Aqueducts and Water Pipes

- Conveyance and distribution:
  - Water, whether it be drawn from surface or ground suppliers, must be conveyed to the community and distributed to the users.
  - Conveyance from the source to the point of treatment may be provided by aqueducts, pipelines, or open channels, but once the water has been treated it is distributed in pressurized closed conduits.

- Aqueducts:
  - The term aqueduct usually refers to conduits constructed of masonry and built at the hydraulic gradient.
  - Such structures are operated at atmospheric pressure, and unless the available hydraulic gradient is very large, tend to be larger and more expensive than pipelines operated under pressure.
  - Possibility of construction with locally available materials, longer life than metal conduits, and lower loss of hydraulic capacity with age.
  - Likelihood of interference with local drainage.
- **Stresses in pipes:**

The stresses which the pipe must resist are produced by:

- The static pressure of the water
- Centrifugal forces caused by changes in direction of flow
- External loads
- Changes in temperature
- Sudden changes in velocity (water hummer)

The magnitude of the stresses resulting from these causes may be calculated by the methods of applied mechanics.

**Internal pressure** of any kinds produces a hoop stress given by:

\[
\sigma_h = \frac{rp}{t}
\]

and a longitudinal stress given by:

\[
\sigma_l = \frac{rp}{2t}
\]

Where:

- \(r\) = radius
- \(P\) = internal pressure
- \(t\) = pipe wall thickness
**water hummer** results from the sudden stopping or slowing of flow in a conduit. Under the worst conditions, this produces a pressure which will not exceed:

$$
    p_h = \rho v \left[ \frac{1}{\rho \left( \frac{1}{K} + \frac{d}{Et} \right)} \right]^{0.5}
$$

Where:

- \( v \) = velocity of flow
- \( d \) = pipe diameter
- \( t \) = pipe wall thickness
- \( K \) = bulk modulus of elasticity of water
- \( E \) = modulus of elasticity of pipe
At changes in direction, the principle of conservation of momentum requires that a force be applied to the moving water. An additional longitudinal tension can develop, equal to:

\[ \partial_t = \frac{d}{2t} \rho V^2 \sin \frac{\alpha}{2} \]

Where:
\( \rho = \) density of water
\( d = \) pipe diameter
\( t = \) pipe wall thickness
\( \alpha = \) angle of deflection of the pipe
\( V = \) velocity of flow
**Thermal stresses**, are calculated in the usual fashion from:

\[
\partial_T = C\Theta E
\]

Where:
- \(C\) = coefficient of thermal expansion
- \(\Theta\) = change in temperature
- \(E\) = modulus of elasticity of pipe material
- \(\alpha\) = angle of deflection of the pipe
- \(V\) = velocity of flow
Pipelines:

- Pipelines are commonly constructed of reinforced concrete, asbestos cement, ductile iron, steel, or plastic (PVC – polyvinyl chloride, UPVC- un-plasticized polyvinyl chloride, GRP-glass reinforced plastic pipe), and are located below the ground surface only so far as is necessary to protect them against freezing and surface loads and to avoid other subsurface structures. In locations in which the ground (and pipe) elevations vary by very large amounts, high pressures at low points may be avoided by breaking the hydraulic gradient with overflows or auxiliary reservoir or by installing special pressure-reducing valves.

- At low points in the system, valved blowoff branches or hydrants are provided to drain the line and permit removal of sediment.

- High points in the line should be kept below the hydraulic grade line, since negative pressure at such locations will lead to accumulation of gases which eventually may block the flow. High points should be provided with vacuum and air relief valves to admit air when the line is being emptied and to release air from which is initially in the line or which accumulates during use.

- Figure show standard pipe bedding conditions
Various Types of Pipes:
The pipes are available in several types and sizes. They may be classified into three groups according to the material used in their manufacturing.

