
CONCRETE

Introduction

- Concrete and Steel are the two most commonly used Structural materials in the construction industry.
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Topics

- Definitions
 - Ingredients
 - Types of cement
 - Types of aggregate
 - Batching & mixing of concrete
 - Transportation of concrete
 - Testing of concrete
 - Pumping of concrete
 - Curing of concrete
 - Joints in concrete
 - Reinforcement for concrete
 - Additives & Admixtures for concrete
 - Useful References
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Definitions

■ Shotcrete

- It is that type of mortar or concrete which is conveyed through a hose (flexible tube) and projected at high velocity.

■ Pozzolanic cement

- A siliceous and aluminous material which in finely graded form chemically reacts with calcium hydroxide at ordinary temperature in the presence of moisture to form compounds possessing cementitious properties.

■ Portland cement

- A cement consisting of Portland (Portland is the origin of stone in England) cement with not more than 5% of other inorganic materials.

■ Hydraulic cement

- They consists mainly of silicates and aluminates of lime and can be broadly classified as natural cements, Portland cements and high Alumina cements.

■ Blended Cement

- A cement consisting of Portland cement and two or more appropriate inorganic materials(fly ash or blast furnace slag) which contribute to the strength gaining properties of the cement with or without other constituents. (**ASTM C 1157-94a**)
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Ingredients

- Concrete consists of following ingredients
 - Cementitious material (cement or lime)
 - Coarse aggregate (Crushed stone etc)
 - Fine aggregate (Sand)
 - Water (which is fit for drinking)
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Manufacture of Portland cement

- It is made up of Lime stone or chalk and alumina and silica found as clay or shale.
 - Process of manufacturing cement consists grinding the raw materials, mixing them in certain proportion and burning in a large rotary kiln at a temp of about 1450 °C. Material partially fuses into balls called clinker. Clinker is cooled and ground to a powder form with some gypsum addition. Product obtained is called Portland cement.
 - Main compounds of portland cement are
 - Tri calcium Silicate $3\text{CaO} \cdot \text{SiO}_2$ C_3S
 - Dicalcium silicate $2\text{CaO} \cdot \text{SiO}_2$ C_2S
 - Tricalcium Aluminate $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ C_3A
 - Tetracalcium Aluminoferrite $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ C_4AF
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Types of Cement

1. Ordinary Portland cement (Type-I)

- Used in general concrete construction where there is no exposure to sulphates in soil or ground water.

2. Modified Cement (Type-II)

- The rate of gain of strength is similar to OPC.
 - The rate of heat development is higher than a low heat cement.
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Types of Cement

3. Rapid hardening Portland cement (Type-III)

- ❑ It is used where high early strength is required or where formwork is to be removed early or where quick construction is required.
 - ❑ High early strength cause high rate of heat development.
 - ❑ Higher **C₃S** content (more than 55% up to 70%) and finer grinding of clinker cause increase rate of strength gaining.
 - ❑ It should not be used for mass construction works (Dam) or for large structural sections.
 - ❑ Setting time of OPC and rapid hardening cement is same i.e. not less than 45 minutes.
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Types of Cement

4. Low heat Portland cement (Type-IV)

- ❑ Due to low thermal conductivity of concrete the rise in temperature in the interior of concrete mass can lead to serious cracking.
 - ❑ Low content of C_3S and C_3A results in a slower development of strength.
 - ❑ **ASTM C150-94** covers the detail of low heat cements.
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Types of Cement

5. Sulphate resisting Cement (Type-V)

- ❑ Calcium aluminates in cement can react with sulphate salt which will increase the volume and cause disintegration of concrete.
 - ❑ Used where sulphate attack is suspected (i.e. shore areas, underground areas, canal linings, culverts, retaining walls, etc.)
 - ❑ **C₃A** content must be low 3.5% which increases power against sulphates as per **BS 40027 : 1991**
 - ❑ **ASTM C150-94** covers the detail of Sulphate resisting Cements.
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Types of Cement

6. White cement and Pigments

- ❑ These cements contain very low Iron Oxide (less than 0.3% by mass of clinker) and Manganese Oxide. China clay with Chalk or limestone is generally used.
 - ❑ White cement satisfy the **BS 12 : 1991**
 - ❑ Pigments used for different colours in cement like ...
 - ❑ Iron oxides can produce Yellow, Red Brown and Black.
 - ❑ Chromic Oxides produces green colour
 - ❑ Titanium Dioxides produces White colour.
 - ❑ **BS 1014 : 1975** for Pigments
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Types of Cement

7. Portland Blast furnace cement

- ❑ It is a mixture of OPC and *GGBS*(ground granulated blast furnace)
- ❑ Slag is a waste product in the manufacturing of Pig Iron (300 kg slag/ton of Pig Iron)

8. Super-sulphated Cement

- ❑ It is highly resistant to high concentration of sulphates
 - ❑ 80-85 % blast furnace slag 10-15% calcium sulphate 5% portland cement clinker.
 - ❑ Suitable for mass concrete works
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Types of Cement

9. Anti-bacterial Cement

- ❑ It's a Portland cement interground with a antibacterial agent which prevents microbiological fermentation.
- ❑ Used in food processing plants, swimming pools etc.

