1. Introduction

Paling PVC-U Underground and Sewage Piping system is one of the most comprehensive on the market with a full range from 110mm to 315mm in diameter. Paling was a pioneer in the development and marketing of PVC-U systems for this application and is well known for its excellent product quality.

The economic advantages are well accepted, they are lightweight, resistant to a wide variety of chemicals, do not support combustion, they are impervious to bacteria and fungi attack and are not subject to electrolytic corrosion. The fittings are designed with a high impact strength, which helps prevent damage during handling and installation. All parts assemble easily using either solvent cement or rubber seal rings to accommodate thermal or ground movement.

Pipes and fittings are manufactured according to the BS 4660 and MS 979/2, and suitable for use below ground for general municipal drainage.

2. Product Properties

2.1 Material Properties

The properties listed in the following table are typical characteristics of PVC-U as a material, and are derived from large numbers of test samples.

These mechanical properties are for PVC-U at 20°C.

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Typical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>-</td>
<td>1.42</td>
</tr>
<tr>
<td>Hardness</td>
<td>Rockwell R</td>
<td>120</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>mg/cm²</td>
<td>0.04 – 0.06</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td>&gt; 45</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>%</td>
<td>&gt; 80</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>MPa</td>
<td>66</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>MPa</td>
<td>2700</td>
</tr>
<tr>
<td>Izod Impact Strength</td>
<td>kJ/m²</td>
<td>6</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td>-</td>
<td>0.35 – 0.4</td>
</tr>
<tr>
<td>Vicat Softening Point</td>
<td>°C</td>
<td>82</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>J/kg°C</td>
<td>1047</td>
</tr>
<tr>
<td>Coefficient of Linear Expansion</td>
<td>mm/mm°C</td>
<td>7 x 10⁻⁵</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/m°C</td>
<td>0.138 – 0.150</td>
</tr>
<tr>
<td>Flame Resistance</td>
<td>-</td>
<td>Self – extinguishing</td>
</tr>
<tr>
<td>Volume Resistance</td>
<td>Ω·cm</td>
<td>&gt; 1 x 10¹⁵</td>
</tr>
<tr>
<td>Dielectric Constant @106Hz</td>
<td>-</td>
<td>3.0 – 3.3</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>kV/mm</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Dielectric Power Factor @106Hz</td>
<td>-</td>
<td>0.02</td>
</tr>
</tbody>
</table>
2.2 Chemical resistance

The excellent chemical resistance of PVC-U to acids, alkalis, oxidising and reducing agents make it particularly suitable for a wide range of industrial applications. Generally PVC-U is resistant to most oils, fats, alcohols and aromatic-free petrol, but is unsuitable for use with aromatic and chlorinated hydrocarbons, ketones, esters and cyclic ethers which can lead to swelling and softening of the material. The comprehensive chemical resistance data is stipulated in Table 3. Paling’s technical personnel can be reached for consultation on the use of chemicals not listed in the table.

