled high yield steel (BS 4449)	All sizes	410
3. Cold worked high yield steel (BS 4461)	Up to and including 16	460
4. Hard drawn steel wire	More than 16	425
	Up to and including 16	485

Sources: *Nota Panduan Politeknik Malaysia (Teknologi Konkrit)*

All reinforcement should be clean and free of rust, oil, grease, paint or layers of other steel before it is placed in the concrete. The reinforcement utilized must adhere to the most recent British structural design standards. Reinforcement must not be heated or burned. All defective reinforcement such as bends, cracks and others, if they need to be repaired should be made in cold conditions.

2.3.3 Distance Reinforcement CP 110

a) Minimum Distance between Steel Bars

The distance of the reinforcement inside the structure is important because if it is too close, it is difficult for the compression work to be done. Therefore, the required concrete strength is not achieved. If too far away, the chances of shear failure will occur. The code of practice in CP 110 has recommended the following:

- i) Individual Bar
The horizontal distance must be not less than H_{agg} = maximum aggregate size
- ii) Paired Bars
The horizontal distance between the two points must be at least $H_{agg} + 5$ mm.
A vertical distance of at least $2/3 H_{agg}$ is required. The vertical distance if the paired bars are side by side must be not less than $H_{agg} + 5$ mm.
- iii) A group of Bars
The horizontal and vertical distances must be not less than $H_{agg} + 15$ mm.

Table 1.11 Nominal Thickness of Concrete Covers

Covers Function	Nominal thickness of concrete cover by grade (mm)				
	Concrete grade				
	20	25	30	40	50
1) Protect from normal weather	25	20	15	15	15
2) Protect from rain, ice melt and submerged concrete.	-	40	30	25	20
3) Protect from heavy rain, rain and heat alternately and the cause of rusting.	-	50	40	30	25
4) Protect from seawater and water flow under pressure.	-	-	-	60	50
5) Protect from salt for the use of office liquid.	-	-	50	40	30

Sources: Nota Panduan Politeknik Malaysia (Teknologi Konkrit)

2.4 Comparison of Concrete and Steel

Table 1.12 The Differences Concrete Properties and Reinforcement

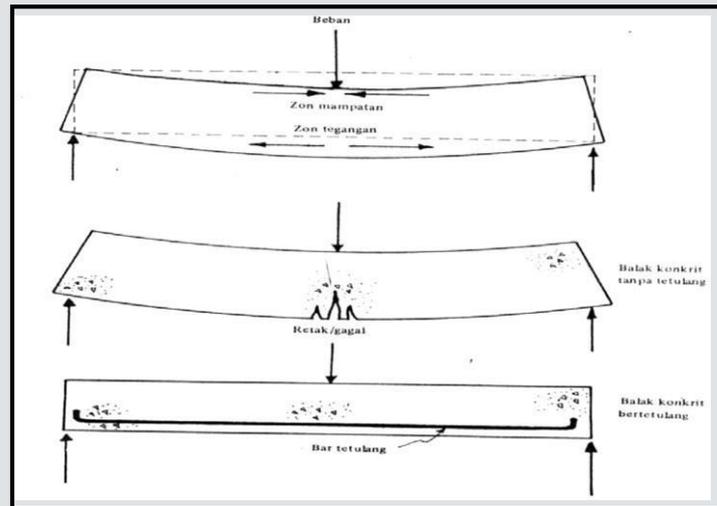
Properties	Concrete	Steel
1) Tensile strength	Weak	Good
2) Compressive strength	Good	Good (slim steel will bend and squeezing)
3) Shear strength	Medium	Good
4) Rugged durability	Good	Rusty if not protected
5) Fire resistance	Good	Weak (lost strength rapidly at high temperatures)

Sources: Nota Panduan Politeknik Malaysia (Teknologi Konkrit)

2.4.1 Functional Reinforcement for Tension Zones

Log bending occurs when the log is supported on two corbels at both ends and a load in the middle. When bending occurs, the upper part of the surface of the log is compressed due to compressive stresses, while the lower part becomes tense and elongated due to tensile stress.