- Metallic pipes: the pipes such as Cast Iron - CI Pipes, Ductile pipes, Steel pipes and GI Pipes.
- Cement Pipes: the pipes such as Cement Pipes, Asbestos cement (AC) pipes, cement concrete pipes.
- Plastic Pipes: the pipes such as PVC – polyvinyl chloride, polyethylene pipe, UPVC- un-plasticized polyvinyl chloride, GRP-glass fiber reinforced thermosetting resin pipe, Polythene Pipes (low density)

The following factors should be considered in selection of pipes.

- Strength of pipe
- Water carrying capacity
- Life and durability of pipe
- Expenditure on transportation
- Jointing process, maintenance and repairs.
Cast Iron (CI) Pipes:

- These pipes are mostly used in water supply.
- They are well suited for pressure and can withstand external load because of their thickness.
- The pipes are easy in manufacturing, layout and joining.
- These pipes are manufactured by vertical casting in sand moulds, horizontal casting in sand moulds and centrifugal casting (spun casting pipes).
- CI pipes are heavy in weight. Therefore transportation is costlier and they are not suitable for inaccessible places.
- Due to heavy weight these are generally made in short length. This increases layout and jointing cost.
- CI vertical casting pipes are not of very good quality and can be replaced by centrifugal casting (spun casting) pipes.
- External corrosion of cast iron pipe is seldom a major problem because of its relatively great wall thickness.
CI Pipes - Strong and heavy
Ductile Iron Pipe:

- Ductile iron, also known as ductile cast iron, nodular cast iron, spheroidal graphite iron, spherulitic graphite cast iron and SG iron, is a type of cast iron. While most varieties of cast iron are brittle, ductile iron is much more flexible and elastic, due to its nodular graphite inclusions.

- Ductile iron is not a single material but is part of a group of materials which can be produced to have a wide range of properties through control of the microstructure.

- The common defining characteristic of this group of materials is the morphological structure of the graphite.

- In ductile irons the graphite is in the form of spherical *nodules* rather than flakes (as in grey iron), thus inhibiting the creation of cracks and providing the enhanced ductility that gives the alloy its name.

- Ductile iron pipe is stronger and easier to tap, requires less support and provides greater flow area compared with pipe made from other materials. In difficult terrain it can be a better choice than PVC, concrete, polyethylene, or steel pipe.
Ductile iron has largely replaced cast iron in new construction, since for a given strength it is lighter and is less brittle.

Although its wall thickness is less, ductile iron pipe has the same outer diameter as cast iron of the same nominal size.

Ductile iron is produced by adding a magnesium alloy to an iron of very low phosphorus and sulfur content which imparts strength, toughness, and ductility.

Ductile iron is specifically useful in many automotive components, where strength needs surpass that of aluminum but do not necessarily require steel.

Other major industrial applications include off-highway diesel trucks, class 8 trucks, agricultural tractors, and oil well pumps.
Ductile Iron Pipes
Steel Pipes:

- These pipes are extensively used for water supply particularly in circumstances where diameters are large and pressures are high, since its stronger and thus lighter for a given strength.
- The steel pipe is cheaper than iron pipe, is more easily transported and more easily assembled.
- Its relatively thin wall also make steel pipe more likely to be structurally damage by corrosion than iron.
- They are best suitable for long distance pipe lines of high pressure and provide satisfactory performance during service.
- These pipes have excellent mechanical properties and are ideally suited for welding.
- The pipes are made in length more than twice the length of CI pipes; which saves in transport, layout of pipe and joining cost.
- There is minimum damage to the pipes in transportation.
- The pipes being light in weight are used for large diameter pipe lines.
- Steel pipe must be cleaned of any mill scale and is then normally coated with tar or a bituminous enamel.
- Its service life is 50 years
Cement (concrete) Pipes:

- Main advantage of cement pipes in place of metallic pipes is their corrosion resistance.
- These pipes are bulky, heavy and require careful transportation and handling.
- The layout process of these pipes is costlier than steel.
- They are well suited for pressure and can withstand external load because of their thickness.
- It is manufactured by wrapping high–tensile–strength wire about a steel cylinder which has been lined with centrifugally placed cement mortar. The wire is wound tightly to prestress the core and is covered with an outer coating of concrete. (reinforced concrete pipe)
- For lower pressures, a similar pipe is manufactured without the prestressing wire (unreinforced concrete pipe)
- Concrete pipe (except in the case of acid waters) is not subject to corrosion and suffer no loss in hydraulic capacity with age.
- Its service life is 75 years
Asbestos Cement Pipes (AC):

- Asbestos cement pipe is composed of a mixture of portland cement and asbestos fiber which built up on a rotating steel mandrel and then compacted with steel pressure rollers.
- Its service life is 60 years.
- Since it has a very smooth inner surface, it has excellent hydraulic characteristics.
- Asbestos has been shown to be carcinogen when the fibers are inhaled, and there is some evidence, although it is debatable, that asbestos fibers in water may cause intestinal cancers as well.
**PVC Pipe:**

- A polyvinyl chloride (PVC) pipe is made from a plastic and vinyl combination material.
- The pipes are durable, hard to damage, and long lasting.
- A PVC pipe does not rust, rot, or wear over time. For that reason, PVC piping is most commonly used in water systems, underground wiring, and sewer lines.
- Plastic pipe, in general, it is far easier to handle and install and generally cheaper than traditional materials such as iron and concrete.
**UPVC Pipe:**

- Un-plasticized PVC pipe are rigid PVC pipes.
- They are light in weight, tough, resistant to chemical attack and large in length.
- Due to large in length the cost of handling is much whereas transportation and installation cost is less.
- Smooth internal surface of pipes provide less friction which results in saving of energy.
- These pipes are not suitable for the area which is very hot.
- Chemical resistance and insulation.
- Resistance to pressure, flame retardant, and high strength.
- Small friction resistance, without fouling, high efficient feeding.
- Durable, with a working life of 20-50 years.
**GRP- Pipe:**

- Glass Reinforced Plastic G.R.P or Fiber Glass Reinforced Plastic F.R.P or Reinforced Plastic Morter (RPM) pipes are widely used where corrosion resistant pipes are required at reasonable costs.
- Fibre Glass Reinforced Plastic Pipe is a matrix or composite of glass fibre, polyeser resin and fillers.
- These pipes possess better strength durability high tensile strength low density and are virtually inert.
- Fibre Glass pressure pipes are intended to be manufactured in diameters upto 2400mm and length upto 18m.
- These pipes are now being taken up for manufacture in the world.
- **Corrosion Resistant** : No coating, gunniting or mortar lining required for longer life.
- **High Strength-to-Weight Ratio** : Better than Steel / C.I. Pipes.
- **Light Weight** : 1/5th of steel, 1/10 of PSC, ease in handling, faster installation, Laying in rough terrain-easier.
- **Smooth Surface** : Better hydraulic properties, less power and lower pump cost. Hazen Williams Coefficient-C-150 Manning, n= 0.01.
- **Longer Lengths** : Faster installation, minimum joints.
- **Excellent Joints** : No exfiltration or infiltration problems.
FRP pipes being light in weight can be easily loaded or unloaded by slings pliable stripes of ropes.

A pipe can be lifted with only one support point or two support points placed about 4 meter apart.

Excavation of trench and back filling of material is similar to that in the case of CI and MS pipes.

GRP / FRP are manufactured in various sizes, pressure ratings & stiffness class for potable water, raw water, effluent & sewerage water, desalination plants, offshore oil production, chemical & fertilizer plants, refinery – petrochemical & petroleum plants, power plants, pharmaceuticals & formulation plants, pickling – metal finishing & metallurgy industries, dye & intermediates, pulp – paper & printing plants, textile & synthetic fibre plants, food stuff industries and biotech & biological parks.