Table 2. PVC-U Chemical Resistance Chart

<table>
<thead>
<tr>
<th>Chemical</th>
<th>25°C</th>
<th>60°C</th>
<th>Chemical</th>
<th>25°C</th>
<th>60°C</th>
<th>Chemical</th>
<th>25°C</th>
<th>60°C</th>
<th>Chemical</th>
<th>25°C</th>
<th>60°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic Acid</td>
<td>S</td>
<td>S</td>
<td>Acetic Acid (80%)</td>
<td>S</td>
<td>P</td>
<td>Hydrochloric Acid (80%)</td>
<td>S</td>
<td>S</td>
<td>Hydrofluoric Acid</td>
<td>S</td>
<td>U</td>
</tr>
<tr>
<td>Aceton</td>
<td>U</td>
<td>U</td>
<td>Alcohol (100%)</td>
<td>S</td>
<td>P</td>
<td>Hydrogen Peroxide 50%</td>
<td>S</td>
<td>S</td>
<td>Hydrogen Sulphide (wet aqueous sol.)</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Alcohol (40%)</td>
<td>S</td>
<td>P</td>
<td>Aluminium Chloride</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium Sulphide</td>
<td>S</td>
<td>S</td>
<td>Ammonia Gas (dry)</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia 0.88,SG aq sol</td>
<td>S</td>
<td>S</td>
<td>Magnesium Carbonate</td>
<td>S</td>
<td>S</td>
<td>Magnesium Chloride</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium carbonate</td>
<td>S</td>
<td>S</td>
<td>Magnesium Hydroxide</td>
<td>S</td>
<td>S</td>
<td>Mercury</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>S</td>
<td>S</td>
<td>Ammonium Phosphate</td>
<td>S</td>
<td>S</td>
<td>Methyl Chloride</td>
<td>U</td>
<td>U</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Phosphate – neutral</td>
<td>S</td>
<td>S</td>
<td>Oxidised</td>
<td>P</td>
<td>U</td>
<td>Molasses</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Sulphate</td>
<td>S</td>
<td>S</td>
<td>Nickel Chloride</td>
<td>S</td>
<td>S</td>
<td>Nickel Nitrate</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aniline Hydrochloride (40% aq)</td>
<td>U</td>
<td>U</td>
<td>Nitric Acid 66%</td>
<td>P</td>
<td>P</td>
<td>Nitric Acid 90%</td>
<td>U</td>
<td>U</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium Carbonate</td>
<td>S</td>
<td>S</td>
<td>Barium Chloride</td>
<td>S</td>
<td>S</td>
<td>Animal</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium Sulphate</td>
<td>S</td>
<td>S</td>
<td>Barium Sulphate</td>
<td>S</td>
<td>S</td>
<td>Vegetable</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beer</td>
<td>S</td>
<td>S</td>
<td>Beet Sugar Liquors</td>
<td>S</td>
<td>S</td>
<td>Vegetable</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene or Benzol</td>
<td>U</td>
<td>U</td>
<td>Bleach (12.5% Active Chloride)</td>
<td>U</td>
<td>U</td>
<td>Phosgene-gas</td>
<td>S</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butanol (Primary Butyl Alcohol)</td>
<td>S</td>
<td>U</td>
<td>Petrol (depending upon type)</td>
<td>S</td>
<td>S</td>
<td>Photographic Solutions</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>S</td>
<td>S</td>
<td>Calcium Chlorate</td>
<td>S</td>
<td>S</td>
<td>Potassium Bromate</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Hydroxide</td>
<td>S</td>
<td>S</td>
<td>Calcium Hydroxide</td>
<td>S</td>
<td>S</td>
<td>Plating Solutions</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>S</td>
<td>S</td>
<td>Sodium Bicarbonate</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide (wet or dry)</td>
<td>S</td>
<td>S</td>
<td>Sodium Chloride</td>
<td>S</td>
<td>S</td>
<td>Sodium carbonate</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castor Oil</td>
<td>S</td>
<td>S</td>
<td>Chloroacetic Acid</td>
<td>S</td>
<td>P</td>
<td>Sodium Hydroxide</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloric Acid (20%)</td>
<td>S</td>
<td>S</td>
<td>Chlorine gas (dry)</td>
<td>S</td>
<td>P</td>
<td>Sodium Hydroxide</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine gas (Wet)</td>
<td>P</td>
<td>U</td>
<td>Chlorine Water</td>
<td>S</td>
<td>S</td>
<td>Sulphur Dioxide (wet)</td>
<td>S</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine (liquid)</td>
<td>P</td>
<td>U</td>
<td>Chrome Slum.Sta.Soln</td>
<td>S</td>
<td>S</td>
<td>Sulphuric Acid 75%-90%</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromic Acid 10%</td>
<td>S</td>
<td>S</td>
<td>Chromic Acid 30%</td>
<td>S</td>
<td>S</td>
<td>Sulphuric Acid 10% - 75%</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromic Acid 50%</td>
<td>S</td>
<td>P</td>
<td>Cottonseed Oil</td>
<td>S</td>
<td>S</td>
<td>Sulphuric Acid 90%</td>
<td>P</td>
<td>U</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cresylic Acid 50%</td>
<td>S</td>
<td>S</td>
<td>Cresylic Acid 100%</td>
<td>P</td>
<td>U</td>
<td>Urine</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude Oil</td>
<td>S</td>
<td>S</td>
<td>Vinegar</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel Oil – Derv</td>
<td>S</td>
<td>S</td>
<td>Diesel Oil - Gas</td>
<td>S</td>
<td>S</td>
<td>Waret (acid mine water)</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detergents (normal dilutions)</td>
<td>S</td>
<td>S</td>
<td>Disodium Phosphate</td>
<td>S</td>
<td>S</td>
<td>Water (salt)</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>S</td>
<td>S</td>
<td>White Liquor</td>
<td>S</td>
<td>S</td>
<td>Water - Fresh</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fatty Acids  | S | S | Ferric Chloride  | S | S | Xylene or Xylol  | U | U | Wetting Agents (Dil)  | S | S |
Ferric Nitrate  | S | S | Ferric Sulphate  | S | S | Zinc Chloride  | S | S |
Ferrous Chloride  | S | S | Ferric Sulphate  | S | S | Zinc Sulphate  | S | S | Zinc Nitrate  | S | S |
Fish Solubles  | S | S | Fluorine Gas (wet)  | S | S |
Gallic Acid  | S | S | Formic Acid 50%  | S | P |
Gas - natural  | S | S |

