An Introduction to Drainage Pipe
Strength, Cover and Bedding

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1. **INTRODUCTION.** A drainage pipe is defined as a structure (other than a bridge) to convey water through a trench or under a fill or some other obstruction. Materials for permanent-type installations include non-reinforced concrete, reinforced concrete, corrugated steel, asbestos-cement, clay, corrugated aluminum alloy, and structural plate steel pipe.

2. **SELECTION OF TYPE OF PIPE.**

   a. The selection of a suitable construction conduit will be governed by the availability and suitability of pipe materials for local conditions with due consideration of economic factors. It is desirable to permit alternates so that bids can be received with contractor’s options for the different types of pipe suitable for a specific installation. Allowing alternates serves as a means of securing bidding competition. When alternate designs are advantageous, each system will be economically designed, taking advantage of full capacity, best slope, least depth, and proper strength and installation provisions for each material involved. Where field conditions dictate the use of one pipe material in preference to others, the reasons will be clearly presented in the design analysis.

   b. Several factors should be considered in selecting the type of pipe to be used in construction. The factors include strength under either maximum or minimum cover being provided, pipe bedding and backfill conditions, anticipated loadings, length of pipe sections, ease of installation, resistance to corrosive action by liquids carried or surrounding soil materials, suitability of jointing methods, provisions for expected deflection without adverse effect on the pipe structure or on the joints or overlying materials, and cost of maintenance. Although it is possible to obtain an acceptable pipe installation to meet design requirements by establishing special provisions for several possible materials, ordinarily only one or two alternates will economically meet the individual requirements for a proposed drainage system.
3. SELECTION OF N VALUES. A designer is continually confronted with what coefficient of roughness n to use in a given situation. The question of whether n should be based on the new and ideal condition of a pipe or on anticipated condition at a later date is difficult to answer. Sedimentation or paved pipe can affect the coefficient of roughness. Tables available in the technical literature give the n values for smooth interior pipe of any size, shape or type and for annular and helical corrugated metal pipe both unpaved and 25 percent paved. When n values other than those listed are selected, such values will be amply justified in the design analysis.

4. RESTRICTED USE OF BITUMINOUS-COATED PIPE. Corrugated-metal pipe with any percentage of bituminous coating will not be installed where solvents can be expected to enter the pipe. Polymeric coated corrugated steel pipe is recommended where solvents might be expected.

5. MINIMUM COVER.

a. In the design and construction of the drainage system it will be necessary to consider both minimum and maximum earth cover allowable on the underground conduits to be placed under both flexible and rigid pavements. Underground conduits are subject to two principal types of loads: dead loads (DL) caused by embankment or trench backfill plus superimposed stationary surface loads, uniform or concentrated; and live or moving loads (LL), including impact. Live loads assume increasing importance with decreasing fill height.

b. AASHTO Standard Specifications for Highway Bridges should be used for all H–20 Highway Loading Analyses. AREA Manual for Railway Engineering should be used for all Cooper’s E 80 Railway Loadings. Appropriate pipe manufacturer design manuals should be used for maximum cover analyses.
c. Drainage systems should be designed in order to provide an ultimate capacity sufficient to serve the planned installation. Addition to, or replacement of, drainage lines following initial construction is costly.

d. Investigations of in-place drainage and erosion control facilities at a number of installations were made during the period 1966 to 1972. The facilities observed varied from one to more than 30 years of age. The study revealed that buried conduits and associated storm drainage facilities installed from the early 1940’s until the mid-1960’s appeared to be in good to excellent structural condition. However, many reported failures of buried conduits occurred during construction. Therefore, it should be noted that minimum conduit cover requirements are not always adequate during construction. When construction equipment, which may be heavier than live loads for which the conduit has been designed, is operated over or near an already inplace underground conduit, it is the responsibility of the contractor to provide any additional cover during construction to avoid damage to the conduit. Major improvements in the design and construction of buried conduits in the two decades mentioned include, among other items, increased strength of buried pipes and conduits, increased compaction requirements, and revised minimum cover tables.

e. The necessary minimum cover in certain instances may determine pipe grades. A safe minimum cover design requires consideration of a number of factors including selection of conduit material, construction conditions and specifications, selection of pavement design, selection of backfill material and compaction, and the method of bedding underground conduits. Emphasis on these factors must be carried from the design stage through the development of final plans and specifications.

f. Tables 1 through 6 identify certain suggested cover requirements for storm drains and culverts which should be considered as guidelines only. Cover requirements have been formulated for asbestos-cement pipe, reinforced and non-reinforced concrete pipe, corrugated-aluminum-alloy pipe, corrugated-steel pipe, structural-plate-aluminum-alloy pipe, and structural-plate-steel pipe. The different sizes and materials
of conduit and pipe have been selected to allow the reader an appreciation for the many and varied items which are commercially available for construction purposes. The cover depths listed are suggested only for average bedding and backfill conditions. Deviations from average conditions may result in significant minimum cover requirements and separate cover analyses must be made in each instance of a deviation from average conditions. Specific bedding, backfill and trench widths may be required in certain locations; each condition deviating from the average condition should be analyzed separately. Where warranted by design analysis the suggested maximum cover may be exceeded.
Table 1
Suggested maximum cover requirements for asbestos cement pipe H-20 highway loading