10. Hydrophobic Cement

- ❑ It is a special type of cement and it can be stored for a long time under unfavorable conditions.
- ❑ Hydrophobic properties are due to the formation of an water-repellent film around each particle of cement.
- ❑ This cement is obtained if **OPC** is grinding with 0.1 to 0.4 % of Oleic acid, stearic acid or Pentachlorophenol.

11. Oil-well cements

- ❑ It is used for grout or slurry to be pumped to depth of thousands meters (Temperature 150-300°F and 100Mpa pressure)
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Types of Cement

12.High Alumina Cement

- ❑ It gain strength at a very high rate i.e 80% strength in 24 hours.
 - ❑ Good to resist sulfate attacks
 - ❑ It contains about 40% alumina and lime 15% of ferrous and ferric oxides 5% silica small amount of magnesia
 - ❑ Raw material are limestone and bauxite
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Aggregate

- Aggregate is an inert material used in concrete to gain volume stability, durability and economy.
 - Theoretically aggregate is not 100% inert, its physical and chemical properties effects the concrete properties.
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Types of aggregate

- As per **BS 882 : 1992** basic division between coarse aggregate and fine aggregate (sand) is 5 mm or 3/16 " sieve
 - As per **ASTM No.4 ASTM** (4.75 MM) is the dividing line for coarse and fine aggregates.
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Fine Aggregate

- **Bulking of Fine Aggregate**
 - It is defined as the increase in the volume of a given mass of sand caused by the films of water surrounding the particles and pushing them apart.
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Water

- Water containing less than 2000 ppm dissolved solids can generally be used satisfactorily for making concrete.
 - Sodium carbonate in water cause rapid setting.
 - Bicarbonates may either accelerate or retard the setting time.
 - Large concentration of above two salts reduces the strength.
 - 20,000 ppm of sodium chloride are generally tolerable.
 - 10,000 ppm of sodium sulphate is tolerable.
 - Magnesium sulphate & magnesium chloride up to 40,000 ppm is tolerable.
 - Iron salts upto 40,000 ppm is tolerable.
 - Inorganic salts like (salts of manganese, tin, zink, copper & lead) up to 500 ppm are tolerable.
 - Sea water containing salts up to 35,000 ppm are tolerable.
 - Acidic water containing hydrochloric acid, sulfuric acid up to 10,000 ppm have no effect.
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Water

- Potassium hydroxide up to 1.2% by wt. is tolerable.
- Industrial waste having less than 4000 ppm total solids cause up to 10% reduction in compressive strength.
- Raw Sewage contain up to 400 ppm of organic matter. Diluted sewage contain up to 20 ppm, which has little effect on the strength of concrete.
- Sugar in water up to 0.03%-0.15% by wt. retard the setting time of cement.
- Sugar 0.15% - 0.2% accelerate the setting time.
- Sugar greater than 0.25% accelerate the setting time but reduce 28 days strength.
- Sugar in water, less than 500 ppm has no effect at all.
- Suspended clay or fine rock particles up to 2000 ppm can be tolerated.
- Mineral (petroleum) oils greater than 2% by wt. reduces the strength more than 20%.
- Algae cause large amount of air to be entrained and they also reduce the bond between aggregate and cement paste thus cause reduction in strength.

Water Cement ratio (W/C ratio)

- It is the ratio of the quantity of water to the quantity of cement.
 - It can be by volume or by weight.
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Batching & mixing of concrete

■ Batching

- ❑ Batching means measuring of the ingredients of concrete. It is of two types
- ❑ Batching by volume
- ❑ Batching by weight

■ Mixing

- ❑ Mixing is of two type
 - ❑ Hand mixing
 - ❑ Machine mixing
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Batching by volume (ASTM C 685-94)

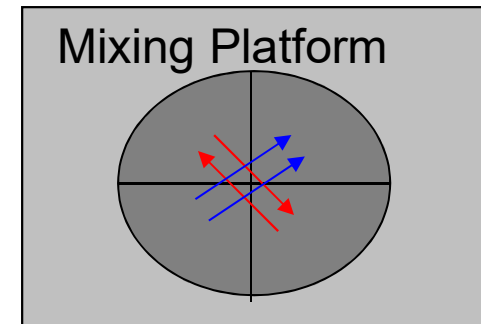
- In volumetric batching, ingredients of concrete are mixed by volume.
 - Buckets are used to measure volume of each ingredient.
 - Normally volume of one cement bag is considered as standard (its volume is 1.25 ft^3)
 - Sand volumes are computed by using bulking factors.
 - No additional quantity is added for coarse aggregate due to moisture.
 - Quantity of water is effected by the moisture of fine and coarse aggregate so minimum desirable computed quantity of water must be added.
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Batching by weight