The lowest curvature of the lower surface of the log was found to be the most stressed. If the logs are unreinforced, there will be cracks at the bottom, and it is likely to continue to break. But if the log is equipped with reinforcement under it, the log will not suffer any failure.



Sources: *Nota Panduan Politeknik Malaysia (Teknologi Konkrit)*

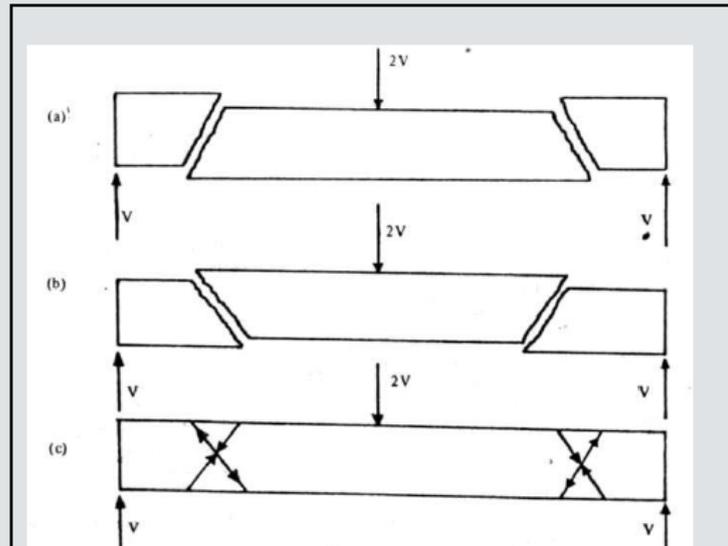
Figure 1.9 Bending of Concrete Logs

2.4.2 Functional Reinforcement for Shear Zone

By using an appropriate size of concrete to withstand the effects of compression and steel reinforcement bars to overcome the effects of tensile, logs can be created that can endure the effects of bending. This identical log, however, will probably fail due to a process called shear.

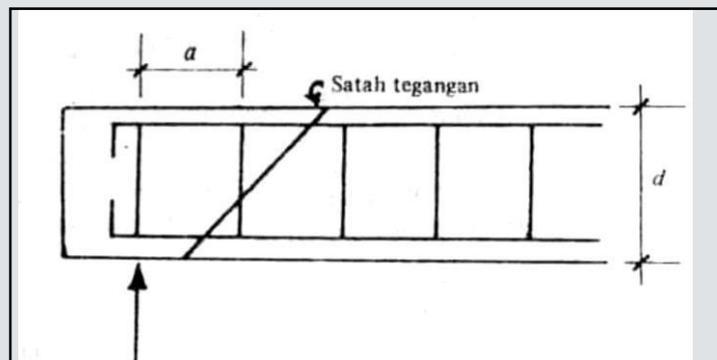
The number of actions external forces acting on the horizontal axis and power will extend the timber is known as a shear force.

The shear strength of a log is held in a part of the log that connects the concrete compression area with the steel tensile area.



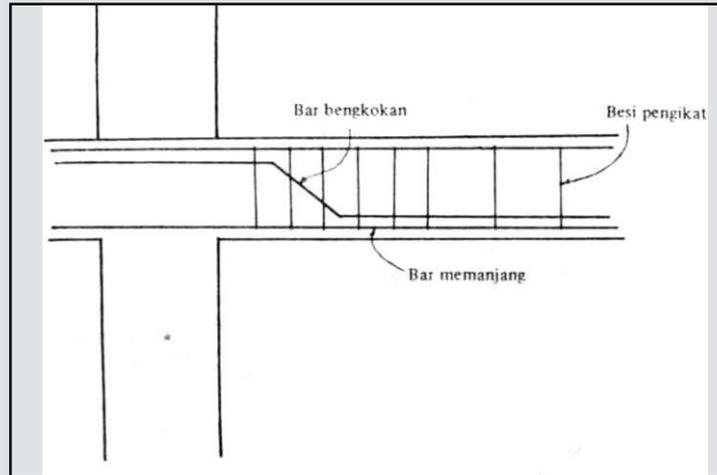
Sources: *Nota Panduan Politeknik Malaysia (Teknologi Konkrit)*

