Section 2

Planning, Material and Design
2.1 Sewers

2.1.1 Pipe Material Selection Factors

The following considerations are the important factors to be considered before selecting or approving any pipe material and pipeline system for sewer networks:

a) Resistance to acidic condition of which is prevalent in sewer networks in tropical climates.
b) Resistance to sulphate attack from aggressive soils and groundwater.
c) Resistance to corrosion in contaminated soils.
d) Resistance to severe abrasion from sewage flow and usual cleaning methods.
e) Resistance to groundwater entry (infiltration) and sewage escape (exfiltration) through joints.
f) Resistance of the joint material to corrosion and microbiological degradation.
g) Structural damages and other damages that may occur during handling.
h) Handling, laying and jointing care and difficulties.
i) Methods of pipe embedment to ensure good structural performance.
j) Maintenance of structural strength and performance in service.
k) Methods of maintenance and repair.
l) Cost of supply, transportation and installation.
m) Range and suitability of fittings for smaller diameter sewers.
n) Previous local experience.
o) Local availability.
p) Pipe pressure ratings.
q) The design life of a pipe shall be at least 50 years.
r) All bolts and nuts shall be stainless steel (SS) 304.
s) Where necessary, special tools and trained personal shall be made available during the handling and installation of pipes.

Additionally, the following factors should be considered before selecting or approving any pipe manufacturer and supplier:

a) Compliance of products to standards.
b) Compliance to additional material and product requirements specified by the Commission.
c) Quality control and assurance practised by the manufacturer and supplier to ensure good pipe product quality from manufacturing to delivery.
2.1.2 Pipe Materials and Fittings

There is an extensive range of pipe materials available in Malaysia to be used as gravity, pressure and vacuum sewers. The materials and the standards which the pipes are required to conform to are as follows:

a) Vitrified clay (VC)
   i) MS 672
   ii) MS 1061
   iii) BS EN 295

b) Reinforced concrete (RC)
   i) MS 881
   ii) BS 5911
   iii) BS 7874
   iv) BS EN 681
   v) BS EN 682

c) Ductile iron (DI)
   i) BS EN 598

d) Mild Steel
   i) BS EN 10025
   ii) BS EN 10225
   iii) BS EN 10224

e) Stainless Steel
   i) BS EN 10220

f) Polyethylene (PE) solid wall
   i) MS 1058
   ii) WIS 04-32-15
   iii) WIS 04-32-14
   iv) WIS 04-24-01

g) Unplasticised polyvinyl chloride (uPVC) solid wall
   i) MS 628 : Part 2 : Section 2
   ii) MS 923
   iii) MS 979
   iv) AS/NZS 1477

h) Polyethylene profiled wall
   i) DIN 16961

i) Unplasticised polyvinyl chloride profiled wall
   i) AS/NZS 1260
j) Glass reinforced plastic (GRP)
   i) BS 5480
   ii) AS 3571

k) Acrylonitrile butadiene styrene (ABS)
   i) AS/NZS 3518

Marking of all pipes shall comply with Malaysian or British Standards where applicable. Additional requirements to those given in the above standards may be specified from time to time by the Commission.

2.1.3 Pipe Selections

Except where otherwise specifically approved by the Commission, the pipe materials to be used for a specific type of sewer are listed below:

1) Gravity sewers
   a) Rigid pipes
      i) VC
      ii) RC
   b) Flexible pipes
      i) GRP
      ii) Ductile Iron
      iii) HDPE (Profile)

2) Force mains (Rising mains)
   i) Ductile Iron
   ii) GRP
   iii) ABS
   iv) HDPE (Solid)
   v) Steel

3) Vacuum sewers
   i) ABS – for internal use
   ii) HDPE (Solid) – for external use

There are specific requirements such as pipe class, joint type, linings etc. which the above approved pipe materials must meet in order to suit the above applications. Also, there are certain limitations for use of each pipe type. These requirements and limitations are specified in the following sections.

From time to time, the Commission will publish sewer selection guides which will provide more detailed direction on the selection and use of sewer materials.

For other pipe materials not listed above, their use will be given considerations in special circumstances. However, only pipes and fittings
from manufacturers and suppliers approved by the Commission are permitted to be used for sewerage applications.

2.1.4 Requirements and Limitations for Use of Certain Pipe Material

Unless the exemption is granted by the Commission, the following limitations or requirements shall be followed when selecting the pipe materials:

I) Gravity Sewer
   a) VC
      i) Only size 150 mm or above shall be used.
      ii) The minimum size for public sewer shall be at least 225 mm.
      iii) Pipe shall not be used in unstable ground.
      iv) Flexible joints are recommended.
   b) RC
      i) Pipe protection linings are required.
      ii) Only sizes 600 mm or above are allowed in compliance to the policy.
      iii) Flexible joints are recommended.
   c) GRP
      i) Pipe shall not be used in ground contaminated with high concentration of chemicals such as solvent that can degrade the pipe.
      ii) Pipe shall not accept any industrial or other aggressive discharges that may affect the pipe integrity.
      iii) Pipe shall be used only when no fittings are required.
      iv) Only sizes 600 mm or above are allowed.
   d) DI
      i) The use is only allowed for applications needed high pipe strength.
      ii) Pipe protection linings and coatings are required.
      iii) Polyethylene sleeving is required for all buried applications.
   e) HDPE
      i) Pipe shall not be used in ground contaminated with high concentration of chemicals such as solvent that can degrade the pipe.
ii) Pipe shall not accept any industrial or other aggressive discharges that may affect the pipe integrity.

iii) Only pipe with profile wall is permitted.

II) **Force Mains**

a) DI
   i) Pipe shall not be used in unstable ground.
   ii) Pipe protection linings and coatings are required.
   iii) Polyethylene sleeving is required for all buried applications.
   iv) Flexible joints are recommended.

b) GRP
   i) Pipe shall not be used in ground contaminated with high concentration of chemicals such as solvent that can degrade the pipe.
   ii) Pipe shall not accept any industrial or other aggressive discharges that may affect the pipe integrity.
   iii) Fittings shall be made of ductile iron.
   iv) Only sizes 600 mm or above are allowed.

c) ABS
   i) Where VC or RC pipes are not suitable.
   ii) Only for nominated projects or as permitted by the relevant authority.

d) HDPE
   i) Pipe shall not be used in ground contaminated with high concentration of chemicals such as solvent that can degrade the pipe.
   ii) Pipe shall not accept any industrial or other aggressive discharges that may affect the pipe integrity.

e) Steel
   i) Pipe is allowed only for sizes 700 mm or above.
   ii) Pipe protection linings and coatings are required.

2.1.5 **Vitrified Clay Pipe**

Vitrified clay (VC) pipe is manufactured in Malaysia in diameters of 100 mm to 600 mm and lengths ranging from 0.91 m to 2.50 m. Larger
diameters of VC pipe are imported. VC pipes are classified according to the pipe ring crushing strength which depend on the manufacturing process and quality. VC pipes and fittings can be produced either unglazed or glazed on the interior and/or exterior. When glazed they need not be glazed on the jointing surfaces of the spigot and socket. VC pipes which are available in Malaysia are normally manufactured with spigot-socket flexible joints. Most manufacturers offer rubber ring seals. However, polyurethane seals are sometimes offered by some manufacturers.

Vitrified clay pipe has extra chemical resistance that is suitable for sewerage applications. The VC pipe may be used even under very corrosive sewage environment. However, the potential for infiltration is great and must be minimised by careful laying procedures on site.

Vitrified clay pipes are permitted for gravity sewers. The minimum permissible size for public gravity sewer shall not be less than 225 mm and for service connection shall not be less than 150 mm.

VC pipes and fittings shall conform to the requirements of MS1061. Pipe strength is classified by the crushing strength (FN) value tested in accordance with BS EN 295-3. The crushing strength for pipe with DN150 shall not be less than 22 kN/m. The crushing strength of the pipe with size ≥ DN 225 is classified by class number. All VC pipes and fittings shall be furnished with spigot-socket flexible joints and rubber ring seals or polyurethane seals. Glazing of VC pipes and fittings are preferred.

2.1.6 Reinforced Concrete Pipe

Reinforced concrete (RC) pipe is manufactured in Malaysia in diameters from 150 mm to 3600 mm. The standard pipe length is 3.05 m. RC pipe is classified according to pipe crushing test load or the three-edge bearing strength which varies with wall thickness and reinforcement.

Common reinforced concrete pipes are not resistant to acidic corrosion which occurs in certain septic sewage conditions. The cement used to manufacture concrete pipe shall be factory produced by the cement manufacturer. Pipes can be manufactured using Portland Cement, Portland Blast Furnace Cement, Portland Pulverised Fuel Ash Cement and Sulphate Resisting Portland Cement. All these types of cements are corrosion resistance, except Ordinary Portland Cement and Rapid Hardening Portland Cement. To improve the corrosion resistance, high alumina cement mortar lining and sacrificial lining have been used. Low heat and super-sulphated cements have also been found in some tests to
improve the corrosion resistance. The inclusion of calcareous or limestone aggregate is another measure found to improve corrosion resistance. To resist corrosion by neutral sulphates occurring in aggressive soils and groundwater, RC pipes are sometimes manufactured using sulphate resistance cement and where not available, Portland Pulverised Fuel Ash Cement or Portland Blast Furnace Cement shall be used with the approval from relevant authority.

RC pipes are permitted for gravity sewers of diameter DN600 and larger. Pipe shall be of Standard Strength or higher as determined from structural design. RC pipes linings shall consist of either 12mm thick high alumina cement or 38 mm thick (as appropriate) sacrificial concrete lining. Other linings may be used if approval from the Commission is obtained. Concrete pipe junctions shall be fixed to the main pipe by the pipe manufacturer and fabricated to clay pipe dimensions. Flexible joints which utilise a rubber ring to join a rebated joint and a spigot to a socket are commonly used and are recommended. Ogee joint (fixed joint) shall be used in conjunction with concrete bedding haunching only. RC pipe when used for pipe jacking purpose, shall comply with BS 5911. The RC pipes also incorporate rebated joints with joint elastomeric ring seals either integrated in the unit or supplied separately.

2.1.7 Ductile Iron Pipe

Ductile Iron (DI) pipe manufactured in Malaysia for diameters from 80 mm to 1200 mm. The diameter imported pipe can be up to 2000 mm. Standard lengths are 6.0 m. DI pipe is classified according to wall thickness. The pressure rating of the pipe increases with an increase in wall thickness. Commonly used pipe strength is class K9 and shall comply with BS EN 598 for working pressure exceeding 6 bars.

DI pipe is permitted for force mains and internal pipings of pump stations. DI pipe shall be used for gravity sewers only where it is needed to take the advantages of the high strength of ductile iron, e.g. shallow cover sewers subjected to high live load or sewers of above ground applications.

Pipes shall have flexible joints, i.e. spigot-socket rubber seal joints or mechanical joints, except for pump station pipeworks and valve connections where flange joints shall be used.

Ductile iron will corrode when exposed to certain aggressive groundwaters and conveying certain aggressive water. Therefore, internal lining and external coating protection are required to protect against corrosions. Unless otherwise approved by the Commission, all ductile iron pipes shall
have an external coating to be determined by a Qualified Person based on actual soil condition. For internal lining of a constant full flowing pipe, ordinary Portland cement shall be used, while high alumina cement mortar or plastic adhesive lining is required for partly full flowing pipes. Buried pipe shall have zinc with bitumen external coating and fittings shall have bitumen external coating. The end surfaces shall include the internal surface of the socket and external surface of the spigot for flexible connection.

The finishing layer, which is normally bituminous product, shall cover the whole surface of the applied coating and shall prevent defects such as the loss of adhesion. In addition, the material of the finishing layer shall be compatible with the coating.

Unless otherwise approved by the Commission, all fittings and accessories shall be provided with external and internal epoxy coating.

Polyethylene sleeving shall be used for all the buried pipe and fittings.