- It is more accurate method of batching.
 - Each ingredient of concrete is weighted and mixed.
 - Weighting coarse aggregate is a laborious work.
 - Batching plants are available now a day. They can be recommended for large projects, where the quantity of concrete is considerable.
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Mixing of concrete

- ❑ Hand mixing
- ❑ Machine mixing



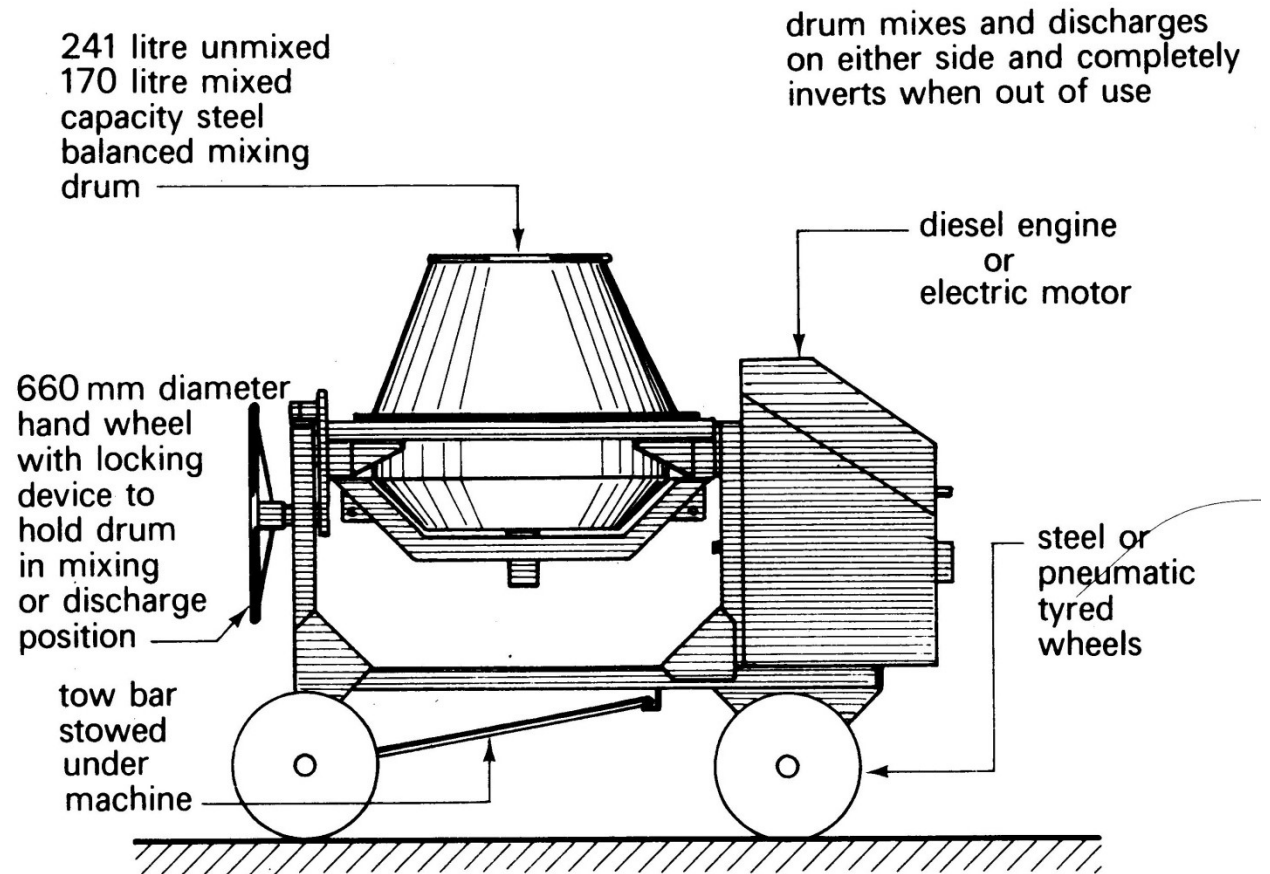
- ❑ In hand mixing first aggregate is deposited on a platform then fine aggregate (sand) is added finally cement is spreaded on the dump of materials.
- ❑ Diagonal parts of material is mixed and processes is repeated for 3 to 4 times until a uniform mixture is achieved.
- ❑ Water is added preferably by shower or by making a ditch inbetween the material.