Figure 1.10 Basic principles of shear on a concrete log



Sources: *Nota Panduan Politeknik Malaysia (Teknologi Konkrit)*

Figure 1.11 Resist shearing forces result from a combination of an elongated bar, bar binder



Sources: *Nota Panduan Politeknik Malaysia (Teknologi Konkrit)*

Figure 1.12 Bending bars, elongated bars and fasteners for a combination of shear reinforcement for continuous logs

2.5 Types of Reinforcement

There are two categories of reinforcement:

- i) Reinforcement Bars.
- ii) Reinforcement Mesh.



Figure 1.13 Bar Reinforcement

i) Reinforcement Bars

a) Mild Steel Bars

Made with hot heat according to BS 449: 1974. It is formed in a state of smooth and twisted surface. It has a tensile strength of 250N/mm². The allowable extension is 22.0%.

b) Twisted Steel Bars

It is made of BS 4449: 1978 alloy. It is different from mild steel due to its twisted surface and tensile strength of 460N/mm². The minimum elongation is at least 12% except for reinforcements greater than 16mm where the tensile strength is 425N/mm² with an elongation of 14%.

c) Cold Rolled Steel Bars

It is a mild steel twisted according to BS 4461: 1978. The tensile strength is 460N/mm² with an allowable elongation of 12%. However, for large reinforcements, the tensile strength is 425N/mm² with an allowable elongation of 14%.

All these reinforcements are made in the following metric sizes: 6,8,10,12,16,20,25,32 and 40mm. Steel lengths are made in the form of standard lengths such as 12 or 5 meters.

ii) Reinforcement Mesh

It is a type of wire made in various sizes. These nets usually contain fine wires and are welded as a single mesh. Preferably it must be easy to use and if necessary easy to bend especially at sharp corners. The function of this mesh reinforcement is as a simple chain to shape and also support the concrete.

Reinforcement mesh consists of several types:

a) Reinforcement hexagonal wire mesh

This network is the easiest and cheapest. This wire is also known as "chicken wire", and the wire used typically has a diameter of 10-25mm (diameter).

b) Welded wire mesh reinforcement

The wire that forms this mesh is made of small and medium strength steel. This wire is stronger and more sturdy than hexagonal type wire. This type of mesh can be formed into the shape of a structural curve. The disadvantage of this mesh is that it is a disadvantage of two-wire connection because the weld is often not done properly at the time of making this mesh.

c) Skeleton reinforcement

Its use is for structural frameworks in which the layers of mesh are bonded. Skeletal reinforcement is placed at a distance of 30cm square. Reinforcement diameter sizes of 4.20mm and 6.25mm are the most commonly used.

2.6 Reinforced Concrete Construction

2.6.1 Reinforcement Bar Bending Method

- i) Reinforcement bar bending work is carried out after completion of cutting work.
- ii) Uses a table mounted manual bending tool.
- iii) The table should be of sufficient length to accommodate a long reinforcing bar.
- iv) Two bending tools are used if the bars are too long and numerous.
- v) The bar is gently folded so that the hair does not crack.
- vi) In the case of large diameter bars, the bar first needs to be heated.
- vii) A high yield bar should not be heated before bending.



Figure 1.14 Work tables and machines for bending reinforcement

2.6.2 Methods of Arrangement, Spacing Bonding and Steel Assembly

After cutting the bar, the work of tying the bar with fine wire. The purpose is to prevent movement, especially when concreting work is carried out. The binding wire used is 0.8 mm to 1.6 mm in diameter. To obtain a suitable distance between the mould and the reinforcement bar, small concrete blocks (spacer blocks) are used.



Figure 1.15 Method of tying wire on reinforcement bars



Figure 1.16 Spaces block

2.6.3 Connection Method

Connections can be divided into 3 types:

- a) Mounted connection
- b) Weld joints
- c) Pressure weld joints



Figure 1.17 Diagram of connection method

2.6.4 Connections for Poles

Ideally, the connection should be made at $\frac{1}{3}$ the height of the column from below.