### 2.1.8 Steel Pipe

Steel pipe is manufactured in Malaysia in a wide range of diameters up to 3000 mm and lengths up to 10 m. Pipe joints are normally welded utilising either spigot-socket ends, plain ends or a collar. Flanged and mechanical joints are also available.

Steel pipes will undergo corrosion when in contact with aggressive soil and sewage and, thus, require an internal lining and an external coating. Pipe internal linings normally include high alumina cement mortar, coal tar enamel, coal tar epoxy, sulphate resistant cement lining, or bitumen. Pipe external coatings often include coal tar enamel, bitumen enamel or asphalt enamel and glass fibre.

Steel pipes are permitted only for inverted siphons (depressed sewers) and internal pump station pipework. For force main larger than 700 mm, steel pipe may be used if the approval from the Commission is obtained.

The internal and external surfaces of the pipes and fittings shall be coated with thermosetting (epoxy paint or powder or epoxy tar resin) or thermoplastic (polyethylene or polyurethane) material. The type of external protection shall be determined by the Qualified Person based on soil condition. Following the completion of pipe jointing, exposed steel at the joints shall be protected from corrosion by manually applied external tape wrap and internal cement mortar lining.
A spigot and socket joint welded both externally and internally shall be used for pipe joints except for pump station pipeworks and valve connections where flange joints shall be used. Mechanical joints are only permitted for cut pipe lengths, where internal cement mortar lining at joints is not possible and where movement of the pipeline is to be allowed for.

### 2.1.9 Solid Wall PE Pipe

Polyethylene (PE) pipe is resistant to sulphuric acid of concentrations that might be found in septic sewage under the worst conditions.

PE solid wall pipe is available locally in diameters up to 1000 mm and in standard lengths of 6 m and 12 m. This pipe is normally butt fusion jointed. Pipe size of 160 mm or less may be flange jointed or electrofusion jointed. PE pipe is classified by pressure rating with static working pressures up to 1.6 MPa. High density PE (HDPE) is used for sewerage applications.

Since PE pipes are flexible, the design of the pipe/trench system is more critical than for rigid pipe materials. Compared to rigid pipes, the stability of flexible pipes relies more on the side support of the earth backfill around the pipe. Consequently, in an urban environment, where the side support may be removed during future adjacent construction of underground services, pipe failures could be more frequent. Ground conditions which provide poor pipe side support are unsuitable for flexible PE pipe.

Solid wall HDPE pipes are suitable for buried pressure sewer and buried vacuum sewer installations. Butt fusion joints shall be used for PE pipe. uPVC fittings are not permitted for force mains. Solid wall pipe for pressure main application shall be of minimum PE80-PN10. The use of specific strength shall depend on the depth and nature of the soil as confirmed by the Qualified Person. Solid wall pipes for vacuum sewer shall be minimum of PE80-PN8 and at least PN10 for heavy vehicle loading.

### 2.1.10 Profiled Wall PE Pipe

A profiled wall pipe is a pipe with a plain inside surface and with a ribbed or corrugated outside surface. The ribs or corrugations are normally either aligned circumferentially or helically. These corrugated or ribbed profiles optimise the pipe ring stiffness to weight ratio. The pipe can be designed with double-wall profile or triple-wall profile.
Corrugated high density PE pipe is available in Malaysia in a range of size from 100 mm to 3000 mm nominal diameter and in standard 6 m lengths. The standard joint is a flexible spigot-socket joint with rubber seal.

Pipes from specific manufacturers in this category may be permitted by the Commission to be used for gravity sewers where special circumstances require the benefits of such pipes.

2.1.11 Glass Reinforced Plastic Pipe

Glass reinforced plastic (GRP) pipe is currently required to be imported into Malaysia.

There are two principal manufacturing methods for GRP pipes, centrifugal casting and filament winding. The centrifugal casting GRP pipe incorporates silica sand in the wall structure in addition to resin and chopped strand mat glass fibres. The silica sand shall have a maximum particles size of 10 mm. The centrifugal casting GRP pipe shall be according to AS 3751.

The filament winding GRP pipe does not normally incorporate sand, which permits centrifugal casting GRP pipe to have a much thicker wall, and thus much higher ring stiffness than the filament winding GRP pipe. The filament winding GRP pipe uses continuous glass fibres wound helically about the pipe. The design of filament winding GRP pipe shall be in accordance with BS 5480.

Centrifugal casting GRP pipe is classified by internal pressure resistance for pressure applications and by pipe ring stiffness for non-pressure applications. Centrifugal casting GRP is available up to 10000 N/m² stiffness and up to 2.5 MPa static working pressure. Filament winding GRP is available up to 5000 N/m² stiffness and up to 1.6 MPa static working pressure.

Centrifugal casting GRP pipe is available in sizes from 200 mm to 2400 mm and standard length of 6 m. The inner surface of the pipe is usually finished with a resin rich lining which is resistance to attack by sulphuric acid that may result from septic sewage. Centrifugal casting GRP pipe has a rubber sealing sleeve joint which is supplied fitted to one end. So jointing is similar to a spigot-socket joint. These pipes can also be supplied with flange joints, sleeve-locking joints and sleeve recessed joints for special applications such as pipe jacking and pipeline towing.

Filament winding GRP pipe is available in sizes up to 3700 mm and standard lengths of 6 m and 12 m (size dependent). It also has a resin
rich inner surface although the thickness of this resin surface layer is often limited by the manufacturing method. Some filament winding GRP pipe manufacturers incorporate corrosion resistant glass fibres. This feature can be essential with this GRP pipe because its resin rich surface (gelcoat) is thinner or, sometimes, removed for fabrication purposes. Filament winding GRP pipe currently being offered can be jointed using a sleeve and two rubber O rings. Filament winding GRP pipe does not have a smooth outer surface like centrifugal casting GRP pipe. Machining may be required for the outer surface where rubber sealing rings are used. Flange joints and mechanical couplings are also available for special applications.

GRP pipe is classified as a flexible pipe. It requires sufficient side support to retain its structural integrity in cross-section in the same way as uPVC and PE pipe. GRP pipe has lower strain limits than uPVC and PE pipes since it is made of thermoset resin, which is brittle compared to thermoplastic material. Due to its inherent structure, GRP pipe has a much higher modulus of elasticity than uPVC and PE pipe. Thus, it may have a much thinner wall than uPVC and PE pipes to achieve equivalent ring stiffness. GRP pipe is generally available in higher stiffness than uPVC and PE pipe.

Approval for the use of GRP pipe shall be sought from the Commission for each project intending its use. GRP pipes are permitted for gravity and pressure sewers. For gravity sewers, GRP pipes are only permitted for sizes of 600 mm nominal diameter and larger where no fittings are required. The minimum pipe stiffness shall be SN 5000 with the appropriate stiffness determined in accordance with structural design to AS 2566. For pressure sewers, fittings must only be of ductile iron meeting the coating, lining and other requirements.

### 2.1.12 Acrylonitrile Butadiene Styrene Pipe

Acrylonitrile butadiene styrene (ABS) pipe is a thermoplastic pipe. It is manufactured in Malaysia in diameters up to 630 mm.

ABS pipe is classified by internal pressure resistance. It comes in various static working pressure ratings up to 1.5 MPa.

The most common jointing method is by solvent cementing. The cementing jointing process is more complex than the jointing process of uPVC pipe. A spigot/socket rubber ring joint is generally not available. Because of the care required to make a solvent cement joint, particularly in larger diameters, the jointing of ABS pipe requires special trainings.
ABS, like uPVC and PE, is resistant to corrosion in the most corrosive sewage environment that could occur. ABS is used in a range of applications requiring pressure pipe. Because of its excellent resistance to abrasion and UV degradation, ABS has found use in industrial and mining applications and also in treatment plants for sewage and water.

ABS pipes may be permitted for force mains under special circumstances which require the benefits of such pipes. If used, the approval of the Commission is required. ABS pipes may be permitted for use in buried forced mains and buried interconnecting pipe-works within pump stations.

2.1.13 Sewer Design - General Requirements

The design of a sewerage system shall generally be in accordance with the principles set out in this Guidelines. Additional requirements in the Malaysian Standard MS 1228:1991 Code of Practice for Design and Installation of Sewerage System shall also be referred to in design.

The sewerage system shall be suitably designed to carry all sewage flows including sullage to the approved disposal point. Unauthorised connections of surface waters or excessive infiltration to the sewerage system are not permitted.

Unless otherwise agreed by the Commission, all sewers shall be sited in public road reserve so that access can be gained for maintenance purposes. Under special circumstances where the sewer cannot be sited in public road reserve then vehicular access for the sewerline of at least 3 m in width and road bearing capacity of not less than 5 tonne shall be provided.

Sewer pipes should not be constructed on slope or within slope failure envelope. In the event where it is unavoidable, the said structures must be designed not to encounter settlement or the sorts and at any time at risk of collapse during its operating lifespan.

An overflow pipe shall be provided at the last manhole before network pump station and/or sewage treatment plant. Otherwise it should be located at the manhole sited at the lowest ground level.

A checklist for sewer reticulation design is given in the MSIG Volume 2.

2.1.14 Flow Rate Estimations

Few principal considerations when selecting the diameter and gradient of a sewer are:
a) to cater for peak flow.
b) to ensure that there will be a sufficient velocity during each day to sufficiently cleanse the sewer of slime and sediment.
c) to limit the velocity to avoid scouring of sewers.

I) **Average Flow**

The volume of sewage that needs to be treated per day is based on an assumed contribution per population equivalent of 225 litres from various types of premises where the contribution from each premise type is defined in terms of a population equivalent. The recommended minimum population equivalent values are given in Table B1.

II) **Peak Flow**

The flow used to determine the diameter and gradient of the pipeline is the peak flow. Peak flow is the most severe flow that could occur on any day when considering daily flow fluctuations and infiltrations. The peak flow is derived from the average flow by applying a peak factor for daily flow fluctuations. The peak factor shall be estimated from the following formula:

\[
\text{Peak Factor} = 4.7 \left( \frac{\text{PE}}{1000} \right)^{-0.11}
\]

Where PE = assumed population equivalent

III) **Infiltration**

Infiltration is the amount of groundwater that enters sewers through damage in the network such as cracked pipes, leaked joint seals and manhole walls, etc. There are many variables affecting infiltration such as quality of workmanship, joint types, pipe materials, height of water table above pipeline, soil type, etc. The peak factor above has included the contribution of infiltrations. The maximum allowable infiltration rate shall be 50 litre / (mm diameter.km of sewer length. day).

2.1.15 **Sewer Cleansing Velocities**

The principal accumulants in sewers are slimes and sediments. The hydraulic requirements for cleansing the sediments of sewer differ from those required for cleansing the slimes of sewer.

I) **Sediment Cleansing**

For the removal of sediments, the traditional design approach has been to set a minimum velocity to be achieved at least once daily.
Minimum velocity values at full bore of 0.8 m/s are commonly specified. However, it has been found that larger pipe diameters require higher velocity to cleanse the sediment. This is mainly due to higher sediment depths in large diameter pipes.

The movement of sediment is mainly a function of shearing stress needed to dislodge sediment off the pipe wall. Similarly, shear stress is a function of pipe diameter. The type of sediment (i.e. grain size, specific gravity, cohesiveness) also influences the movement of sediment and, thus, the amount of required shear stress. For design purposes however, only a single sediment type needs to be assumed.

II) Slime Cleansing

The removal of slime depends on the stress needed to shear sections of slime from each other or from the pipe wall. However, the shear stress required to remove slimes is not a function of pipe diameter. The necessary shear stress depends on the thickness of slime to be removed and the pipe material. The degree of removal of slimes in any pipe material varies with the sewage velocity.

Removal of large portion of slimes requires high sewage velocities. It has been found that 85% or more of the sulphide producing slimes are removed when the grade of the sewer is 2.5 times of that for sediment cleansing. In many instances, it may not be practical to design a sewer to achieve such velocities due to the excessive cost of constructing such a deep and steep sewer. Although increasing the velocity up to the critical velocity will increase the amount of slime being sloughed off, the rate of sulphide production remains substantially unaffected by the thinner slime layer. Therefore, the selection of steep gradient to achieve velocities for full slime stripping is not a design requirement.