Machine mixing

- Concrete mixers used on building sites must conform **BS 1305 :1974**
 - Several types of concrete mixers are available like
 1. Pan mixers or forced action mixers (P)
 2. Drum mixers
 1. Tilting mixers (T)
 2. Non tilting type mixers (NT) or Reversing Drum mixers
 3. Specialized mixers (Colloidal mixer)
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Tilting mixers (T)

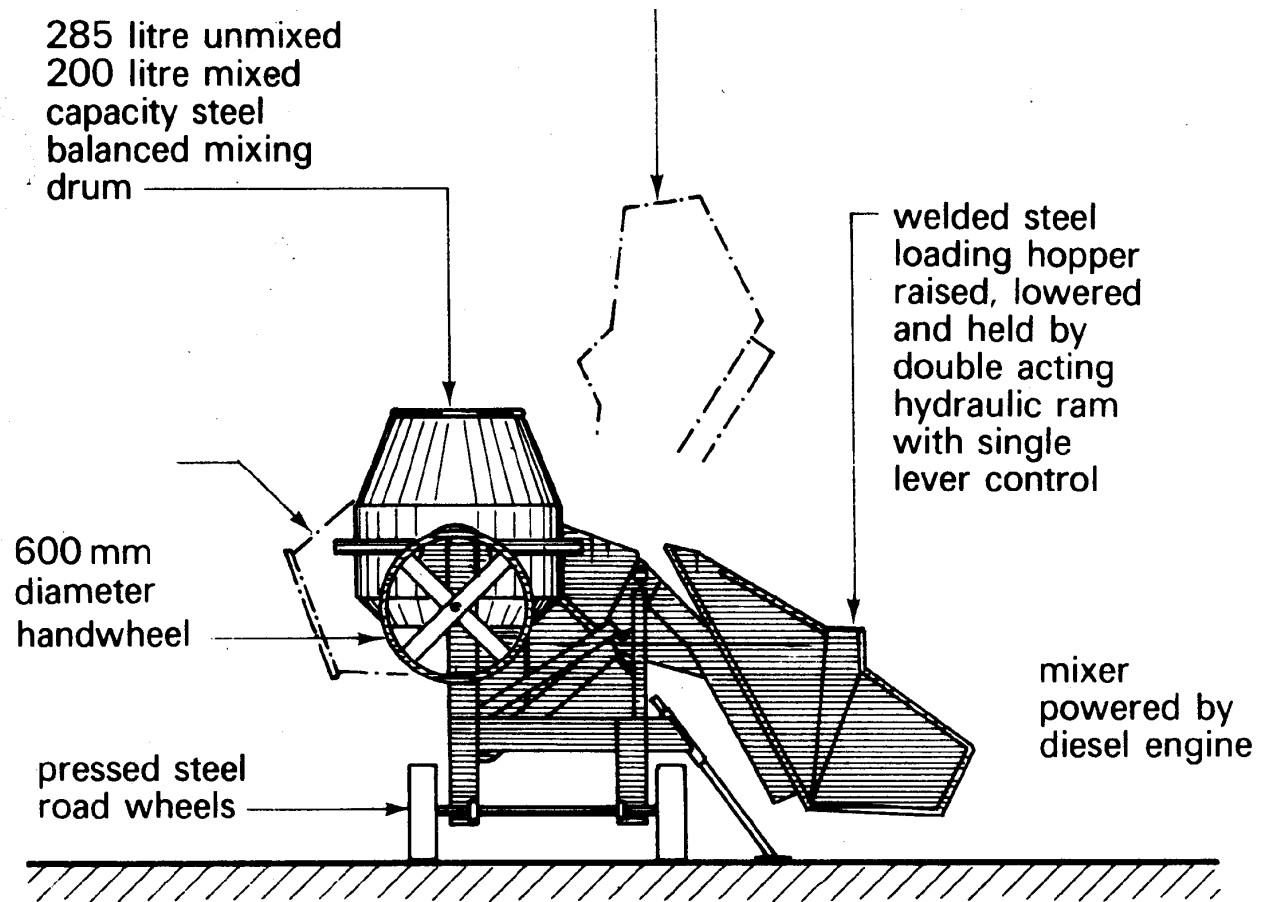
- The mixing chamber is called Drum.
- It consists of a bowl shaped drum having vanes inside.
- For discharging concrete drum can be tilted.



Typical (one bag) tilting drum concrete mixer

Tilting mixers (T)

- It can be with or without hopper.