2.6.5 Beam Connections

The connection of the beam should be formed $\frac{1}{4}$ the distance of the beam from both ends.

2.6.6 Mooring

Occurs when connecting two parts of a reinforced concrete construction to which the bars are conveyed into the other part. Examples are between columns and beams or between foundations and columns.

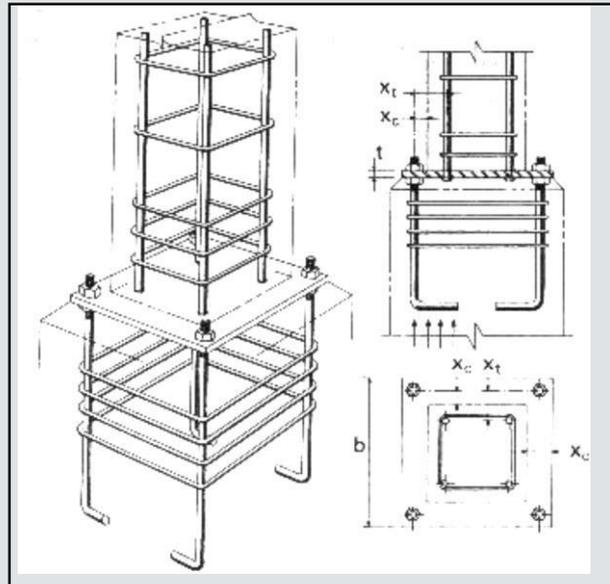


Figure 1.18 Mooring for Columns and Foundations

2.6.7 The Arrangement and Spacing Reinforcement

Reinforcement should be placed where the maximum stress is below the structure's surface. This is because the inclusion of reinforcement can cause the bar/reinforcement to rust, weakening the bond with the concrete. The cover (concrete cover) bridges the gap between the concrete surface and the reinforcement, which is typically 15 mm to 40 mm.

2.6.8 Formwork Construction

- i) The materials commonly used are the board, plywood, steel, polystyrene, rubber, thermos systems and many others.
- ii) For large construction works, the formwork is part of the work system.
- iii) Scaffolding system is used to support the formwork. The purpose is to withstand the load imposed on it.
- iv) Commonly used steel scaffolding or steel strut.

2.6.9 Uses of Formwork

The use of formwork on construction sites are:

- i) To insert wet concrete before compression so that it can reach the required strength.
- ii) Obtain concrete structure members according to the desired shape and size.
- iii) To obtain a good finish.