<table>
<thead>
<tr>
<th>Diameter in.</th>
<th>Suggested Maximum Cover Above Top of Pipe, ft</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1500</td>
</tr>
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<td>12</td>
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<td>42</td>
<td>11</td>
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</table>

U.S. Army Corps of Engineers

Notes:
1. The suggested values shown are for average conditions and are to be considered as guidelines only for dead load plus H-20 live load.
2. Soil conditions, trench width and bedding conditions vary widely throughout varying climatic and geographical areas.
3. Calculations to determine maximum cover should be made for all individual pipe and culvert installations underlying roads, streets and open storage areas subject to H-20 live loads. Cooper E-80, railway loadings should be independently made.
4. Cover depths are measured from the bottom of the subbase of pavements, or the top of unsurfaced areas, to top of pipe.
5. Calculations to determine maximum cover for Cooper E-80 railway loadings are measured from the bottom of the tie to the top of the pipe.
6. The number in the class designation for asbestos-cement pipe is the minimum 3-edge test load to produce failure in pounds per linear foot. It is independent of pipe diameter. An equivalent to the D-load can be obtained by dividing the number in the class designation by the internal pipe diameter in feet.
7. If pipe produced by a manufacturer exceeds the strength requirements established by indicated standards then cover depths may be adjusted accordingly.
8. See table C-9 for suggested minimum cover requirements.
Table 2
Suggested maximum cover requirements for concrete pipe, reinforced concrete, H-20 highway loading

6. CLASSES OF BEDDING AND INSTALLATION. Figures 1 through 5 indicate the classes of bedding for conduits. Figure 6 is a schematic representation of the subdivision of classes of conduit installation which influences loads on underground conduits.
Table 3
Suggested maximum cover requirements for corrugated aluminum alloy pipe, riveted, helical or welded, fabrication 2-2/3 inch spacing, ½ inch deep corrugations, H-20 highway loading

7. STRENGTH OF PIPE. Pipe shall be considered of ample strength when it meets the conditions specified for the loads indicated in tables 1 through 8. When railway or vehicular wheel loads or loads due to heavy construction equipment (live loads, LL) impose heavier loads, or when the earth (or dead loads, DL) vary materially from those normally encountered, these tables cannot be used for pipe installation design and separate analyses must be made. The suggested minimum and maximum cover shown in the tables pertain to pipe installations in which the back fill material is compacted to at least 90 percent of CE55 (MIL-STD-621) or AASHTO-T99 density (100 percent for cohesionless sands and gravels). This does not modify requirements for any greater degree of compaction specified for other reasons. It is emphasized that proper bedding, backfilling, compaction, and prevention of infiltration of backfill.
material into pipe are important not only to the pipe, but also to protect overlying and nearby structures. When in doubt about minimum and maximum cover for local conditions, a separate cover analysis must be performed.

8. RIGID PIPE. Tables 1 and 2 indicate maximum and minimum cover for trench conduits employing asbestos-cement pipe and concrete pipe. If positive projecting conduits are employed they are those which are installed in shallow bedding with a part of the conduit projecting above the surface of the natural ground and then covered with an embankment. Due allowance will be made in amounts of minimum and maximum cover for positive projecting conduits. Table 9 suggests guidelines for minimum cover to protect the pipe during construction and the minimum finished height of cover.

9. FLEXIBLE PIPE. Suggested maximum cover for trench and positive projecting conduits are indicated in tables 3 through 6 for corrugated aluminum-alloy pipe, corrugated-steel pipe, structural-plate-aluminum-alloy pipe, and structural plate-steel pipe. Conditions other than those stated in the tables, particularly other loading conditions will be compensated for as necessary. For unusual installation conditions, a detailed analysis will be made so that ample safeguards for the pipe will be provided with regard to strength and resistance to deflection due to loads. Determinations for deflections of flexible pipe should be made if necessary. For heavy live loads and heavy loads due to considerable depth of cover, it is desirable that a selected material, preferably bank-run gravel or crushed stone where economically available, be used for backfill adjacent to the pipe. Table 9 suggests guidelines for minimum cover to protect the pipe during construction and the minimum finished height of cover.