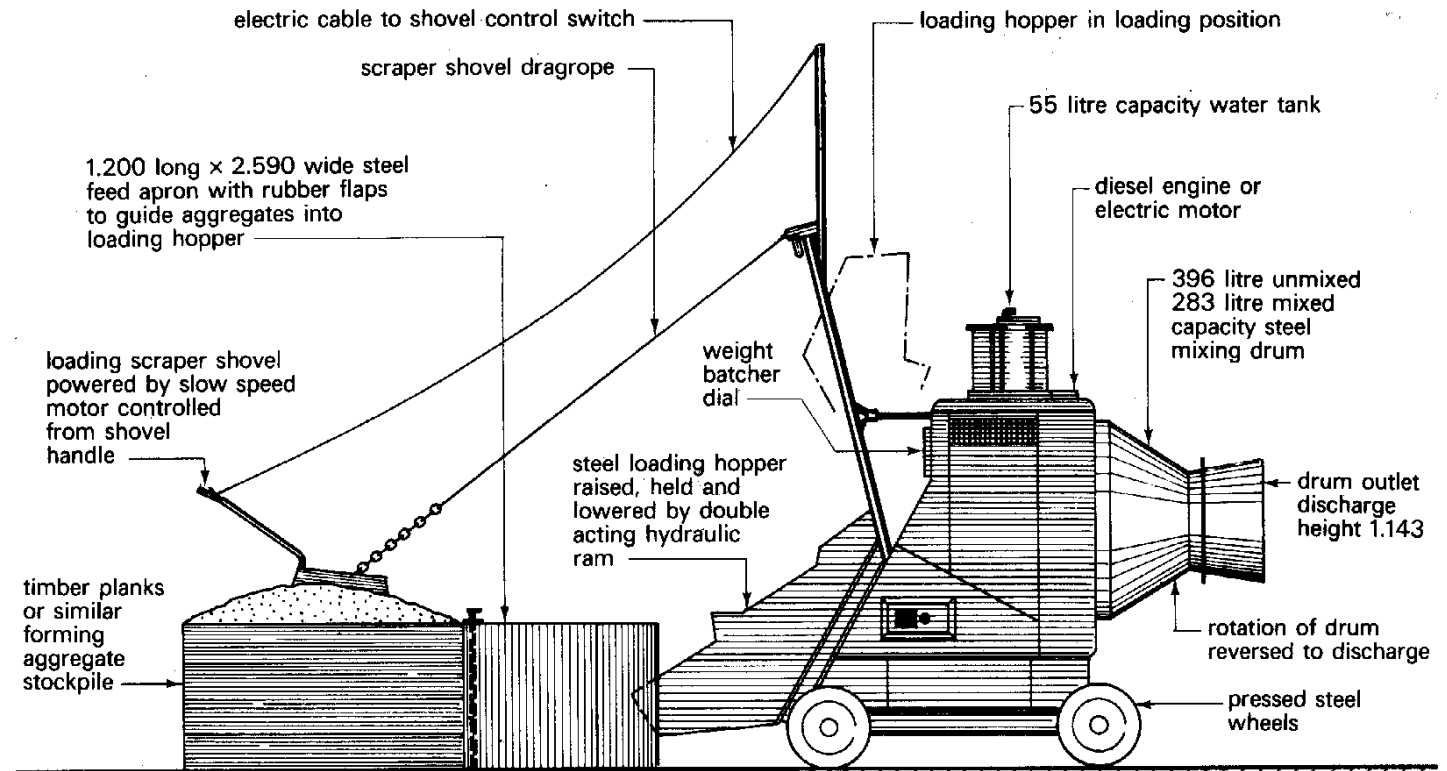


Typical hopper fed tilting concrete mixer

Fig VII.33 Typical tilting drum mixers (Liner Concrete Machinery Co Ltd)

Non tilting mixer (Reversing drum mixer)