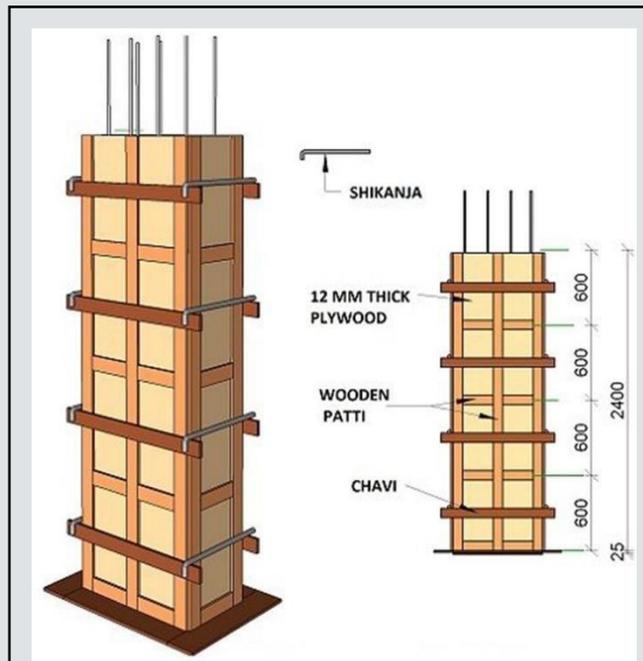


Figure 1.19 Formwork for column

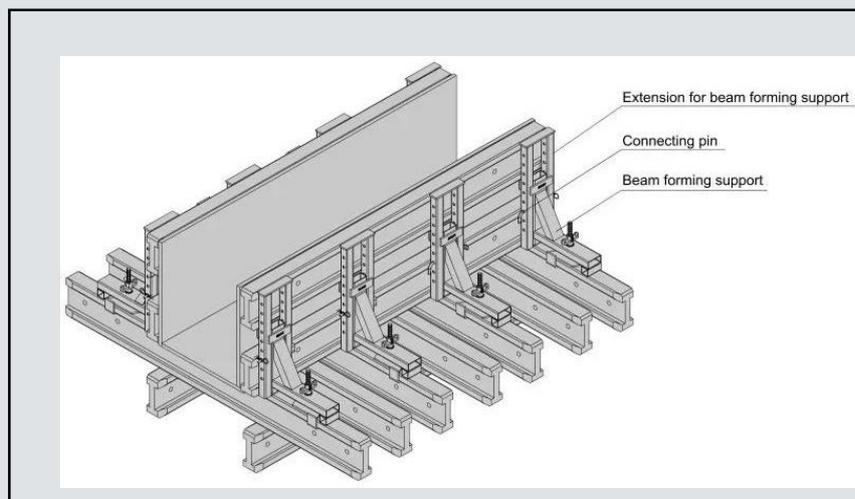


Figure 1.20 Formwork for beam

2.6.10 Characteristics of A Good Formwork

The characteristics of the formwork are as following:

- i) The box must be strong to withstand the force of the deflection during the placement of wet concrete is done.
- ii) Must be strong to support the working load
- iii) Must be constructed accurately without exceeding established limits.
- iv) All connections should be tight to prevent loss of wet concrete mortar.
- v) The size of the panel and the unit should be easy to handle and the design should take into account the methods of enforcement and also the opening.

2.6.11 Minimum Duration for The Opening Formwork to Structure

Duration opening formwork is dependent on the type of concrete used, weather, preservation methods and others. The formwork is opened when it is strong enough to bear its own heavy load and the loads to be applied.

Table 1.13 Duration for The Opening Formwork

Mold	Maximum duration
Floor (floor) with a width of 3.3 meters	21 days
Floors that exceed 3.3 meters	28 days
Concrete Beam	28 days
Column	14 days
Wall	7 days