Key:  S – Satisfactory           P – Some Attack              U – Unsuitable

2.3 Effect of low temperature

The impact strength of PVC-U pipe and fittings decreases with reduction in temperature therefore increased care should be exercised if installations are carried out near 0 °C.

2.4 Effect on elevated temperatures

PVC-U is capable of handling typical waste water discharge temperatures up to approximately 60 °C and is therefore satisfactory for use in soil and waste systems where continuous full bore discharges of effluent are unlikely to exceed this figure. The low thermal conductivity of the material does allow full bore discharges at higher temperatures provided the duration of the discharge is limited to 2-3 minutes.

2.5 Expansion and contraction

Piping which is being laid in hot weather will be in an expanded condition and will subsequently contract on cooling. It must be remembered that every 6m length of PVC-U will expand or contract approximately 5mm for every 10 °C rise or fall in temperature. Precautions against damage due to contraction can be taken. Probably the most effective being to cool the line immediately before backfilling, by filling it with cold water (not under pressure within 24 hours of making solvent weld joints), taking care to examine pipe joints and connections to fittings to ensure that no disturbance has occurred. It may be helpful to "snake" pipes of smaller diameters in the trench, when contraction will tend to straight out the line, thus reducing direct pull on the joints. Backfilling in cool early morning conditions is also effective.

3. Product Features and benefits

3.1 Underground Pipes

- Dimensions and performance meet the requirement of standards.
- High quality of finish with smooth internal and external surface.
- Provides low coefficient of flow friction.
- Excellent resistance to chemicals and gas naturally found in sewerage.
- Extensive size range to suit installation needs.

3.2 Underground Fittings

- Wall thickness of fittings and materials are constructed and formulated to achieve strength that exceeds the performance requirements of standards.
- High quality of finish with smooth internal and external surface.
- Provides low coefficient of flow friction.
- Excellent resistance to chemicals and gas naturally found in sewerage.
- Ability to accommodate deformation without structural damage.
• Comprehensive range of fittings offers solutions to various installation requirements.

3.3 PVC-U Underground and Sewer System

High flow rate - Extremely smooth bores, precision joints, and lack of internal projections ensure unrivaled hydraulic capacity over the total life of the system. Flatter grades are possible using PVC-U systems.

Flammability - PVC-U does not support combustion.

Non-conductivity - PVC-U is a non-conductor of electricity, and is therefore not subject to galvanic or electrolytic action.

Tree root infiltration resistance - Penetration of tree roots causing blockages and infiltration is controlled by the high interface ring pressure of the rubber ring, or the welding action of the solvent cement jointing system.

Low installation cost - Longer pipe lengths, flexibility and the use of narrow trench widths significantly reduces installation costs, the major portion of the total in-situ costs.

Corrosion resistant - The inert nature of PVC-U pipe provides complete corrosion resistance, and renders wrapping, coating and lining unnecessary. This inert nature ensures that PVC-U sewer and drainage pipes have a long operational life.