2.1.16 Pipe Roughness

Except for very high velocities, slime will always be present, which will increase the pipe roughness. Abrasion by sediments will also impart a permanent increase in roughness. Pipeline roughness decreases as the velocity increases. However, there is insufficient data to accurately determine the pipeline roughness for a wide range of velocities or at small incremental changes in velocity. In addition, the velocity of the sewage flow varies due to the factors such as daily fluctuations, different type of catchment, different stage of catchment maturity, etc. Therefore, it is not possible to select the pipe roughness with great accuracy.

Conservative roughness values as given in Table 2.1 shall be referred to when determining sewer discharge capacity.
Table 2.1a Normal Pipe Roughness for Gravity Sewer

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Roughness, ( k_s ) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
</tr>
<tr>
<td>Vitrified Clay</td>
<td>0.06</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.15</td>
</tr>
<tr>
<td>Plastic</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Old and new roughness values shall be used to determine the sewer cleansing and maximum design velocities respectively.

Table 2.1b Normal Pipe Roughness for Force Mains for All Pipe Materials

<table>
<thead>
<tr>
<th>Mean Velocity, ( V ) (m/s)</th>
<th>Roughness, ( k_s ) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 0.8 \leq V &lt; 1.5 )</td>
<td>0.6</td>
</tr>
<tr>
<td>( 1.5 \leq V &lt; 2.0 )</td>
<td>0.3</td>
</tr>
<tr>
<td>( V \geq 2.0 )</td>
<td>0.15</td>
</tr>
</tbody>
</table>

2.1.17 Design of Gravity Sewer

Unless special arrangements have been agreed for the structural protection of pipes, the minimum depth of soil cover over the sewer shall be 1.2 m. Sewers are not to be constructed under buildings.

The minimum size of public gravity sewers shall be 225 mm in diameter. The minimum size of domestic connections to the public sewer shall be 150 mm in diameter. The maximum design velocity at peak flow shall not be more than 4.0 m/s.

The design shall be based on the worst case scenario. The selection of the gravity sewer diameter and gradient to cope with the peak flow shall be based on the following equations:

1. **Colebrook - White Equation**

\[
V = -2 \sqrt{\frac{2gDS}{3.7D}} \log \left( \frac{k_s}{3.7D} + \frac{2.51v}{D \sqrt{2gDS}} \right)
\]

where

- \( V \) = velocity
- \( S \) = hydraulic gradient (m/m)
- \( \nu \) = kinematic viscosity of water (m²/s)
- \( D \) = internal diameter (m)
- \( g \) = acceleration due to gravity (m/s²)
- \( k_s \) = roughness coefficient (m)
Typical $k_s$ values for various types of sewer pipes are presented in Table 2.2 below:

**Table 2.2 Typical Roughness Coefficient, $k_s$**

<table>
<thead>
<tr>
<th>Material</th>
<th>Roughness Coefficient, $k_s$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>0.3 to 3</td>
</tr>
<tr>
<td>Cast iron</td>
<td>0.26</td>
</tr>
<tr>
<td>Asphalted cast iron</td>
<td>0.12</td>
</tr>
<tr>
<td>Ductile iron</td>
<td>0.046</td>
</tr>
</tbody>
</table>

2. **Manning Equations**

$$V = \frac{R^{2/3}S^{1/2}}{n}$$

where

$V = \text{velocity (m/sec)}$

$S = \text{hydraulic gradient}$

$R = \text{hydraulic radius}$

$n = \text{Manning coefficient}$

Typical n values for various types of sewer pipes are presented in Table 2.3 below:

**Table 2.3 Typical Manning Coefficient, n**

<table>
<thead>
<tr>
<th>Material</th>
<th>Manning Coefficient, n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good Condition</td>
</tr>
<tr>
<td>Uncoated cast-iron</td>
<td>0.012</td>
</tr>
<tr>
<td>Coated cast iron</td>
<td>0.011</td>
</tr>
<tr>
<td>Ductile iron</td>
<td>0.012</td>
</tr>
<tr>
<td>Vitrified clay pipe</td>
<td>0.010</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.012</td>
</tr>
</tbody>
</table>
3. Hazen - Williams Equations

\[ V = 0.849 \ C \ R^{0.63} S^{0.54} \]

where

- \( V \) = velocity (m/sec)
- \( S \) = hydraulic gradient
- \( R \) = hydraulic radius
- \( C \) = Hazen - Williams coefficient

Typical \( C \) values for various types of sewer pipes are presented in Table 2.4 below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Hazen-Williams Coefficient, ( C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top quality pipes, straight and smooth</td>
<td>130 to 140</td>
</tr>
<tr>
<td>Smooth masonry</td>
<td>120</td>
</tr>
<tr>
<td>Vitrified clay</td>
<td>110</td>
</tr>
<tr>
<td>Old cast iron</td>
<td>100</td>
</tr>
<tr>
<td>Old cast iron in bad condition</td>
<td>60 to 80</td>
</tr>
</tbody>
</table>

Colebrook-White Equation has been deemed to give the most accurate results. However, the other equations, such as Hazen-Williams Equation and Manning Equation are easier to use and may be used too. Various design charts and tables have been developed elsewhere to aid the manual computations.

2.1.18 Design of Force Mains

The minimum diameter of force mains (also known as rising mains) shall be 100 mm diameter. There shall be no reduction in force main diameter with distance downstream.

All bends on force mains shall be securely anchored to resist lateral thrusts and subsequent joint movements.

Air release valves and washouts shall be provided at appropriate locations along the longitudinal profile.

For long and undulating force mains, hydraulic pressure transient analyses may be required to ensure that the force main can cope with water hammer pressures.
Retention times in force mains must not exceed 2 hours without special precautions to mitigate septicity.

All force main shall be designed to withstand at least 1.5 times the working pressure. Approval from the Commission is required if any force main is to be designed to withstand pressure less than the pressure stated above.

Where retention times in the force mains exceed two hours and where concrete pipe are laid downstream of the force mains, an induct vent shall be provided at manholes receiving pumping discharges.

Friction losses are normally calculated using either Darcy-Weisbach (Colebrook-White) Equation or Hazen-Williams Equations. The forms of the equations are different from the equations used to design gravity sewers. The equations are listed below:

1. **Darcy-Weisbach Equation**

   \[ h_f = \frac{fLV^2}{2gD} \]

   where

   - \( h_f \) = Friction loss
   - \( f \) = Coefficient of friction
   - \( V \) = Velocity in the pipe
   - \( g \) = Acceleration due to gravity
   - \( D \) = Equivalent diameter of the pipe
   - \( L \) = Length of pipe

   The value of \( f \) is known to depend on the Reynolds number, \( Re \), pipe roughness, \( k_s \), and pipe diameter, \( D \), through the Colebrook-White equation as follows:

   \[ \frac{1}{\sqrt{f}} = -2 \log \left( \frac{k_s}{3.7D} + \frac{2.51}{Re\sqrt{f}} \right) \]

   The Reynolds number is defined as follows:

   \[ Re = \frac{VD}{\nu} \]

   where \( \nu \) is the kinematic viscosity of the fluid, typically equal to 1 x 10^{-6} \text{ m}^2/\text{s} for sewage.

   The above equations together with the Moody Diagram are used to
2. Hazen-Williams Equation

\[
h_f = 6.82 \left( \frac{V}{C} \right)^{1.85} \frac{L}{D^{1.167}}
\]

where

- \( h_f \) = Friction loss
- \( C \) = Hazen-Williams Coefficient (refer to Table 2.4)
- \( V \) = Velocity in the pipe
- \( L \) = Length of pipe
- \( D \) = Equivalent diameter of the pipe

Force mains shall be designed to handle the full range of flows from present minimum to future peak.

The design velocity shall fall within the range of 0.8 to 3.0 m/sec over the full range of design flows.

The hydraulic resistance of force main fittings and bends shall be included in the hydraulic design.

### 2.1.19 Vacuum Sewerage System

The design requirements of this Guidelines are the minimum requirements, and do not constitute in themselves a comprehensive design guide sufficient to ensure a correctly functioning system. Every system must be individually designed, based on the design parameters of the system employed; where proprietary systems are employed, it shall be designed in compliance with the requirements of system manufacturers.

#### 2.1.19.1 General

Specification of a vacuum sewage collection system shall only be considered where the life-cycle costs of a conventional gravity sewage collection system are clearly shown to be higher.

This Guidelines assumes that all sewage transportation modes have been identified, their respective feasibilities evaluated against technical, environmental, financial, economic and other relevant criteria over the design life of the asset and that vacuum sewage collection system has been confirmed as the best option. The Commission may request for net present value (NPV) calculations for all options prior to approving construction of a vacuum sewage collection system.
I) Application of Vacuum Sewerage Collection System

Consideration shall be given to the use of the vacuum system in one or more of the following circumstances:

a) Flat or undulating terrain.
b) Obstacles to the sewer route eg utility services, waterways.
c) Poor ground subsurface eg high ground water table, rocky terrains.
d) Isolated, low density communities.
e) Where it is necessary to minimise the impact of construction work.
f) Where it is necessary to minimise the environmental impact.

II) Unit Processes

Typical unit processes for a vacuum sewerage collection system is shown in typical drawing in Appendix A. The unit processes shall comprise of, but not limited to, the followings:

a) Collection chamber for housing vacuum interface valve and also forming a sump from which collected sewage is evacuated.
b) A vacuum sewer network for the transport of sewage collected in the collection chambers to a central vacuum station.
c) A central vacuum station where the vacuum pressure is generated which allows the sewage to be collected and forwarded to a receiving gravity sewer manhole or a sewage treatment plant.

III) Description of System

a) Collection Chamber and Vacuum Pipeline

When the volume of sewage draining into a collection chamber reaches a predetermined level in the sump, the normally closed interface valve opens. The differential pressure between the vacuum sewer and atmosphere forces the sewage from the collection chamber into the vacuum sewer via a crossover pipe. Typical crossover pipe connection is shown in typical drawings in Appendix A. After the sump is emptied, the valve closes. Air is admitted simultaneously with, or after, the admittance of the sewage. The sewage is driven along the sewer until frictional and gravitational forces eventually bring it to rest in the lower section of the pipe profiles. The characteristics of the vacuum sewerage system ensure that peak discharges into the sewer are rapidly attenuated.

The vacuum sewer discharges into the vacuum vessel at the vacuum station. The vacuum is maintained by vacuum pumps at a predetermined level. The sewage is generally pumped from the vacuum station by sewage discharge pumps.
b) Vacuum Station

The vacuum station is similar to a conventional pump station with the addition of vacuum pumps and a closed vacuum vessel. Typical vacuum station is shown in typical drawings in Appendix A. The levels of the sewage in the vacuum vessel are monitored by a set level detection probes which activate the sewage discharge pumps. If the sewage rises too high in the vessel then a high level detection probe stops and locks out the vacuum pumps to prevent the flow of sewage into the vacuum vessels. The vacuum in the vacuum vessel is maintained within the operational range by pressure switches.

c) Warranty of System Performance

Since the vacuum system involves proprietary design and equipment, specialised system designers shall be accountable to the performance of the entire vacuum system including both design and construction aspects. The specialised system designers shall also specify clearly the specific maintenance and operational requirements of the system.

2.1.19.2 Collection Chamber

I) General Design Requirements

Collection chambers shall have sufficient capacity to store sewage discharged from all connected properties for at least 6 hours in the event of a valve failure or similar emergency, which is sufficient to cover the Services Licensee emergency response time.

The overflow storage time shall be based on the ultimate sewage design flow that will enter the collection chamber. The volume that can be used for emergency storage shall be the volume contained in the collection chamber from the base of the collection chamber up to the lowest ground level at any point served by the chamber as well as the volume contained in the gravity lateral sewers entering the collection chamber.