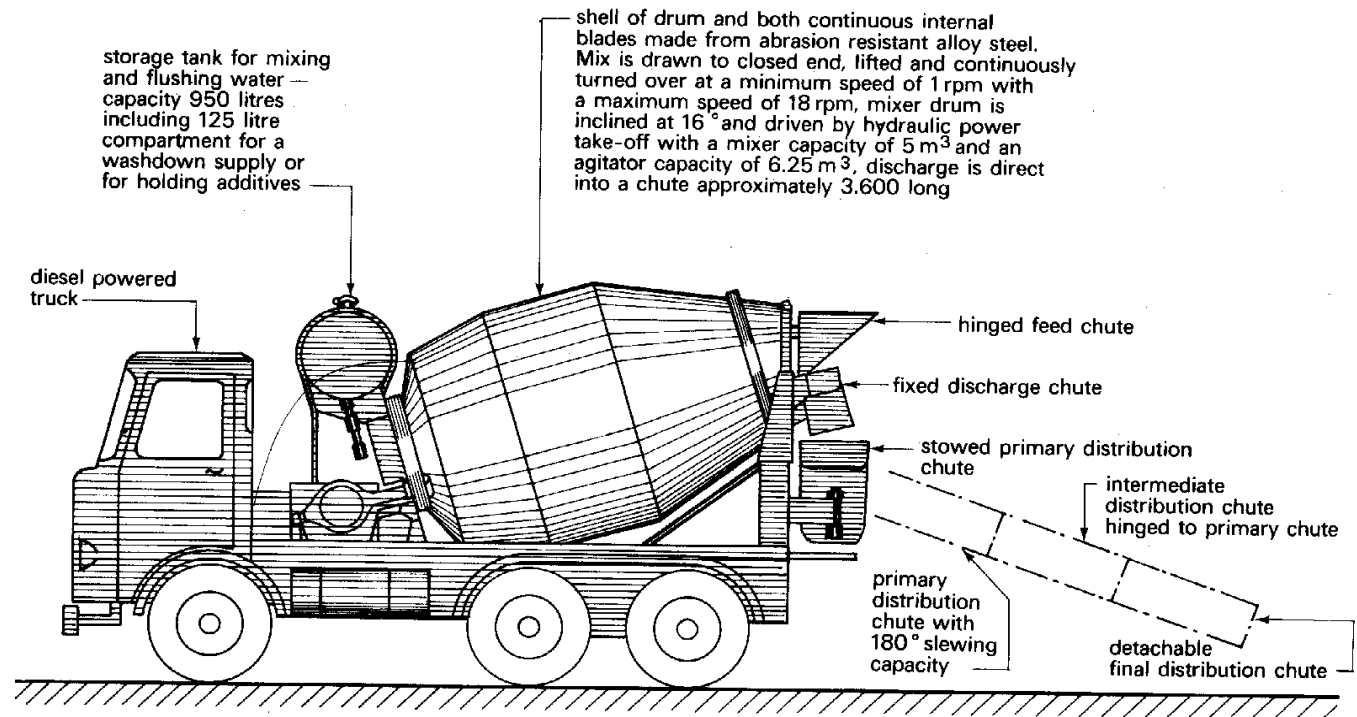
- Axis of mixer is always horizontal



g VII.34 Typical reversible drum mixer (Liner Concrete Machinery Co. Ltd)

Truck mixers

- They are used when concrete is required to transport to a long distance
- They work with a batching plant.



//11.35 Typical ready mix concrete truck details

Specialized mixers (Colloidal mixer)

- They are used for shotcreting.
 - Colloidal mixers are used for mortar mixing.
 - Cement and water is mixed at a speed of 2000 rev/min then sand is added.
 - Pre mixing of cement and water allow better hydration
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Segregation

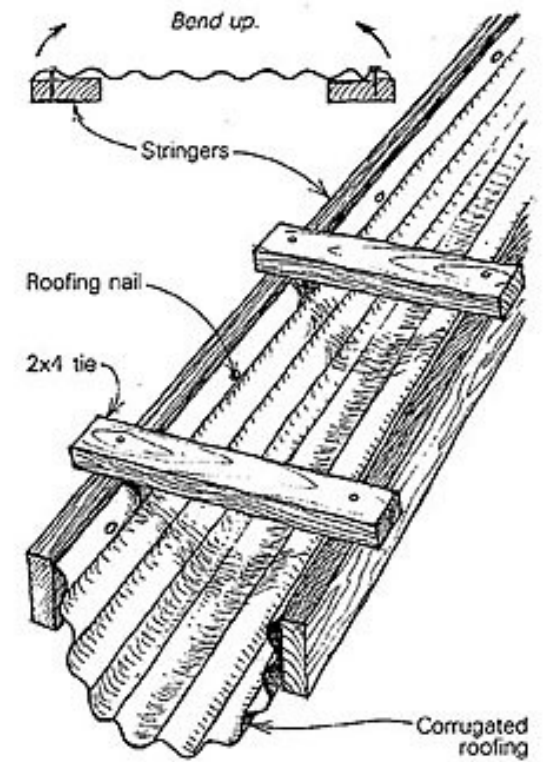
- Segregation can be defined as the separation of the constituents of a heterogeneous mixture so that their distribution is no longer uniform.
 - Segregation is of two types
 1. Separation of coarse aggregate
 2. Separation of grout
 - Practical rules to avoid segregation are discussed in **ACI 304R-85**
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Bleeding