Sources: *Nota Panduan Politeknik Malaysia (Teknologi Konkrit)*

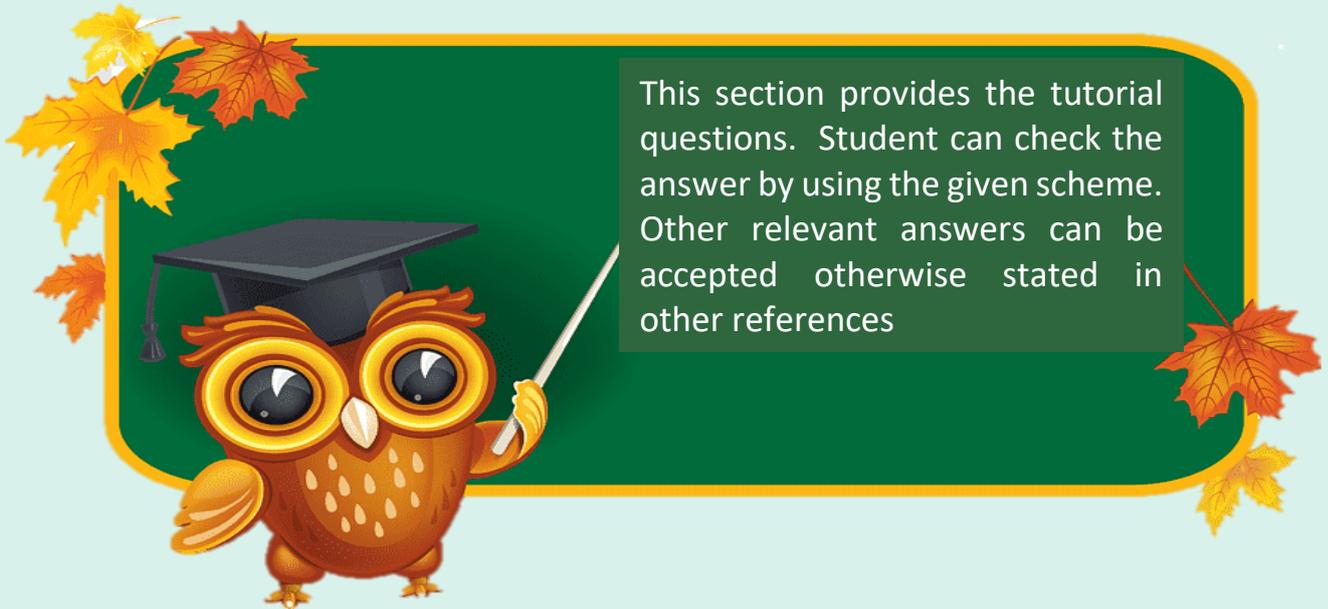


EXTRA INFO

There are types of formwork used in reinforced concrete.

- 1. Timber formwork**
- 2. Steel formwork**
- 3. Plywood formwork**
- 4. Aluminum formwork**
- 5. Plastics formwork**





This section provides the tutorial questions. Student can check the answer by using the given scheme. Other relevant answers can be accepted otherwise stated in other references

QUESTIONS

1. List **FOUR (4)** materials that are being used in a concrete mixture.
2. Explain the ratio of proportions and the usage in concrete mixture.
3. Describe **THREE (3)** factors that influencing the workability of concrete.
4. Explain the procedure of the slump test for measuring workability of concrete.
5. Define the terms segregation and bleeding.
6. Describe the following batching method of concrete:
 - a. Volume method
 - b. Weighing method
7. Explain the method of compacting concrete process in concrete work.
8. Advantages and disadvantages of compacting concrete using vibrator and steel rod.
9. List the types of bar reinforcement.
10. Identify the relationship between formwork and reinforced concrete.

ANSWER

Let's Check

1. List FOUR (4) materials that are being used in concrete mixture.
 - a. Cement 2.
 - b. Fine aggregate 3.
 - c. Course aggregate 4.
 - d. Water

2. Explain the ratio of proportions and the usage in concrete mixture.

MIX RATIO	USAGE
1:2:4	Reinforced concrete
1:3:6	Concrete slab
1:1 1/2:3	Pre-stressed concrete
1:5:10	Base of the trench

3. Describe THREE (3) factors that influencing workability of concrete.

i) Water cement ratio

A higher water-cement ratio will cause the lower concrete strength but workability is high.

While a lower water-cement ratio would lower workability.

ii) Aggregate / cement ratio

A lower aggregate-cement ratio will increase the workability.

iii) Shape and fleshiness of aggregate

Angular aggregates give a low workability, while the round aggregates will lead to high workability. Aggregates that have a smooth surface can provide a good workability, while aggregates with a rough surface produces a lower workability.

iv) Additives substance

The addition of air entraining admixture and plasticizer will increase workability.

4. Explain the procedure of slump test for measuring workability of concrete.

1. The mould for the concrete slump test is a frustum of a cone, 300 mm (12 in) of height. The base is 200 mm (8in) in diameter, and it has a smaller opening at the top of 100 mm (4 in).

2. The base is placed on a smooth surface, and the container is filled with concrete in three layers, whose workability is to be tested.

3. Each layer is tamped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end.
4. When the mould is completely filled with concrete, the top surface is struck off (levelled with mould top opening) by means of screening and rolling motion of the tamping rod.
5. The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot - rests brazed to the mould.
6. Immediately after filling is completed and the concrete is levelled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump.
7. The decrease in the height of the center of the slumped concrete is called slump.
8. The slump is measured by placing the cone just beside the slumped concrete and the tamping rod is placed over the cone so that it should also come over the area of slumped concrete.
9. The decrease in height of concrete to that of mould is noted with scale. (usually measured to the nearest 5 mm (1/4 in)).