Separate chambers shall be provided to serve properties at different elevations where there is a likelihood of sewage from one property flooding another property.

The chamber shall resist external forces and internal water pressure.

The preferred material of construction for collection chambers is
pre-cast concrete. The two sections (the valve compartment and the collection sump) may be mounted vertically one on top of the other as shown in typical drawings in Appendix A. The diameter of the sections may be as small as 1200 mm or as large as 1500 mm.

The collection sump requires a benching section that allows a scouring action from the sewage as it enters the suction pipe, thereby rendering the sump self-cleansing. The internal surfaces of the sump shall be both strong as well as resistant to corrosive attacks from the collected sewage.

Where the interface valve is situated over the collection sump, a working platform shall be provided for allowing maintenance personnel to stand on when carrying out scheduled maintenance to the interface valve.

The sump shall be sufficiently vented to allow the intake of air without causing a noise nuisance and to ensure that the operation of the vacuum system does not unseal the water traps on the gravity drainage system.

II) Number of Properties Connected

The location of each collection chamber and the number of properties connected to each collection chamber shall be specified in the design drawings / calculations.

Sewage flow from the maximum number of existing or future properties that are proposed to be connected to a collection chamber shall be quantified, and the retention time of the collection chamber can be then established. The retention time shall exceed 6 hours.

III) Maximum Flows to Collection Chambers

The maximum sewer design flow to a single vacuum interface valve collection chamber shall not exceed 0.25 l/s. Where single point flows in excess of 0.25 l/s occur, multiple vacuum interface valves shall be installed. Typical multi-valve collection chamber is shown in typical drawings in Appendix A.

IV) Breather Pipes

Some vacuum interface valves inhale and exhale air during their operation. This is accomplished through a screened air pipe known as a “breather”.
While breather bells are generally mounted inside the collection chamber, it may be necessary to mount them externally.

Each breather pipe shall be fitted inside the “breather bell” located at the top of the collection chamber in an accessible location to allow their removal for maintenance purposes.

V) Covers and frames

Collection chamber covers shall provide an access opening of at least 600 mm diameter. Covers and frames shall be installed in accordance with the requirements stipulated in Clause 2.3.

2.1.19.3 Vacuum Interface Valves

I) General

The interface valve shall fail safe in the closed position and shall prevent backflows from the crossover pipes to the collection sump. When the valve is open, the flow path shall not be obstructed by the valve mechanism. The valve shall evacuate at least the batch volume each time per cycle. Valves installed in the sump shall be capable of operating when submerged provided that the breather pipe is not submerged.

The valve shall be installed in the collection chamber using demountable, re-useable “No Hub” couplings suitable for vacuum service.

II) Level Sensor

The valve shall be equipped with a sensor to determine the level of sewage in the collection sump; this sensor shall be designed to be fouling resistant. Level sensor pipes shall not be less than DN/ID 45.

III) Interface Valve Controller

The controller shall open the valve only if there is a minimum partial vacuum of 0.2 bar below atmospheric available and shall maintain the valve fully open until at least the batch volume has been evacuated. If the design provides for the introduction of air after the sewage has been evacuated, the controller shall maintain the valve open for a further period. The controller shall be adjustable so that a range of air to sewage ratios can be obtained. Controllers installed in sumps shall be capable of operating when submerged.
IV) **Explosion Proof**

The valve mechanism and controller shall be explosion proof if exposed to potentially explosive atmosphere.

V) **Life of Valves and Membranes**

Every interface unit, comprising the interface valve, controller and sensor shall be expected to last in excess of 25 years. Manufacturers shall clearly specify scheduled maintenance, thus allowing the operators to keep the interface units in tip-top conditions at all times.

### 2.1.19.4 Vacuum Sewer Design

I) **General**

For a completely flat area, the length of a single sewer branch shall not be more than 3 km. However, the maximum limit of the pipe length would vary according to the gradient achievable in that line. Specialised system designer shall provide a detailed hydraulic calculation for the vacuum sewer network.

Vacuum main routes shall be selected to:

a) Minimise lift.
b) Minimise length.
c) Equalise flows on each vacuum main.
d) Provide adequate access for operation and maintenance.

II) **Sewer Depth**

Vacuum sewers, branch sewers and crossover pipe connections from the collection chambers, shall have a minimum cover of 0.9 m to withstand the stresses arising from traffic loads.

When sewers are not buried, they shall be protected from extremes of temperature, ultra-violet radiation and possibility of vandalisms.

When sewers are suspended underside walkways or bridges, they shall be rigidly supported so there is no visible sagging between supports. Supports shall withstand all static and specified dynamic conditions of loading to which the piping and associated equipment may be subjected. As a minimum, consideration shall be given to the following conditions:
a) Weights of pipe, valves, fittings, pipe protection materials, and medium in the pipe.
b) Reaction forces due to the operation of isolation valves.
c) Wind loadings on outdoor piping.

III) Sewer Profiles

Pipeline profiles shall be self cleansing and prevent the accumulation of solids. Typical pipeline profiles are shown in typical drawings in Appendix A. For crossover pipes, the minimum distance between lifts shall be 1.5 m. Vacuum sewers shall have a minimum gradient of 1 in 500. Where the ground has a gradient of 1 in 500 or more in the direction of flow, the vacuum sewer may be laid parallel to the surface as shown in typical drawings in Appendix A.

a) Design Tolerances

The chainage and invert levels of the pipeline(s) shall be determined to the following levels of design accuracy and specified in the Design Drawings:

i) Sewer chainage to the nearest 0.5 m.
ii) Sewer invert levels to the nearest 0.01 m.

b) Lift Design

To provide for efficient vacuum transport to sewer extremities, the size of individual lifts shall be kept as small as possible. Many small lifts are preferable to one large lift. The change in invert at each lift shall not exceed 1.5 m. For vacuum sewers, the minimum distances between lifts shall be 6 m.

c) Crossover Pipe Connection

Crossover pipe shall initially fall away from the interface valve and shall connect into the top sector of the vacuum sewer contained within the angle of ± 60° about the vertical axis as shown in Appendix A.

d) Branch Connections

All branch connections to vacuum sewers shall be by a Y-junction connected to the sewer above the horizontal axis as shown in Appendix A. In plan, the angle of the Y-junction shall ensure that flow towards the vacuum station is generated and backflows are minimised. No connection shall be made within 3m of a lift.
e) Water-logging

The profile shall ameliorate water-logging at any change in gradient even when a prolonged power failure occurs (both TNB supply and standby genset fail), and the vacuum interface valves continue to operate and admit sewage until the vacuum level reduced to the point when they will no longer open. When the power is again available, the system shall be capable of recovering to normal operation without intervention by an operator.

IV) Pipework and Fittings for Vacuum Sewers

The recommended material from which to construct vacuum sewers is minimum PE 80-PN 8 rated solid wall polyethylene pipe. Pipe fittings shall be PE 100-PN 8. Pipes shall be UV stabilised with carbon black which shall give the pipe a black colour throughout. The polyethylene pipe is selected because it is both structurally strong and compatible with potentially chemically aggressive and abrasive flows in the sewage.

a) Pipe Size

The suction pipe DN/ID shall not be greater than the DN/ID of the interface valve. The minimum diameter of crossover pipe shall be DN/ID 50 and shall be greater than the DN/ID of the suction pipe. Vacuum sewer shall have a minimum diameter of DN/ID 80.

b) Jointing of PE Pipes and Fittings

PE pipes and fittings less than DN 160 shall be jointed using electrofusion fittings. Pipes and fittings DN 160 and larger shall be jointed with electrofusion fittings or butt fusion welding.

c) Warning System

To act as a warning to an excavation possibly carried out at a later date, the use of a marker tape laid 300 mm on top of the pipe is recommended. This shall be a 150 mm wide polyethylene and printed with a descriptive warning of the pipeworks below.

V) Isolation Valve

The isolation valve clear opening shall be not less than the DN/ID of the pipe, and be capable of sustaining a vacuum pressure of -0.8 bar(g).
Isolation valves shall be resilient seated gate valves with the body, bonnet, gate and bridge fabricated from ductile or cast iron. The stem shall be stainless steel, and the gate shall be encapsulated with Ethylene Propylene Diene Monomer (EPDM). End connections to the valves shall be flanged.

**a) Isolation Valve Installation**

Each isolation valve shall be located in a chamber, which shall contain a dismantling arrangement for replacement of the isolation valve if needed.

When isolation valves are buried, they shall have extension spindles and surface boxes.

**b) Isolation Valve Location**

Means of isolating lengths of vacuum sewer to permit repairs or to locate faults shall be provided at distances of not more than 500 m and on branch sewers longer than 200 m.

### 2.1.19.5 Vacuum Station Design

**I) General**

It is desirable to have the vacuum station located as centrally as possible within the sewer network. This lends itself to a system with multi-branches hence giving added operating and design flexibility. Ideally, the design capacity of a single-vessel vacuum station shall not exceed a population equivalent of 8000 persons.

A dual-vessel station, or more than a single-vessel station that is completely isolated, shall be provided when the population equivalent exceeds 8000 persons.

**II) Vacuum Station Layout**

A typical vacuum station layout is shown in typical drawings in Appendix A. The vacuum station shall be divided into two main areas, an above ground plant room and a below ground dry well.

The floor level of the dry well shall be designed to suit the invert levels of the incoming sewers, the vacuum vessel diameter and the dimensions of the selected sewage discharge pumps.
The vacuum vessel, the sewage discharge pumps, valves and pipework associated with the sewage discharge pumps and a small sump to collect washdown water shall be located in the dry well.

The plant room shall contain the vacuum pumps, control panel, standby diesel generator, vacuum pressure gauges, and moisture trap.

III) Vacuum Vessel

Vacuum vessels shall be designed to meet the requirements of ASME Section VIII Division 1 – 2004 Edition. The vessel shell shall be constructed from mild steel or any other approved material.

Sewer inlets shall be provided with short radius elbows inside the vessel to direct the sewage inflow away from the sewage discharge pump suction connections and the vessel walls.

A vacuum vessel may have up to five (5) incoming vacuum sewers connected directly to the vessel. No inlet pipes shall be connected below the system emergency stop level. Sewage discharge pump suction connections shall be provided at the invert of the vacuum vessel. The vacuum vessel shall be fitted with an externally mounted sight glass which is suitable for operation in a vacuum and is easily removed for cleaning without decommissioning the vessel.

The vacuum vessel shall be provided with a DN 600 access opening, and the cover shall be provided with a lifting eye. Wherever possible, the opening is preferably positioned on the top of the vessel in order to minimise the size of the structure necessary to house the vessel, this conserves valuable resource, reduces the footprint of the building, and thus allows adjacent residences to enjoy more buffer spaces.

During the inspection or maintenance works, safe entry procedures shall be adhered to, according to the Department of Occupational Safety and Health (DOSH) codes of laws, by trained certificated operator, and that the vessel is decommissioned, with the access opening removed and discharge pipeworks at the two (2) draw-off points dismantled, and a forced air ventilation is applied.

It is important to ensure that the system would operate continuously in the face of having the vacuum vessel temporarily out of service during an interval inspection. The incoming sewage shall manually be bypassed to a mobile vacuum tanker via a flexible ribbed pipe.
The pipe is of an adequate length to reach the bypass valves safely. Typical bypass valve arrangement is shown in typical drawings in Appendix A.

VI) Moisture Trap

When mechanical vane vacuum pumps are selected, moisture trap shall be provided for the vacuum pumps.

Baffles or moisture removing material shall be fitted inside each vessel to assist with moisture removal.