- Bleeding or water gain is a form of segregation.
 - Water rise on the surface of freshly mixed concrete.
 - **ASTM C 232-92** describe two methods for finding bleeding.
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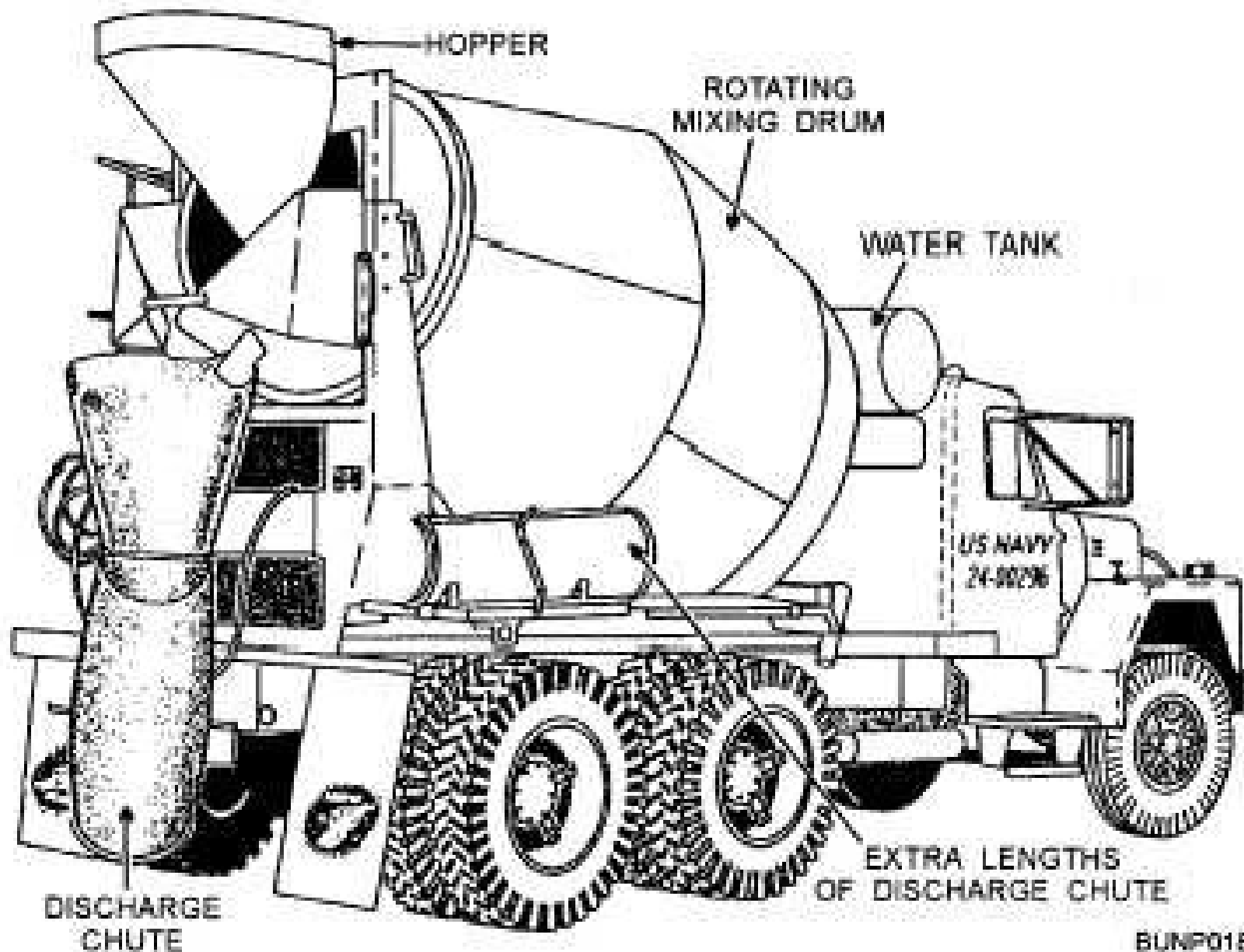
Transportation of concrete

- Concrete can be transported from the mixing place to its final placement position by following means
 1. Wheel barrows
 2. Chutes
 3. Trucks
 4. Belt conveyers.
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HOPPER

ROTATING
MIXING DRUM

WATER TANK

U.S. NAVY
24-80296

DISCHARGE
CHUTE

EXTRA LENGTHS
OF DISCHARGE CHUTE

BUNP0187

Testing of concrete

- Concrete testing can broadly classified in to two major divisions.
 - Fresh concrete Tests.
 - Workability tests
 1. Slump test
 2. Compacting factor test
 3. ASTM flow test
 4. Remoulding test
 5. Vebe Test
 6. Flow test
 7. Ball penetration test
 8. Nasser's K-test
 9. Two point tests
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Testing of concrete

- Hardened concrete tests.
 - Strength in compression
 - Cube test (BS 1881 : Part 111 :1983)
 - Cylinder test (BS 1881 : Part 110 :1983) (ASTM C 192-90a)
 - Flexural strength test
 - Tensile test
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Testing of concrete

- Workability
 - Workability determines the ease of placement without segregation.
 - **ASTM C 125-93** says “ it is the property determine the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity”
 - ACI 116R-90 says “it is that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished”
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Types of Slump



True Slump



Shear



Collapse

Slump: true, shear, and collapse

Recommended Slump Values for different works

- Slab -----1" to 2"
 - Narrow column sections --- 4" to 7"
 - Vibrating concrete -----1/2" to 1"
 - General RC. Works ---- 2" to 6"
 - Road work concrete ---- 3/4" to 1-1/2"
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Curing of concrete

- Curing means to keep the concrete moist , nearly saturated.
 - Basically loss of moisture from the concrete must be reduced.
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Pumping of concrete