5. Define the term of segregation and bleeding.

Segregation of concrete is the separation of cement paste and aggregates of concrete from each other during handling and placement. Segregation also occurs due to over-vibration or compaction of concrete, in which cement paste comes to the top and aggregates settles at the bottom.

Bleeding can be defined as the tendency of water to rise to the surface of freshly placed concrete. It is another form of segregation where some amount of water comes to the concrete surface after placing and compacting. The water content carries some particles of sand and cementing materials.

6. Describe the following batching method of concrete:

a. Volume method

In volume batching, materials are measured on the basis of volume. It is a less precise method of batching Measurement boxes or gauge boxes of known volume are used to measure materials.

Cement is taken in the form of bags, where the volume of one bag of cement (50 kg) is taken as 35 litres. The volume of gauge box used is made equal to the volume of one bag of cement which is 35 litres or multiple thereof.

Gauge boxes are generally deeper and contains a narrow top surface and they are made of timber or steel or iron.

Volumes of different sized fine aggregate and coarse aggregate are measured individually by these gauge boxes.

Water is measured using a water meter, or water cans of known volume are used. To make a 1:1:2 ratio concrete mix according to volume batching, one should take one bag of cement (35 litres), 1 gauge box of fine aggregate (35 litres) and 2 gauge boxes of fine aggregate (70 litres). If the water-cement ratio is 0.5, then half of the volume of cement which is 25 liters of water should be taken.

b. Weighing method

In this method, Materials are measured on the basis of weight. It is an accurate method of batching.

Weigh batchers or other types of weighing equipment are used to measure the weight of materials.

Cement, fine aggregate, coarse aggregate and water are taken by weighing. Weigh batchers used are available in two types namely mechanical weigh batcher and electronic weigh batcher.

In mechanical weigh batchers, weights are measured using spring and dial gauge arrangement and it is widely used equipment in weigh batching.

In electronic weigh batchers, electronic scales and load cells supported by hoppers are used to measure the weight of ingredients of concrete. To prepare a 1:1:2 concrete mix using weigh batching, measured quantity of materials are 50 kg of cement, 50 kg of fine aggregate and 100 kg of coarse aggregate.

7. Explain the method of compacting concrete process in concrete work.

Method of compacting concrete

Compaction significantly increases the ultimate strength of concrete and enhances the bond with reinforcement. It also increases the abrasion resistance, and general durability of the concrete, decreases the permeability and helps to minimise its shrinkage and creep characteristics.

Proper compaction also ensures that the reinforcement, tendons, inserts and fixings are completely surrounded by dense concrete, the formwork is completely filled – i.e. there are no pockets of honey-combed material – and the required surface finish is obtained on vertical surfaces.

8. Advantages and disadvantages of compacting concrete using vibrator and steel rod.

Vibrator	Advantages	Disadvantages
	<ol style="list-style-type: none"> 1. The honeycomb structure can be avoided. 2. Structure with heavy reinforcement can be easily compacted. 3. Low water-cement ratio can be used. 4. Work speed increases. 	<ol style="list-style-type: none"> 1. If the concrete mixture is designed with low workability, the over vibration causes additional power consumption, resulting in energy dissipation.
Steel rod	<ol style="list-style-type: none"> 1. Obtained for small quantities of concrete. 2. Use hand compaction when Vibrators are not available on site. 	<ol style="list-style-type: none"> 1. It can be done by tamping, ramming and rodding

9. List the types of bar reinforcement.

- a) Hot Rolled Deformed Bars
- b) Mild Steel Plain bars
- c) Cold Worked Steel Reinforcement
- d) Prestressing Steel

10. Identify the relationship between formwork and reinforced concrete.

1. All support for formwork sheets should be strong enough to bear the concrete and steel loads and lifespan
2. The formwork must be waterproof, and the connection should be tight to prevent cement water from flowing
3. The formwork should be easily re-opened to prevent damage to the concrete surface
4. The formwork needs to be fastened to prevent the reinforcement from moving during the concrete work.

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