V) Vacuum Pumps

Vacuum pump capacity \(Q_{vp}\) shall be rated. The selection of appropriate size of vacuum pump is determined by the following four factors:

a) The peak flow of the sewage to be collected.

b) The length of the longest single sewer within the sewer network.

c) The total volume of the sewer pipework within the network.

d) Air to liquid ratio employed (ratio not less than 3).

a) Evacuation Time

When the vacuum pumps, collection chamber and vacuum vessel have been sized, system evacuation time for an operating range of \(-0.55\) bar(g) to \(-0.65\) bar(g) shall be calculated using:

\[
t = \left(\frac{2}{3}\right)V_{vs} + \left(V_{vv} - V_{o}\right) + V_{mt}\times 60 \quad \frac{Q_{vp}}{Q_{vp}}
\]

Where,

\(t = \) system evacuation time, minutes
\(V_{vs} = \) volume of vacuum sewers, \(m^3\)
\(V_{vv} = \) volume of vacuum vessel, \(m^3\)
\(V_{o} = \) operating volume of vacuum vessel, \(m^3\)
\(V_{mt} = \) moisture trap volume (if fitted), \(m^3\)
\(Q_{vp} = \) vacuum pump capacity, \(m^3/hr\)
NOTE: In normal operation it is assumed that the vacuum sewers will be approximately 1/3 liquid filled.

The system evacuation time, which is defined as the time period between the vacuum pump start and stop, shall be between 2 and 5 minutes.

b) Selection of Vacuum Pumps

Vacuum pumps shall have sufficient capacity to serve the system. A minimum of two vacuum pumps of equal capacity shall be installed such that one pump can be removed for maintenance without the loss of system capacity. Vacuum pumps, where used, shall be suitable for both continuous operation and for a minimum of 6 starts per hour.

c) Vacuum Pipework

ABS pipes and fittings shall be used for interconnecting pipework between the vacuum pumps and the vacuum vessel within vacuum stations.

Pipework shall be fully supported.

VII) Sewage Discharge Pumps

Two sewage discharge pumps of equal capacity are recommended for use in a vacuum station. Each pump shall be sized to discharge sewage at a rate at least equal to the calculated design peak flow for the vacuum system. Sewage discharge pumps shall be capable of pumping unscreened sewage and suitable for immersed operation in the event of the vacuum station dry-well flooded. In normal operation the dry-well will not contain water.

Pumps may have a vertical or horizontal configuration.

Sewage discharge pumps shall be suitable for a minimum of 6 starts per hour. Equalising lines connecting the discharge side of the centrifugal sewage discharge pumps to the vacuum vessel shall be installed if required to prevent cavitation or to ensure that the pump inlet is always flooded.

Sewage discharge pumps shall be fitted with isolation valves to allow removal of the pump without disrupting the system operation.

Discharge pipework for each pump shall be fitted with a non-return
valve and a resilient seated gate valve on the discharge side. Where the discharge pipework is manifold, the final discharge pipe shall also be fitted with a non return valve. The valves shall be able to be operated from the vacuum station floor.

VIII) Vacuum Gauges

150mm vacuum gauges calibrated to read 0 to -1 bar to an accuracy of ±2% shall be fitted to the vacuum vessel and each incoming vacuum sewer. Vacuum gauges shall also have bottom outlets fitted with lever-operated ball valves. All gauge diaphragms shall be suitable for use with sewage gases. The gauges indicate the vacuum pressure within each sewer and enable pressures within the sewer network to be monitored.

IX) Fire-fighting System

Fire-fighting system using carbon dioxide at the genset / fuel room shall be provided at every vacuum station in accordance with Bomba’s requirements.

X) Odour Control

Effective odour control system shall be provided to treat air vents from a vacuum station to prevent malodour impacts being imposed on downstream residential areas.

Biofilters is one of the systems used to remove the odours from the vacuum pump exhaust gases containing toxic and odorous compounds by passing the gases through a natural biologically active filter medium.

XI) Noise Control

Vacuum station shall be acoustically designed and fitted with noise control measures, as required to control noise to levels that comply with local council’s regulations.

XII) Controls and Telemetry

a) Vacuum Level Control

Vacuum levels in the vacuum vessel shall be controlled by vacuum switches with operating range of 0 to -1 bar(g). Their purpose is to control the operation of the vacuum pumps and to maintain the vacuum within the vessel inside the operating range. A minimum of four vacuum switches shall be provided to operate the duty and assist pumps, and to provide a high and a low vacuum alarms.
b) **Level Control**

The level detection probes shall be mounted on the vacuum vessel. The purposes are to control the operation of the sewage discharge pumps and to maintain the sewage within the vessel inside the operating range.

Probes shall be manufactured in one length without any screw joints along their length. Any form of float switch, including magnetic and ultrasonic types shall not be permitted.

The level control system shall respond to the following sewage levels in the vacuum vessel:

- **Emergency stop level** - stops vacuum generation;
- sewage discharge pump operates;
- **Start level** - starts sewage discharge pump;
- **Stop level** - stops sewage discharge pump;

**c) Vacuum / Sewage Discharge Pump Control**

The controls shall permit the selection of duty, duty assist (where provided) and standby vacuum pumps and sewage discharge pumps and shall provide for the automatic introduction of the standby units in the event of failure.

The electrical controls shall allow sequential operation of all pumps so that running times are equalised. The standby pump shall automatically cut-in should the duty pump fail.

d) **Valve Monitoring System / Station Telemetry**

Valve monitoring and station telemetry systems are optional, but, shall be implemented for larger schemes comprising more than 50 interface valves.

The open and closed status of interface valves shall easily be detected by the use of a remote control via infrared/radio signals. Alternatively, system suppliers may install a signal cable to relay this information to a display panel within the vacuum station. All monitoring components installed at the collection chambers shall be robust and suitable for use in sewerage application.

Large schemes shall also include a telemetry section with volt-free contacts for each condition/alarm of the station equipment as shown in Table 2.5
Table 2.5 Condition/alarm of the Station Equipment

<table>
<thead>
<tr>
<th>DESCRIPTIONS</th>
<th>INPUT / OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station power</td>
<td>Failed / OK</td>
</tr>
<tr>
<td>Vacuum pump power</td>
<td>Isolated / OK</td>
</tr>
<tr>
<td>Sewage discharge pump power</td>
<td>Isolated / OK</td>
</tr>
<tr>
<td>Vacuum pump overload</td>
<td>Tripped / OK</td>
</tr>
<tr>
<td>Sewage discharge pump overload</td>
<td>Tripped / OK</td>
</tr>
<tr>
<td>Vacuum level</td>
<td>Low / OK</td>
</tr>
<tr>
<td>Vacuum level</td>
<td>High / OK</td>
</tr>
<tr>
<td>Sewage level</td>
<td>High / OK</td>
</tr>
<tr>
<td>Intruder alarm</td>
<td>Activated / OK</td>
</tr>
<tr>
<td>Fire alarm</td>
<td>Activated / OK</td>
</tr>
</tbody>
</table>

XIII) Emergency Power Generation

A back-up diesel generator shall be provided to adequately run the station in the event of an electric power disruption. The generator shall be capable of providing 120% of power for at least one vacuum pump and one sewage discharge pump and other necessary equipment.

2.1.20 Computerised Sewer Designs

Manual computations for the hydraulic design of a sewer network can be avoided for many aspects using proprietary computer software or in-house computer programs. However, there are many variations possible for the different aspects of hydraulic design, i.e. flow contributions from different sources, quantity of infiltration, quantity of inflow, sediment cleansing requirements, pipeline roughness coefficients, etc. It is therefore necessary that the computer software or programs adopt the hydraulic design requirements as detailed in this guideline. Some proprietary softwares may not permit certain adaptations required to conform to the hydraulic design requirements given in this guideline. As such, these software would be unsuitable.

2.1.21 Design of Inverted Siphon

Inverted siphons are introduced along a gravity sewer line in order to pass
under an obstacle (e.g. railway line, stream, culvert, etc). An alternative to an inverted siphon for bypassing obstacles is a pump station. But such an option may be economically not viable. The profile of an inverted siphon encourages solids settlement and accumulation and therefore they require more frequent cleaning. They must be avoided as much as practicable.

Inverted siphon shall consist of at least two or more parallel pipelines (or barrels). The minimum pipe size of a barrel shall be 225 mm, and shall be provided with necessary appurtenances for convenient flushing and maintenance. There will be an inlet chamber designed to divide the flow among the pipes by allowing each pipe to come into operation in succession and an outlet chamber designed to prevent eddies from carrying solids and sediments back into the siphons.

Longer siphons shall be provided with hatch box with access for maintenance and cleaning. These siphons shall have independent washout facilities.

The manholes shall have adequate clearance for rodding. In general sufficient head shall be provided and pipe sizes selected to secure flow velocities of at least 0.9 m/sec for average flow. The inlet and outlet shall be arranged so that the normal flow is diverted to one barrel, and so that either may out of service for cleaning. Its choice should be taken into consideration the operational and maintenance aspect of siphons. The siphons shall not have sharp bends, either vertical or horizontal. The horizontal leg of the siphon shall have a negative gradient of 8° to 10°, whilst the rising leg shall be limited to 30° to 45° should space permitting. There shall be no change in pipe diameter along the length of the barrel. Pipes and pipe joints used for siphons shall be designed at the appropriate pressure rating.

2.1.22 Structural Design of Sewers

The structural design of a buried sewer can be divided into the following two categories:

a) Rigid pipe.
b) Flexible pipe.

All two structural designs shall take account of how the sewer is supported to determine the loading which the sewer can safely withstand.

The structural design of a buried sewer normally considers only the structural integrity of the pipe cross section. Although not as critical as
the structural integrity of the pipe cross section, the considerations for the ground conditions and sewer installation practices that will affect the longitudinal structural integrity shall not be omitted.

There are many design approaches for each of the two structural design categories. However, there are only minor alterations among these different approaches. Some design approaches tend to give a more favourable prediction of performance for a particular pipe material than other approaches. The use of standard design approaches given in this guideline will prevent the selection of a particular design approach purely to favour one material over another. Also, the following recommendations are only meant for general design aspects. Any design aspects that are not covered by this Volume, the designer shall refer to BS EN 752 or any other standards deemed appropriate by the Commission.

a) **Rigid Pipe Structural Design**

Pipes which are classified as rigid are:

i) Vitrified clay (VC) pipe.

ii) Reinforced concrete (RC) pipe.

The failure of a rigid pipe normally occurs by pipe fracture. Thus, for structural performance, the determination of the pipe ring crushing strength / load is required. This strength is determined using three points loading test as described in the respective Malaysian Standards for the above pipes. Both VC pipe and RC pipe can be made to achieve different ring strengths as defined in the Standards.

When a buried rigid pipe is supported, the load which the pipe can safely withstand is higher than the load which caused failure in the three point loading test.

The improvement in load resistance provided by different pipe support designs is defined by the bedding factor. Where the sewer is supported on granular material, such as crushed rock, the bedding factor becomes a function of the density of the granular material and the height to which the granular material is placed above the sewer.

By varying the pipe ring strength and the pipe support, different load resistance can be achieved.

The pipe support designs permitted by this Volume are limited to those in typical beddings in Appendix A. They include the following:
i) Granular bedding/ Crusher rock.
ii) Concrete cradle.
iii) Concrete arch (with granular bedding).
iv) Concrete surround.

Granular bedding design shall be adopted wherever possible. Concrete support or arch designs should be avoided. This is due to the difficulty in achieving full contact of the concrete support with the pipe ring. A higher strength pipe in combination with crushed rock support is preferred over a lower strength pipe in combination with concrete support or arch designs.

It is important that the pipe bedding should be properly constructed to allow for the flexibility at the pipe joints and to ensure uniform pipe supports. Point supports or loads which may lead to pipe failure must be avoided.

The soil load to which a rigid pipe can be subjected to shall be determined from Martson Load Theory. According to the theory, the soil load on a rigid pipe differs from that on a flexible or semi flexible pipe. The load on a rigid pipe is a function of trench width, backfill soil type and trench depth. In a narrow trench, trench wall friction reduces the load applied by the soil backfill. Therefore, wide trench gives a more conservative loading and shall be used to determine the load on rigid pipe.