Manhole reduction - The spacing of manholes can be increased due to greatly reduced incidence of blockage and increased flow rates possible with PVC-U sewers. In some cases manholes can be replaced with PVC-U riser and access points. Manholes are often the greatest single cost element in sewerage systems, and any reduction in their number makes sound economic sense.

Leakage elimination - Groundwater infiltration due to broken and cracked elements in the system, joint opening and ground movement are eliminated by the precision joints, flexible pipe barrel and sealed access points provided by the PVC-U sewer pipe and fittings system. Longer pipe lengths mean fewer joints, further reducing possible sources of leaks, which research has shown to be directly proportional to the number of joints.

Both the hydraulic seal and the solvent cement joint provided with the system eliminates the contamination of the groundwater and surface waters by sewer effluent with the resulting health hazards, visual pollution and public concern.

4. Pipe line design

4.1 Hydraulic Design

The capacity of flow in a pipeline can vary due to various factors, which include the roughness of pipe bore, influenced by the growth of slime, roughening due to abrasion and joint imperfections/fitting types and configurations.

Flow capacity is calculated by using the Colebrook White Transition Equation and it is assumed pipes are flowing full. This equation takes into account, liquid viscosity and pipe roughness, and is recognised as being one of the most accurate in general use but requires an iterative solution. This equation also enables user to establish the relationship between friction loss, discharge and velocity:

\[ v = -2 \cdot \sqrt{2gdJ} \cdot \log_{10} \left( \frac{2.51 \cdot \mu}{d_i \cdot \sqrt{2gdJ}} + \frac{k}{3.71 \cdot d_i} \right) \]
where;
\[ v = \text{velocity of flow cross section (m/s)} \]
\[ g = \text{gravity constant (9.81 m/s}^2) \]
\[ d_i = \text{pipe internal diameter (m)} \]
\[ J = \text{gradient} \]
\[ k = \text{hydraulic effective pipe roughness (m), taking into consideration of: misaligned joints, diametrical deformation, change of direction and side inlets recommended figure is } k = 2.5 \times 10^{-4} \text{ m} \]
\[ \mu = \text{kinematic viscosity of fluid (1.31 \times 10^{-6} \text{ m/s}^2)} \]

If filling degree is less than 100%, the internal pipe diameter \( d_i \), is replaced with the hydraulic diameter, \( d_h \), in the above equation. The relationship of the two parameters are defined as:

\[ d_i = d_h = \frac{4A}{U} \]

where;

\[ A = d_i^2 \left( \frac{\pi - 2 \arccos(1 - 2h/d_i)}{180^\circ} - \sin[2 \arccos(1 - 2h/d_i)] \right) \]
\[ U = \pi \frac{d_i}{2} \left( \frac{2 \arccos(1 - 2h/d_i)}{180^\circ} \right) \]

and \( h/d_i \) as defined in diagram below;

The flow capacity is determined by the following equations:

\[ Q = v \times \left( \frac{\pi d_i^2}{4} \right) \text{ for full bore flow and;} \]
\[ Q = v \times A \text{ for partial bore flow} \]

### 4.2 Structural Design

Paling range of PVC pipes are classified as "flexible" pipes, which means they have the ability to deform or deflect diametrically within specified limits without structural damage or impairing the performance of the pipes.

The external soil and live loadings imposed on flexible pipes may cause a decrease in the vertical diameter and an increase in the horizontal diameter of the pipe. The horizontal movement of the pipe walls in the soil material at the sides develops a passive resistance within the soil to support the external load. Hence, the
pipeline performance is influenced by the soil type and density. The higher the effective soil modules at pipe depth, the less the pipe will deflect.

A complete design approach is covered in BS EN 1295-1.

5. Installation

One of the most significant advantages of Paling PVC-U pipe system is its light weight. This means that the pipe can be easily handled and longer lengths can be installed without sophisticated lifting machinery and with minimum in-trench labour.

Long pipe lengths increase the speed with which a system can be installed, and also mean that pipelines are less susceptible to misalignment and consequent blockage following possible ground movement, than those made up of short pipe lengths.

Sewer and waste pipelines rely on gravity to ensure adequate flow of fluid. Strict adherence to the designed grade along the entire pipeline is essential and the line must be maintained to specification between inspection or manhole position.