- **ACI Guide 304R-89** is the relevant document.
 - A slump of 50-150 mm is recommended for pumped concrete.
 - Lubrication of pipes require 0.25 m³/100 mortar for 150 mm diameter pipe.
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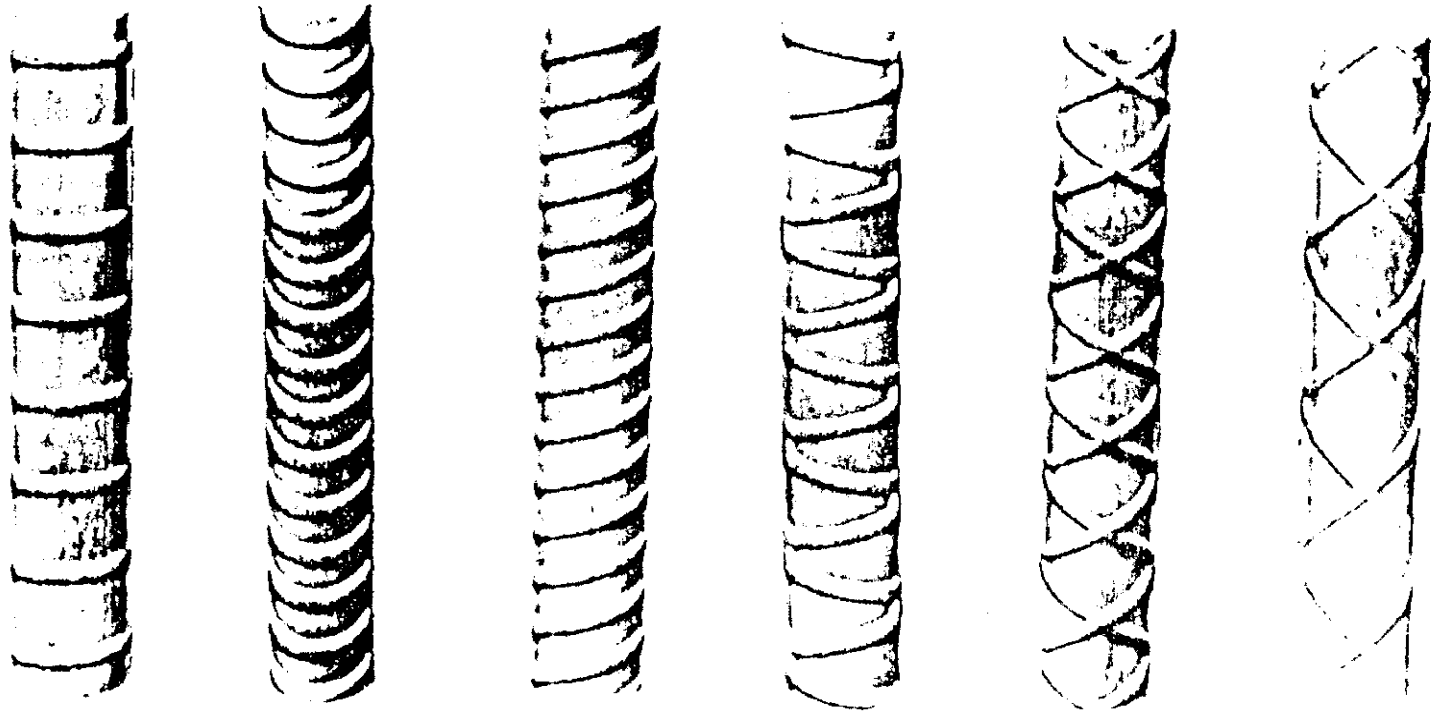
Reinforcement for concrete

- Reinforcement in concrete is provided to supplement its tensile strength deficiency.
 - Reinforcement can be of bar, wires or welded wire fabric.
 - Important properties of reinforcement are
 - MOE
 - Yield strength
 - Ultimate strength
 - Grade designation
 - Bar size (diameter)
 - Reinforcement can be of following types.
 1. Round Bars
 2. Deformed Bars
 3. Twisted Bars
 4. Mesh or fibers
 5. High tensile wires
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Reinforcement for concrete

- MOE is taken as 29×10^6 psi or 200×10^3 MPa.
 - Grade is the yield strength in kips per sq inches, for example, Grade 40 steel exhibits 40,000 psi yield strength.
 - Round bars are available from 3/16" to 2" and in length of 40'.
 - Deformed bars improves the bond strength between steel and concrete and provided with different shapes rings, projections on the surface.
 - Twisted bars are prepared by twisting the bars. Yielding zone of these bars are removed by twisting.
 - Meshes are prepared in different weights from 4-16 lbs/yd²
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ASTM approved deformed bars



Various forms of ASTM-approved deformed bars.

Types of reinforcement (ASTM)

Table 4.1 Reinforcement Grades and Strengths

1982 Standard Type	Minimum Yield Point or Yield Strength, f_y (psi)	Ultimate Strength, f_u (psi)
Billet steel (A615)		
Grade 40	40,000	70,000
Grade 60	60,000	90,000
Axle steel (A617)		
Grade 40	40,000	70,000
Grade 60	60,000	90,000
Low-alloy steel (A706): Grade 60	60,000	80,000
Deformed wire		
Reinforced	75,000	85,000
Fabric	70,000	80,000
Smooth wire		
Reinforced	70,000	80,000
Fabric	65,000, 56,000	75,000, 70,000

Additives & Admixtures for concrete

- Admixtures are chemicals added to concrete mix (not more than 5%) for achieving specific modifications to the normal properties of concrete.
 - **ASTM C 494-92** classify (7) types of admixtures as follows
 - Type A Water reducing.
 - Type B Retarding.
 - Type C Accelerating.
 - Type D Water reducing and retarding.
 - Type E Water reducing and accelerating.
 - Type F Superplasticizing.
 - Type G Superplasticizing and retarding.
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