Where vehicles will pass over the sewer and the sewer is laid with a cover depth of less than 2.5 m, the sewer will be subjected to additional loads from such vehicles. The Boussinesq Theory should be used to determine the loads from vehicles in the design.

The ultimate vehicle load to which the sewer will be subjected to shall be used for structural design. Where the sewer may be subjected to construction traffic or may have temporary shallow cover during installation, structural design must examine such loading conditions to ensure the sewer can withstand such temporary vehicle loadings.

Determination of vehicle loading shall be in accordance with AS 3725 (Loads on buried concrete pipes) and AS 4060 (Loads on buried vitrified clay pipes.)

Loads on buried rigid pipe for field conditions and for main roads can be found in Simplified Tables of External Loads on Buried Pipelines published by the UK Transport Research Laboratory.
b) **Flexible Pipe Structural Design**

Pipes which are classified as flexible are:

- i) PE pipe
- ii) GRP pipe
- iii) ABS pipe
- iv) Steel pipe

The mode of failure of a flexible pipe is usually by excessive pipe ring deformation, except for GRP pipe which may be by excessive pipe ring strain. The occurrence of such a GRP pipe failure depends on the wall thickness.

Normally a standard long term allowable ring deflection is applied for all flexible pipe. A 5% long term deflection limit has been the most commonly adopted limit and shall be used except for steel pipe with cement mortar lining. For steel pipe with cement lining, a 2% deflection limit shall be used. Where surface settlement is critical, a lower allowable deflection limit may be adopted.

The resistance of a flexible pipe to ring deformation is classified by pipe ring stiffness. The stiffness classification is derived from a two point short term loading test. It is a function of the loading force divided by the specified test deflection. Flexible pipe can be made to achieve different ring stiffness by varying the wall thickness. For PE pipes, the ring stiffness can also be varied by varying the wall structure.

Similar to rigid pipe, the loading which a flexible pipe can withstand can be increased when the pipe is supported. For flexible pipes, this external ring support is more critical. Without it, a flexible pipe would fail under the loads applied by usual soil cover for gravity sewers and under vehicle loads for shallow cover force mains.

By varying the pipe ring stiffness and surrounding soil stiffness, different load resistance can be achieved for flexible pipe. Flexible pipe must be completely embedded in crushed rock, with the rock to be finished at 150 mm over the top of the pipe. Crushed rock will give a uniform support around the pipe.

The soil load used for structural design for flexible pipe support shall be the prism load or the weight of the column of soil directly above the pipe. Marston Load Theory mentions that this column of soil
is partly supported by friction provided by adjacent soil. Therefore, this frictional support of soil column causes the load on the flexible pipe to be less than the weight of soil directly above the pipe. This frictional support may be lost with time and the design using prism load represents a conservative design.

Where vehicles will pass over the sewer and the sewer is laid with a cover depth of less than 2.5 m, the pipe will be subjected to additional loads from such vehicles. The Boussinesq Theory should be used to determine the loads from vehicles in the design approach in this guideline.

The ultimate vehicle load to which the pipe will be subjected to shall be used for structural design. Where the pipeline may be subjected to construction traffic or have a temporary shallow cover during installations, structural design must examine such loading conditions to ensure the pipeline can withstand such temporary vehicle loadings.

Granular bedding design shall be adopted wherever possible. Typical details of granular bedding for flexible pipe is given in Appendix A. The structural design of flexible pipe support must be in accordance with Australian Standard AS/NZS 2566, which uses a modified form of Spangler’s equation for the determination of pipe deflection. This Spangler equation incorporates Leonhardt’s factor to account for the change in support provided by surrounding soil stiffness when the trench width is varied.

For force mains with shallow cover, structural design of flexible pipe may not be necessary. However, when the structural design of flexible pipe for such a force main is undertaken, the re-rounding effect of internal pressure should be ignored to allow for the worst case design, which occurs when the line is out of service.

### 2.2 Manhole

#### 2.2.1 General

Pre-cast concrete manholes shall conform to MS 881 and BS 5911. Manholes shall be constructed with pre-cast concrete sections surrounded by an in-situ concrete surround. Protecting lining / coating shall be provided to prevent corrosion of the concrete due to sulphide attack. Walls shall be either rendered with sulphate resistant cement mortar at least 20 mm thick or lined with PVC, HDPE or epoxy coating. PVC
or HDPE lining shall be at least 5 mm thick. Continuity of the lining shall be provided by means of welding or fusing each individual sheet to the next prior to the concrete curing. The epoxy coating shall either be high build tar epoxy system complying with AS 3750.2 and applied in two or more coats to give a total dry film thickness of not less than 500 µm; or high build micaceous iron oxide pigmented epoxy system complying with AS 3750.12 and applied in two or more coats to give a total dry film thickness of not less than 250 µm. The benching shall be protected with epoxy coating, high alumina cement mortar, or equivalent. Only materials and application processes approved by the Commission may be used.

Brick manholes shall not be used, due to the high risk of excessive infiltration.

Details of manhole types and construction are shown in Appendix A. Straight back type taper top shall be used while reducing slabs type are acceptable as alternative. Any other type of pre-fabricated manhole will require prior approval of the Commission.

The minimum diameter of manhole chambers constructed from pre-cast concrete rings shall be as given in Table 2.6 below:

**Table 2.6 Minimum Manhole Diameters**

<table>
<thead>
<tr>
<th>Depth to Soffit from Cover Level (m)</th>
<th>DN Largest Pipe in Manhole (mm)</th>
<th>Min. Internal Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>&lt; 150</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>225 to 300</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>375 to 450</td>
<td>1350</td>
</tr>
<tr>
<td></td>
<td>525 to 710</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>820 to 900</td>
<td>1800</td>
</tr>
<tr>
<td>&gt; 900</td>
<td></td>
<td>Subject to designer’s requirements based on site condition</td>
</tr>
<tr>
<td>≥ 1.5</td>
<td>&lt; 300</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>375 to 450</td>
<td>1350</td>
</tr>
<tr>
<td></td>
<td>525 to 710</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>820 to 900</td>
<td>1800</td>
</tr>
<tr>
<td>&gt; 900</td>
<td></td>
<td>Subject to designer’s requirements based on site condition</td>
</tr>
</tbody>
</table>
Note:
a) These sizes apply to straight-through pipes; larger sizes may be required for turning chambers or chambers with several side branches or where specific maintenance requirements are necessary, e.g. disconnecting traps.

An induct vent shall be provided at manholes receiving pumping discharges where retention times in the force mains exceed two hours and where concrete pipe are laid downstream of the force mains. The induct vent shall have a diameter of approximately one half of the force mains but shall not exceed 300 mm in diameter. The top of the concrete support of the vent shall be built up above flood level. Details of the induct vent are shown in Appendix A.

Provision of back-drop manhole shall be based on the following criteria:

a) For pipe size equal to 225 mm or less, back-drop manhole shall be provided when the difference in invert level is equal to 900 mm or more.
b) For pipe size more than 225 mm, back-drop manhole shall be provided when the difference in invert level is equal to 1000 mm or more.

2.2.2 Manhole Location

Unless otherwise agreed by the Commission, all manholes shall be sited in public road reserve so that access can be gained for maintenance purposes. Manhole shall be provided for the following locations:

a) The starting end of all gravity sewers, this may be replaced by a terminal layout
b) Every change in direction or alignment for sewers less than 600 mm in diameter
c) Every change in gradient
d) Every junction of two or more sewers
e) Every change in size of sewer

Unless adequate modern cleaning equipment is used for the maintenance of the sewer, the spacing between manholes shall not be more than 100 m for sewers less than 1.0 m in diameter. For sewers with diameter larger than 1.0 m, the spacing between manholes shall not be more than 150 m.

Where site conditions prevent manhole construction on the existing public sewer, a manhole shall be provided on the connection pipe as near to the public sewer as possible.
The connections, details, and methods of manhole construction not covered in this Guidelines shall be in accordance with MS 1228. In addition, the current policies of the Commission with respect to safety and operation shall be strictly followed.

2.2.3 Pipe Lengths from Manhole

To prevent the differential settling of the manhole and the connecting sewer from breaking the sewer pipe, rotational flexibility in the sewer close to the manhole is required. A single flexible joint placed immediately outside the entry to the manhole is not sufficient to solve the differential settlement problem, unless graded (governed by gradient permissible range) to connect directly to match invert level of manhole channel, if unable to match invert level. A short length of “rocker pipe” having a flexible joint at both ends shall be provided. A 600 mm length short “rocker pipe” is sufficient to provide the rotational flexibility required for most circumstances in small diameter pipelines (≤300 mm). For larger pipe, a 900 mm length short “rocker pipe” shall be provided. Refer to drawings in Appendix A.

2.2.4 Structural Design Considerations for Manhole

a) Concrete used in situ shall be 25MPa Portland cement unless shown otherwise by the qualified person.

b) A cement blinding with a minimum of 50 mm thickness shall be placed before pouring the concrete manhole base.

c) The base of the manhole shall not be less than 300 mm thickness, which is measured from the channel invert.

d) Channel inverts shall be laid accurately to meet entry and exit pipe inverts.

e) The channel invert shall be graded evenly between the entry and exit pipes.

f) Flexible joints shall be provided at the exit and entry of the manholes and shall be placed immediately outside any poured-in-situ concrete surround.

g) Joints between the pre-cast chamber rings shall be sealed with suitable mortar, which can be high alumina cement mortar or equivalent.

h) The top of the benching shall be sloped at 1 in 12 towards the channel.

i) The finish surfaces of cast in-situ concrete structures shall be trowelled smooth without poke holes or exposed aggregate.
j) A minimum of 150 mm thick Grade 25 concrete in-situ shall be encased to the precast concrete section. Brick manholes shall not be used.

k) Box outs sealed with bricks or equivalent shall be made for any proposed connections.

l) Drop connection pipes and fittings in the manhole shall be of the same diameter and material as the connecting sewer.

m) A factory pre-cast intermediate slab shall be provided at every 3 meters depth and placed at half of the manhole depths. The slabs must have holes for ventilation.

n) Pre-cast reinforced concrete landing, cover slap and flat top’s undersides shall be painted with 2 layers of coal tar epoxy.

o) Manhole covers in roads shall be set to the road profile and shall be flushed with the road surface.

p) Manhole covers in unimproved areas shall be set at an elevation to prevent entry of surface water.

q) Manhole frame surrounds shall be filled with non-shrink cementitious material or premix.

r) Field coatings to manhole covers and frames shall be applied to surfaces that are clean, dry and free from rust.

s) Bolted-in steps are not permissible in all manholes. Provision shall be provided for portable ladder for access. The lightweight removable ladders shall be used in manholes where they can easily be inserted and secured from the surface, in order to deter unauthorized access to sewers.

t) Manhole structures shall not be constructed on slope or within slope failure envelope. In the event where it is unavoidable, the said structures must be designed not to encounter settlement or the sorts and at any time at risk of collapse during its operating life span.

u) Maximum depth shall be equal or less than 9 meter and all manholes deeper than 6 meter are subjected to the Commission’s prior approval. Depending on the catchment area and size of sewer pipe, manholes deeper than 9 meter may be considered for the Commission approval.

v) Precast or cast in-situ concrete base of minimum Grade 25 with 1 layer of A6 BRC, 400 mm thick or to qualified person’s design shall be provided under poor soil condition including piling, if necessary.
2.3 Manhole Covers and Frames

2.3.1 General

Manhole covers and frames shall comply with the specifications in this Guideline and BS EN124. Where the specifications in this Guidelines contradict the specifications given in BS EN124, the specifications in this Guidelines shall take precedence.

2.3.2 Load Class

Manhole covers and frames shall be capable of bearing wheel loads of up to 400 kN and, as such, shall meet the test load requirements for Class D400 manhole covers and frames given in BS EN124.

2.3.3 Material

The material for manhole covers and frames shall be of spheroidal or nodular graphite iron (otherwise known as ductile iron) complying with the requirements specified in BS EN1563 for Grade 500/7.