5.1 Special application

The systems are more than adequate for normal domestic applications in low and high rise buildings. Where more specialised applications, such as hospitals, industrial kitchens and laboratories are concerned, where prolonged discharges of liquids at elevated temperatures can occur, the Technical department of Paling pipelines should be consulted.

5.2 Use of short lengths of pipe

PVC-U pipe may be cut on site when shorter lengths are required to suit the installation, or for the installation of fittings.

The cutting of PVC-U pipe is easily achieved using a fine-toothed handsaw or a PVC-U pipe cutter. The position of the cut should be measured and carefully re-checked before cutting: reasonable accuracy should be exercised to ensure that the cut is square to the axis of the pipe and all burrs must be removed from the cut end before making a joint.

5.3 Handling and storage

While PVC-U pipes are light and easy to handle, careless handling can cause unnecessary damage. Pipes and fittings should not be dropped or thrown onto hard surfaces or allowed to come into contact with sharp objects that could inflict deep scratches. PVC-U pipes should not be allowed to slide across sharp edges.

PVC-U is subject to distortion under high loads, particularly at elevated temperatures, and also to bowing due to uneven heating; stacks should therefore be protected from direct sunlight, or other heat source, if stored for extended periods.

Temporary storage in the field, where racks are not provided, can be in stacks on the ground, providing this surface is level and free from loose stones or other sharp projections.
Socketed pipes should be stacked in layers with sockets placed at alternative ends of the rack, and protruding, to avoid uneven stacks and distortion. The sockets should not be load bearing.

If mechanical handling equipment such as fork lifts or cranes are to be used on bundles, adequate spreader and lifting bars should be provided. Wire slings must be kept clear of the pipes.

Racks for long term storage are recommended and should preferably provide continuous support, but if this is not possible then supports of at least 75mm bearing widths at 1m centres (max) should be placed beneath the pipes. Side restraints should be placed at centres not exceeding 1.5m and stacks should not exceed 1m in height.

When unloading alongside dug trenches, it is recommended that pipes be placed on the opposite side of the trench from excavated material.

Rubber rings, lubricant, solvent cement and priming fluid should be stored under cover until pipelaying commences.

5.4 Trenching

Trenches should be excavated in accordance with plans and specifications. They should be as narrow as practicable at the level of the top of the pipe and, in a straight trench, have a bed width not less than 200mm wider than the pipe diameter, to provide working space for the laying crew.
5.4.1 Stable conditions

Stable conditions are those where, after excavation, the trench walls remain solid and do not show any signs of collapse or cave-in. Under such conditions the recommended trench widths are shown in the following table:

<table>
<thead>
<tr>
<th>Pipe Diameter (mm)</th>
<th>Normal Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>150 - 200</td>
<td>600</td>
</tr>
<tr>
<td>225 - 300</td>
<td>750</td>
</tr>
<tr>
<td>375</td>
<td>900</td>
</tr>
</tbody>
</table>

5.4.2 Unstable conditions

Unstable conditions are those where, during or after excavation, the trench walls tend to collapse and cave-in. Under these conditions, in open or unrestricted areas, the top of the trench can be widened until stability is reached. A smaller trench should then be dug in the bottom of the excavation to contain the pipe as shown. In areas where space is limited, e.g. in streets, it may be necessary to support trench walls by timber or other suitable shoring.
5.4.3 Trench depths

The minimum trench depth should be such that pressures created by the weight of fill material plus anticipated traffic or other superimposed loads will not damage the pipes. As a guide the recommended minimum clear cover above is listed below:

- Where no subject to vehicular loading: 300mm
- Where subject to vehicular loading:
  - Under driveways: 450mm
  - In sealed roadways: 600mm
  - In unsealed roadways: 750mm

5.5 Laying and Compaction

5.5.1 Preparing the trench

The trench bottom should be as level as possible, so that the barrel of the pipe is fully supported along its whole length. In good working conditions, sandy or loamy soil, the trench bottom can be made sufficiently even with stones and rocks removed to provide continuous support for the pipes without the need of under-bedding.