The production, quality and testing of spheroidal graphite cast iron shall comply with ISO 1083.

2.3.4 Dimensions, Marking and Surface Finish

The manhole covers shall be free of defects which might impair their fitness for use.

The dimensions, marking and surface finish of manhole covers and frames shall comply with the requirements given in Figure A1 to A4 in Appendix A.

Tolerance on dimensions shown in Figures A1 to A2 shall be ± 1 mm. The casting of markings shall be clearly legible.

2.3.5 Seating

When a random cover is placed in a random frame, the adjacent top surfaces of the cover and frame shall have flushness of level within ± 1 mm.

The manholes covers shall be compatible with their seatings. These seatings shall be manufactured in such a way to ensure stability and quietness in use.
2.3.6  **Casting**

All cast units shall be cleanly cast and free from air holes, sand holes, cold shuts and chill. They shall be neatly dressed and carefully fettled. All castings shall be free from voids, whether due to shrinkage, gas inclusions or other causes.

2.3.7  **Protective Coating**

All surfaces of manhole covers and frames shall be supplied coated with either a:

i)  hot applied bituminous material complying with BS 4147 Type I Grade C
ii) cold applied bituminous material complying with BS 3416 Type II

Immediately prior to coating, surfaces shall be clean, dry and free of rust. The coating shall be free of bare patches or lack of adhesion. The mean thickness shall be no less than 70 µm and the local thickness shall be no less than 50 µm.

2.3.8  **Water-tightness**

No visible leakage shall occur between the manhole cover and its seating in the frame when tested in accordance with Appendix E of AS 3996.

2.3.9  **Safety Features**

Manhole covers shall be provided with locking device and hinge to prevent rocking due to traffic and to provide a theft proof design.

a)  **Locking Devices**

Locking devices shall be either bolts and nuts or a mechanism with a special key design. The mechanism shall be able to be integrated with the covers and can also be used as a lifting device. All the mechanism for locking device shall be of stainless steel in accordance with BS EN ISO 3506. Bolts and nuts for locking devices shall be hexagonally headed, complying with BS3692.

b)  **Hinge**

All manhole covers shall be hinged. The hinge shall be designed such that, when in the open position, they shall be secured by a positive mechanical retainer to prevent accidental closure of the covers. The opening angle of hinged covers shall be at least 100° to the horizontal. If hinge bolt is used for coupling separate sections of covers and frames, it shall be of stainless steel in accordance with BS EN ISO 3506.
2.3.10 **Product Certification**

Manhole covers and frames shall be certified as complying with the requirements of this specification. The product testing for certification purposes shall be undertaken by SIRIM QAS, IKRAM QA services or other third party certification body. The approval of the product shall be from the Commission.

The quality control of the certified manhole covers and frames shall meet the requirements given in Clause 10 of BS EN 124. However, the final inspection and tests and the frequency of tests/inspection shall not be as shown in Table A3 of BS EN 124. Instead, the specifications as shown in Table 2.7 below must be followed. All final inspection and test documents shall be retained for at least 5 years.

**Table 2.7 Final inspection and testing**

<table>
<thead>
<tr>
<th>Final Test/Inspection</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markings legibility inspection</td>
<td>Every unit</td>
</tr>
<tr>
<td>Casting defects inspection</td>
<td>Every unit</td>
</tr>
<tr>
<td>Protective coating inspection</td>
<td>Every unit</td>
</tr>
<tr>
<td>Locking devise inspection</td>
<td>Every unit</td>
</tr>
<tr>
<td>Seating flushness of cover in frame</td>
<td>1 per 20</td>
</tr>
<tr>
<td>Measurements of all dimensions</td>
<td>1 per 100</td>
</tr>
<tr>
<td>Load Class Test</td>
<td>1 per 100</td>
</tr>
<tr>
<td>Water-tightness Test (only applicable for covers required to be watertight)</td>
<td>1 per 100</td>
</tr>
<tr>
<td>Protective coating thickness measurement</td>
<td>1 per 200</td>
</tr>
</tbody>
</table>

2.4 **Design of Network Pump Stations**

2.4.1 **Specifying of Network Pump Stations**

Network pump stations shall be provided only where:

i) Sewage flow by gravity is not allowed by the topography.

ii) Excessively deep and expensive excavation for sewer installations will be required.

iii) Sewage needs to be delivered from an area that is outside the natural drainage catchment of a sewage treatment plant.
2.4.2 General Requirements

i) Network pump stations shall be preceded by screens to protect pumps from being damaged or clogged.

ii) The type of pump used must be suitable for sewage application. Water pumps must not be used as they are not designed to transfer sewage.

iii) Drainage of dry wells and valve pits shall be provided. Drainage lines shall be equipped with back flow protection to ensure that the chamber is not flooded.

iv) Wherever possible, the wet-well shall not be housed within a building structure with insufficient ventilation.

v) Where separate valve pits are used, then the connecting pipes shall incorporate at least two flexible joints to allow for differential settlement.

vi) The designer shall ensure that his/her designs comply with all relevant legislation, standards, guidelines and requirements, and its latest amendments.

vii) Access and appropriate parking shall be provided at all times for emergency vehicles, maintenance vehicles and ancillary equipment.

viii) Adequate protection against lightning shall be provided.

2.4.3 Buffer Requirements

In order to minimise the nuisance of odours from pumping stations, buffer zone shall be provided at all sides. The zone shall be at least 20 m from the pumping station fence to the nearest habitable building fence. The presence of a pumping station in any development may draw negative visual impacts. To minimise the visual impact of surface structures of the pumping station, landscaping shall be provided. Landscaping shall comprise of trees that are non-shedding to minimise maintenance. The buffer requirements are shown in Appendix A.

Under conditions where there exists the potential of odour nuisance to the nearest habitable building property line within residential and commercial development despite having the minimum buffer zone, such odour shall be minimised to the lowest possible level and in compliance with the Environmental Quality Act.

2.4.4 Pipeworks Requirements

i) Pipeworks shall be of ductile iron with approved internal lining. Other approved material by the Commission may be used.
ii) External surface of pipeworks in chambers and wells shall be epoxy coated.

iii) Buried ductile iron pipe shall have polyethylene sleeving.

iv) Pipeworks shall be adequately supported.

v) Flanges shall be located at least 150 mm away from structures.

vi) Dismantling joints such as bends shall be provided.

vii) Pumping thrust shall be resisted using pipe supports.

viii) All internal pipeworks within the pump station shall have flanged joints unless the pipe selected has special jointing requirements.

ix) Flexible couplings should be used where they will facilitate dismantling and accommodate vibration.

2.4.5 Wet-well Requirements

i) Suction channels shall be designed to avoid “dead zones”, i.e., prevent solids and scum accumulation.

ii) Minimum hopper bottom slope shall be 1.5 vertical to 1.0 horizontal.


iv) The difference between stop and start levels shall be a maximum of 900 mm and a minimum of 450 mm.

v) The difference in level between start or stop of duty and assist pumps shall be greater than or equal to 150 mm.

vi) The minimum sump volume required shall accommodate the pumping cycle as per Table 2.4.

vii) Benching shall be designed to minimise deposition of solid matter on the floor or walls of wet-wells. The minimum slope of benching shall be 45° to the horizontal.

viii) Benching shall preferably extend up to the pump intake.

ix) Self cleansing pumps shall be provided.

x) Access into wet-wells can be by vertical rung ladders with a maximum height of 6 m. When the height exceeds 6 m, intermediate platforms shall be provided with a change in direction of the ladder. Safety cages shall be provided for ladders exceeding 6 m.

xi) Access covers shall have a minimum clear opening of 600 mm diameter and be sufficiently large to withdraw pumps vertically.

xii) Access covers shall be capable of being lifted by, at most, two operators.

xiii) On small pump stations (PE < 500), the practice is to provide difference between the cut-in and cut-out levels, the storage volume
equal to 2 to 3 times the peak flow into the wet-well in litres per minute merely to protect the starting equipment from overheating and failure caused by too frequent starting and stopping.

xiv) Emergency bypass shall be provided either at any suitable manhole or wet-well. The discharge of the bypass is preferred to the nearest watercourse and not to the perimeter drain of the pumping station. However, if this is not available then discharge to the nearest surface drain is allowed.

xv) All wet-well shall be opened and come with stainless steel or other non-corrosive handrails. If stainless steel tubing is used, it shall be in-filled with concrete.

2.4.6 Dry-well Requirements

i) The size of dry-well depends primarily on the number and type of pumps selected and on the piping arrangement.

ii) The requirement of pump installation is to provide at least 1.0 m from each of the outboard pumps to the nearest side wall and at least 1.2 m between each pump discharge casing.

iii) Sufficient room is required between pumps to move the pump off its base with sufficient clearance left in between the suction and discharge piping for site repairs, inspection or removal from the pit to the surface for repairs.

iv) Consideration should be given to the installation of monorails, lifting eyes in the ceiling and A-frames for the attachment of portable hoist cranes and other devices.

v) Provision should also be made for drainage of the dry-well to the wet-well.

2.4.7 Structural Requirements

i) Substructure shall be constructed of reinforced concrete with sulphate resistant cement to resist aggressive soils and groundwater.

ii) Below ground walls shall be waterproofed and protected against aggressive soils and ground water.

iii) Safe and suitable access to the wells shall be provided.

iv) Internal walls shall be made resistant to sulphide corrosion by coating with high alumina cement or equivalent coatings.

v) A penstock shall be installed upstream of the wet-well to isolate the pump station.

vi) For safety and operational reasons, a double penstock system may be required at specific plant.
vii) The penstock spindle shall extend to pump station ground level and shall be suitably positioned to allow unrestricted operation of the penstock.

viii) Access platforms shall be provided at all locations where dismantling work takes place.

ix) Access covers shall be hinged with a lifting weight not exceeding 16 kg.

x) Internal walls shall be made resistant to sulphide corrosion by coating with high alumina cement mortar lining, PVC lining or epoxy coating. Other materials used under special circumstances are subjected to approval from the relevant authority.

xi) Penstock greater than 610 mm x 610 mm shall be motorised and come with manual overwrite switches. The actuator shall be located above ground level and above flood level for easy access in the event of flooding.

xii) Protection against falling shall be provided by means of handrails at walkways and other working areas, where the fall equal or exceeds 1.5 m.

xiii) Edge protection by means of kick plates of at least 50 mm in height shall be provided, where the drop is equal or exceeds 2.0 m.

xiv) Proper drainage shall be provided at the collection bin area to ensure that liquid collected could be channelled back to the pump sump.

2.4.8 Ventilation Requirements

i) Ventilation shall be provided for all hazardous zones of the pump station.

ii) Covered pits shall have mechanical ventilation.

iii) Separate ventilation shall be provided for wet-wells and dry-wells.

iv) Lighting systems shall be interconnected with ventilation.

v) Permanent ventilation rate and air changes shall comply with MS 1228.

vi) uPVC pipe is not permitted to be used as ventilation ducting between wet-well and dry-well.

2.4.9 Odour Control

i) The potential for odour generation, its impact and treatment, shall be considered in all aspects of design.
ii) Isolate odorous gasses from general ventilation exhausts by containing identified odour generating sources with a separate local exhaust system.

iii) Containment of the odour sources shall be by installing lightweight and corrosion resistant covers/enclosures designed for practical operation and maintenance works.

iv) The local exhaust odorous air shall be conveyed through well designed and balanced ductworks by a centrifugal fan to an effective odour treatment equipment.

2.4.10 Requirements for Lighting and Electrical Fittings

i) Wet-wells and dry-wells shall be adequately lit.

ii) Electrical installations shall be water proof, vapour proof and explosion proof.

iii) If lights are fitted outside the well, then a spotlight system may be used to provide adequate illumination.

iv) If portable lighting is used, proper ancillaries shall be made available.

v) Equipments shall be sited above the highest water level.