5.5.2 Wet conditions

In wet ground, sloppy working conditions can be alleviated by first placing a layer of hard granular material, or by de-watering the area in and around the trench. If patches of ground are so wet that there is a risk of subsidence and possible damage to sections of the pipeline, these areas should be consolidated by the addition of suitable fill material.

5.5.3 Trench installation

The trench should be excavated deeply enough to allow for the specified grade, the required depth of bedding, and the minimum cover over the pipe.

The figure below suggests the following typical installation in a trench.

The following materials are suitable for bedding and overlay in the trench:
a. Suitable sand, free from rock or other hard or sharp objects.

b. Crushed rock or gravel of approved grading up to a maximum size of 14mm

c. The excavated material, if it is free from rock or hard matter and broken up so that it contains no soil lumps having any dimension greater than 75mm which would prevent adequate compaction of the bedding.

d. Cement mortar, containing one part of cement and four parts of sand by volume, mixed with clean water to a workable consistency (bedding only).

5.6 Completing sitework

Once the pipe is laid in the trench backfilling can commence. Two distinct phases are involved with pipelines:

a. backfilling prior to testing the pipeline

b. backfilling after testing the pipeline

Backfilling usually follows pipe installation as closely as possible in order to protect the pipe from external damage, to eliminate the possibility of the pipe floating due to flooding of open trenches, and to avoid shifting the pipe out of line due to cave-in.

It should be remembered that the purpose of backfilling is not only to protect the pipe by covering it, but to provide firm continuous support under the pipe. Where concrete or mortar bedding has been used, however, the bedding must have obtained its required strength prior to backfilling.

5.7 Initial backfilling

The first step in providing firm continuous support for the pipeline is to tamp soil solidly under the entire barrel of the pipe, care being taken not to disturb the grade.

This backfilling material should be free from stones, rock or clay. When this is not available other suitable material e.g. loamy earth or sand, should be taken to the site. The initial backfill should be placed by hand-shovel in layers not exceeding 100mm deep. Each layer should be well tamped round and under the pipeline using the long tamper illustrated. In this way air pockets are eliminated from beneath the pipe.

The layers should be shovelled in and tamped, the process being repeated until the pipe is firmly bedded. The flat tamper illustrated is used to consolidate this fill to heights of 300mm above the top of the pipe for diameters up to 300mm.
The illustrations A and B below show the wrong and right ways of tamping the initial backfill.

In case A, too much soil is present and the tamping bar cannot compact it properly leaving a void underneath the pipe.

Case B, shows the correct fill of a 100mm layer of soil which can be compacted to form a firm bed for the pipe.

Pipe joints should be temporarily left exposed when placing the initial backfill, to enable pressure tests to be carried out. After testing the line, backfilling and final filling may be completed.
5.8 Assembly of pipelines

PVC-U pipelines are easy to assemble. The rubber ring is preinstalled in the socket groove to facilitate jointing and avoid using the wrong rubber ring profile. While Paling rubber ring jointed pipes can be fully assembled above the trench, care must be taken to ensure joints do not pull apart during lowering into the trench and all joints must subsequently be inspected.

Lubricant should be used when jointing pipes to ease the insertion of spigot and is supplied together with pipes.

5.8.1 Rubber Ring Jointing Instructions

The rubber ring joint should be assembled as recommended by the pipe manufacturer.

When the rings are colour coded, be sure to consult the pipe manufacturer or his literature for the significance. In all cases, clean the ring, the socket or the coupling interior, especially the groove area (except when the ring is permanently installed) and the spigot area with a rag, brush or paper towel to remove any dirt or foreign material before assembling. Inspect the ring, pipe spigot chamber, ring groove and sealing surfaces for damages or deformation. Use only rings which are designed for and supplied with the pipe. Insert them as recommended by the manufacturer.

Lubricant should be applied as specified by the pipe manufacturer. Bacterial growth, damage to gaskets or the pipe, may result from the use of non-approved lubricants. Use only the lubricant supplied by the pipe manufacturer.
6. Testing Pipelines

Modern construction practice is to adopt some rigorous form of acceptance test on newly constructed sewer lines. It is usual for two separate tests to be made: one prior to backfilling and another towards the end of the job when backfilling has been completed and settled, and manholes and sidelines constructed.