2.4.11 Acceptable Pump System (Fixed Speed Pumps Only)

The acceptable pump types are:

i) Centrifugal

ii) Screw

iii) Screw Centrifugal

Pumps are to be equipped with an auto restart mechanism to allow for automatic pump restart after power supply has resumed from a power failure. Pumps shall be equipped with protection accessory, e.g. thermal sensor, leakage sensor, etc. Dry-well mounted pumps shall be equipped with auxiliary services such as cooling and gland seal water supply.

Guide rail, lifting device and other wet-well fittings must be fabricated of stainless steel, that is corrosion resistant. The use of hot dip galvanised iron is not recommended.

Pre-fabricated pump stations are acceptable for small installations of PE less than or equal to 2000.
2.4.12 Valve Requirements

2.4.12.1 General

i) All valves shall be anticlockwise opening.

ii) All valves shall be suitable for use with wastewater and shall be designed to prevent retention of solids.

iii) All valves shall be identified by durable name plate. Direction of flow shall be stamped on the valve body.

iv) Bodies and cover for all valves shall be made of ductile iron to BS EN 1563: 1997. Special protective surfaces finishing by short blasting and finished externally with epoxy corrosion resistant coating shall be provided.

2.4.12.2 Gate Valve

i) Gate valves shall be of the non-rising screw wedge-gate type, double-faced ductile iron made and with resilient seated.

ii) Gate valve shall conform to MS 1049, BS 5163 EN 1074 Part 2 or BS EN 1171: 2002.

iii) The wedge of the gate valves shall be coupled and integral to the wedge hut in dezincification resistant high tensile brass (CZ 132) conforming to BS EN 2287 2: 1993, ISO 2872: 1985.

iv) The spindle of the gate valve shall be of the inside screw non-rising with machined square or acme threads and operated by a handed or tee-key.

v) Resilient seat valves shall have Ethylene Propylene Diene Monomer (EPDM) covered gates with inside screw non-rising stem. Stem shall be stainless steel conform to BS EN 10088-3: 2005.

2.4.12.3 Check Valve

i) Check valve shall be of approved by the Commission and suitable for their intended used and shall comply to BS 12334: 2001.

ii) Check valves of non-slam swing type with extended spindle if necessary shall be provided at the upstream of a flow detection device.

iii) Only single disc type of check valve shall be used.

iv) The uses of internal counter weights are not permitted for Check Valve.
v) Type non-slam Check valve shall be of the full body type, with a domed access cover and only on moving pant, the flexible disc.

vi) Disc of Check valve shall be of precision molded Nitrile Butadiene Rubber (NBR) to BS EN 681-2: 2000. the disc shall be of one-piece construction, precision molded with an integral o-ring type sealing surface, and contain alloy steel and nylon reinforcement in the flexible use area.

vii) In the absence of check valve, the reverse rotation of the pump shall not exceed 150% of the rated speed or limit set by the manufacturer.

viii) Tapping (12 mm British Standard Parallel (BSP)) shall be located upstream and downstream of check valves.

2.4.13 Requirements for Level Controls

i) Either floats, electrodes or ultrasonic level controls may be used for start-stop level of pumps. Those level controls with environmental friendly features are recommended.

ii) Ultrasonic level control is recommended due to its clog-free nature.

iii) Non-mercury type floats are recommended.

iv) Hollow tube electrodes are not acceptable.

v) Level controls shall be placed where they are not affected by the turbulence of incoming flow and where they can be safely removed.

vi) When floats are used, cable hanger shall be installed.

2.4.14 Requirements for Alarms

i) Provision of alarms shall be considered inclusive of flammable gas, fire, high water level, bearing temperature, motor temperature, pump failure, power failure and vandalism.

ii) An alarm system should have an emergency power source capable operating for at least 24 hours in the event of failure of the main power supply and shall be telemetered thereto.

iii) Where no such facility exists, an audio-visual device shall be installed at the station for external observation.

2.4.15 Requirements of Hydraulic Design and Performance

The followings items shall be provided:

i) System curves.

ii) Pump curves.
iii) Operating point of pumps with respect to flow and total dynamic head (TDH).
iv) Operating characteristics such as efficiency, horsepower, motor rating and Net Positive Suction Head (NPSH).

2.4.16 Maintenance Considerations

i) Mechanical and electrical equipment selected shall be robust and reliable and shall require minimal maintenance.
ii) Consideration should also be given to the availability of spare parts.
iii) The provision of appropriate lifting hoists and beams, and lifting eyes or similar features on heavy equipment, shall be considered.
iv) Complete sets of current general arrangement and sectional drawings, operational, maintenance and service manuals, circuit diagrams and parts lists shall be supplied and be available at all times.

2.4.17 Hazard and Operability (HAZOP)

i) All pumping station design shall give consideration to all potential hazard and operability of design.
ii) HAZOP study may need to be conducted for pumping station design to identify the hazards and operability issues.
iii) The need for HAZOP study shall comply with requirements stipulated in the MSIG Volume 2.

2.4.18 Other Requirements

Also refer to MS1228 for additional requirements.
### Table 2.8  Recommended Design Parameters for Pump Stations (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>PE ≤1,000</th>
<th>1,000 &lt; PE ≤ 5,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of station</td>
<td></td>
<td>Wet-well</td>
<td>Wet-well</td>
</tr>
<tr>
<td>Number of pumps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(all identical and work sequentially)</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 duty,</td>
<td>1 duty,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 standby</td>
<td>1 standby</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100 % standby)</td>
<td>(100 % standby)</td>
</tr>
<tr>
<td>Pumps design flow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>each at $Q_{peak}$</td>
<td>each at $Q_{peak}$</td>
</tr>
<tr>
<td>Maximum retention time at $Q_{ave}$</td>
<td>min</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Min pass through openings</td>
<td>mm</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Minimum suction and discharge openings</td>
<td>mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Pumping cycle</td>
<td>start/hour</td>
<td>6 - 15</td>
<td>6 - 15</td>
</tr>
<tr>
<td>Lifting device*</td>
<td></td>
<td>lifting davit</td>
<td>lifting beam and block</td>
</tr>
</tbody>
</table>

* - Weight < 16 kg: Manual lifting

- 16 kg ≤ Weight ≤ 250 kg: A davit or ‘A’ frame shall be arranged to allow items lifted by using manual chain hoist to be projected on a 1.2 m truck tray and positioned at 2m above road level. In the pump station, motorized hoist is required for lifting weight exceeding 100kg.

- Weight > 250 kg: A gantry with motorised hoist shall be arranged to allow items to be projected on a 1.2m truck tray and positioned at 2m above road level truck tray.
### Table 2.8 Recommended Design Parameters for Pump Stations

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>5,000 &lt; PE ≤ 20,000</th>
<th>PE &gt; 20,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of station</td>
<td></td>
<td>wet-well or dry-well up to 10,000 PE 10,000 PE above – wet well and dry-well</td>
<td>wet-well and dry-well</td>
</tr>
<tr>
<td>Number of pumps (all identical and work sequentially)</td>
<td></td>
<td>4 (2 sets) 1 duty, 1 assist, per set (100% standby)</td>
<td>6 (3 sets) 1 duty, 1 assist, per set (50% standby)</td>
</tr>
<tr>
<td>Pumps design flow</td>
<td></td>
<td>each at 0.5 $Q_{peak}$</td>
<td>each at 0.25 $Q_{peak}$</td>
</tr>
<tr>
<td>Maximum retention time at $Q_{ave}$</td>
<td>min</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Min pass through openings</td>
<td>mm</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Minimum suction and discharge openings</td>
<td>mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Pumping cycle (average flow conditions)</td>
<td>start/hour</td>
<td>6 - 15</td>
<td>6 - 15</td>
</tr>
<tr>
<td>Lifting device*</td>
<td></td>
<td>Mechanical and block</td>
<td>mechanical</td>
</tr>
</tbody>
</table>

* - Weight < 16 kg: Manual lifting
- 16 kg ≤ Weight ≤ 250 kg: A davit or ‘A’ frame shall be arranged to allow items lifted by using manual chain hoist to be projected on a 1.2 m truck tray and positioned at 2 m above road level. In the pump station, motorized hoist is required for lifting weight exceeding 100 kg.
- Weight > 250 kg: A gantry with motorised hoist shall be arranged to allow items to be projected on a 1.2 m truck tray and positioned at 2 m above road level truck tray.
2.5 Interceptors

All development schemes including individual premises that involve any sewerage works are vetted by the Commission. As part of this vetting, a check is made on the means of protecting public sewers from the discharge of prohibited matters such as oil, grease, petrochemicals, fats and solid food wastes. These matters can lead to congealment, constriction and blockage of sewers and pipelines and can also present hazards for sewer operations and maintenance. Therefore, suitable interceptors must be provided on the sewerage systems of garage workshops, engineering workshops, canteens or any premises that collect such matters. The design specification may be acquired from the Commission for such a system.

2.5.1 Oil Interceptors

Oil interceptors shall be provided in drain lines from areas such as garages, parking zones, service stations, machine shops and industrial plants where oil sediments and other volatile liquids are generated.

Oil interceptors shall be designed in such a way that pollutants that are lighter than water liquid are trapped in a chamber and are prevented from being discharged to the public sewer. The chamber shall be normally fitted with a device to trap sediments and heavy particles that settle to the bottom. The removal of these sediments is required periodically.

Intercepted oils shall be capable of being drained off for storage from suitable draw off points on a continuous operational basis.

The interceptor shall be sized to accommodate the volumes of liquid likely to be discharged into the drainage system and the trapped pollutants.

2.5.2 Grease Traps

Grease traps shall be provided in drain lines from areas such as restaurants, canteens, food processing and animal product or feeds factories, where grease and fat are likely to present in wash down waters or sullage.

Grease traps shall be designed in such a way that solidified grease and fats are trapped in a chamber prior to discharge and may be skimmed off by means of a perforated strainer or bucket.

The trap shall be sized adequately to contain the volume of liquid to be discharged from the drain line and the accumulated grease.
2.6 **Concrete and Reinforcement Requirements**

Unless otherwise specified in other sections of this guidelines, all the concrete and reinforcement designed for pump stations and sewer networks shall comply with the following subsections.

### 2.6.1 Concrete

i) Structural use of concrete shall be designed in accordance with MS 1195.

ii) Concrete shall generally comply with the relevant requirements in MS 523.

iii) Concrete for purposes other than manholes and pumping stations shall have a strength grade not less than Grade C20 where unreinforced, and not less than Grade C30 where reinforced.

iv) Structures that are designed for retaining sewage or other aqueous liquids shall be in accordance with BS8007, which specifies C35A concrete. Where required, higher strength grades may be specified by the Commission.

v) Concrete exposed to a sewage atmosphere shall be lined with minimum 20 mm high alumina cement mortar complying with BS 915 Part 2 or 2 mm epoxy coating using a method of application approved by the Commission.

vi) Concrete and cement mortar shall be made using a cement with sufficient resistance to sulphate attack if contacted with sewage.

vii) Approval for admixtures shall be obtained prior to inclusion in the concrete mix. All admixtures shall comply with MS 922.

viii) Aggregates shall comply with MS 29 and shall be coarse aggregate of maximum 20 mm nominal size.

### 2.6.2 Cement

One of the following cement shall be used to resist sulphate attack:

a) Sulphate-resisting Portland cement complying with MS 1037
b) Portland pulverised fuel ash cement complying with MS 1227
c) Portland blast furnace cement complying with MS 1389
d) High silica content Portland cement complying with AS/NZS 3582
e) Super-sulphated cement complying with BS 4248
2.6.3 **Steel Reinforcement and Falsework**

a) Steel reinforcement shall comply with:
   i) MS 144 for cold reduced mild steel wire
   ii) MS 145 for steel fabric
   iii) MS 146 for hot rolled steel bars

b) Scheduling, dimensioning, bending and cutting of steel reinforcement shall be in accordance with BS 8666

c) Welding of steel reinforcement shall be in accordance with BS 7123

d) Falsework shall be in accordance with BS 5975