The purpose of testing a non-pressure pipeline is to ensure that the line has been correctly laid to line and grade, will flow satisfactorily and is sealed at each joint and fitting.

In the case of a sewer pipeline system, three distinct areas require testing.

1. The sewer rising mains
2. The gravity pipeline sections
3. The gravity reticulation sections

The first is a pressure pipeline and should be tested accordingly. The latter two require testing for which recommended practices follow.

6.1 Preparing for the test

During the installation careful checking and adequate supervision will ensure that sewer lines are laid to line and grade. If an installation specification exists it should be followed. Otherwise the pipeline section to be tested should be backfilled leaving all couplings and fittings exposed for inspection during testing. In solvent weld PVC-U jointed non-pressure pipelines, at least 24 hours should have elapsed since the last joint was made before testing commences.

6.2 Test procedures

Two types of testing are in current use - hydrostatic testing and air testing. The choice of the type of test, its duration and test pressures required depend on the requirements of the authority concerned and may also be governed by the availability of water on the site, but in general hydrostatic testing is recommended.

6.3 Hydrostatic testing

The single opening at the top of the test section should be fitted with a special test plug. The test plug should have two entries; an upper one connected to a calibrated container capable of supplying make-up water when filled, and a lower entry connected to a water supply.

The pipeline should be filled with water allowing air to escape through the upper entry in the test plug via the calibrated container.

Unless otherwise specified by the client or relevant Government Authority, the following figures are recommended.

When pipeline is full, using the calibrated container raise the pipeline pressure to between 2m and 3m above the natural surface at the top of the test section. Allow the pipeline time to settle during which period make-up water should be added. This period should be a minimum of 24 hours.

During a subsequent one hour test the water loss measured by the drop in water level should not exceed 0.55 litres per 10mm internal diameter per 100 metres of pipe length. During the test all joints should be inspected.

Should the pipeline fail to pass the test it must be further examined to locate the leak, then drained, repaired and retested.
6.3.1 Volume of water required to fill the pipeline

The following table guides as to how much water is required to fill up the test section of pipeline. However, slight variation from the tabulated figure should be expected due to change in pressure and temperature.

<table>
<thead>
<tr>
<th>Size, mm</th>
<th>Volume, liter/meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>8.4</td>
</tr>
<tr>
<td>160</td>
<td>18.1</td>
</tr>
<tr>
<td>250</td>
<td>44.4</td>
</tr>
<tr>
<td>315</td>
<td>70.5</td>
</tr>
</tbody>
</table>

6.3.2 Make-up water

Make-up water will generally be necessary to obtain a satisfactory test, because of entrapped and entrained air etc., even if the pipeline is laid with the best of care under favourable conditions.

6.4 Low pressure air testing

The methods and test procedures outlined in any installation specification should be followed. If no such specification exists the following test procedures of AS2032 are recommended for air testing of a sewer pipeline section.

The pipeline should be sealed in the manner described for hydrostatic testing, but incorporating an air pressure gauge. Air should be introduced slowly by a suitable means until a pressure of 50 kPa is obtained.

The pressure should then be maintained for a period of at least 3 minutes. Should no leaks be apparent at the end of 3 minutes, the air supply should be shut off and provided the air contained in the pipes under test does not fall below 35 kPa within 50 seconds, the pipeline may be considered satisfactory. If however, the pressure is not maintained within these specified limits, the air should be reintroduced and the pipeline examined for leaks using a concentrated solution of soft soap and water over the joints and fittings. When the source of the leak has been detected and repaired the pipeline should be retested.

6.5 Completing final backfill

After testing of the pipeline, selected material should be hand shovelled over each exposed joint and tamped to give 300mm minimum cover. Final backfilling to ground level can be completed by hand or machine, using the soil originally excavated from the trench. Care should be taken to exclude large rocks and stones from the final backfill.

Responsibility lies solely with the user to ensure the currency and validity of information or advice contained herein in the context of his circumstances. It is recommended that advice be obtained from a Registered Consultant.

No warranty is expressed or implied as to the content of the information or results obtained by use thereof, and Paling Industries Sdn Bhd will not be held liable for any costs, direct or indirect, that may arise therefrom.