10. BEDDING OF PIPE (CULVERTS AND STORM DRAINS). The contact between a pipe and the foundation on which it rests is the pipe bedding. It has an important influence on the supporting strength of the pipe. For drainpipes at military installations, the method of bedding shown in figure 3 is generally satisfactory for both trench and positive projecting (embankment) installations. Some designs standardize and classify
various types of bedding in regard to the shaping of the foundation, use of granular material, use of concrete, and similar special requirements. Although such refinement is not considered necessary, at least for standardized cover requirements, select, fine granular material can be used as an aid in shaping the bedding, particularly where foundation conditions are difficult. Also, where economically available, granular materials can be used to good advantage for backfill adjacent to the pipe. When culverts or storm drains are to be installed in unstable or yielding soils, under great heights of fill, or where pipe will be subjected to very heavy live loads, a method of bedding can be used in which the pipe is set in plain or reinforced concrete of suitable thickness extending upward on each side of the pipe. In some instances, the pipe may be totally encased in concrete or concrete may be placed along the side and over the top of the pipe (top or arch encasement) after proper bedding and partial backfilling. Pipe manufacturers will be helpful in recommending type and specific requirements for encased, partially encased, or specially reinforced pipe in connection with design for complex conditions.
Table 4
Suggested maximum cover requirements for corrugated steel pipe, 2-2/3 inch spacing, ½ inch deep corrugations, H-20 highway loading
### Table 5
Suggested Maximum Cover Requirements for Structural-Plate-Aluminum-Alloy Pipe, 9-Inch Spacing, 2 1/2-Inch Corrugations

**H–20 Highway Loading**

<table>
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<tr>
<th>Diameter, in.</th>
<th>0.10</th>
<th>0.125</th>
<th>0.15</th>
<th>0.175</th>
<th>0.20</th>
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**Notes:**
2. Soil conditions, trench width and bedding conditions vary widely throughout varying climatic and geographical areas.
3. Calculations to determine maximum cover should be made for all individual pipe and culvert installations underlying roads, streets and open storage areas subject to H–20 live loads. Cooper E–80 railway loadings should be independently made.
4. Cover depths are measured from the bottom of the subbase of pavements, or the top of unsurfaced areas, to top of pipe.
5. Calculations to determine maximum cover for Cooper E–80 railway loadings are measured from the bottom of the tie to the top of the pipe.
6. The number in the class designation for asbestos-cement pipe is the minimum 3-edge test load to produce failure in pounds per linear foot. It is independent of pipe diameter. An equivalent to the D load can be obtained by dividing the number in the class designation by the internal pipe diameter in feet.
7. If pipe produced by a manufacturer exceeds the strength requirements established by indicated standards then cover depths may be adjusted accordingly.
8. See table C–9 for suggested minimum cover requirements.
Table 6
Suggested Maximum Cover Requirements for Corrugated Steel Pipe, 125-mm Span, 25-mm Deep Corrugations
H–20 Highway Loading

<table>
<thead>
<tr>
<th>Diameter, inches</th>
<th>.064</th>
<th>.079</th>
<th>.100</th>
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Figure 1
Three main classes of conduits
Figure 2
Free-body conduit diagrams
Figure 3

Embankment Beddings Circular Pipe
Figure 4
Trench Beddings for Circular Pipe
Figure X
Figure 6
Installation conditions which influence loads on underground conduits
Figure Y

Beddings for positive projecting conduits
Figure Z

Flexible pipe bedding and installation
### Table 7

Suggested Maximum Cover Requirements for Structural Plate Steel Pipe, 6-Inch Span, 2-Inch Deep Corrugations
NOTES
2. The suggested maximum heights of cover shown in the table are calculated on the basis of the current AASHTO Standard Specifications for Highway Bridges and are based on circular pipe.
3. Soil conditions, trench width and bedding conditions vary widely throughout varying climatic and geographical areas.
4. Calculations to determine maximum cover should be made for all individual pipe and culvert installations underlying roads, streets and open storage areas subject to H–20 live loads. Cooper E–80 railway loadings should be independently made.
5. Cover depths are measured from the bottom of the subbase of pavements, or the top of unsurfaced areas, to top of pipe.
6. Calculations to determine maximum cover for Cooper E-80 railway loadings are measured from the bottom of the tie to the top of the pipe.
7. If pipe produced by a manufacturer exceeds the strength requirements established by indicated standards then cover depths may be adjusted accordingly.
8. See table 9 for suggested minimum cover requirements.
Table 8

Suggested Maximum Cover Requirements for Corrugated Steel Pipe, 3-Inch Span, 1-Inch Corrugations, H-20 Highway Loading

NOTES:
1. Corrugated steel pipe will conform to there requirements of Federal Specification WW-P-405.
2. The suggested maximum heights of cover shown in the table are calculated on the basis of the current AASHTO Standard Specifications for Highway Bridges and are based on circular pipe.
3. Soil conditions, trench width and bedding conditions vary widely throughout varying climatic and geographical areas.
4. Calculations to determine maximum cover should be made for all individual pipe and culvert installations underlying roads, streets and open storage areas subject to H-20 live loads. Cooper E-80 railway loadings should be independently made.
5. Cover depths are measured from the bottom of the subbase of pavements, or the top of unsurfaced areas, to top of pipe.
6. Calculations to determine maximum cover for Cooper E-80 railway loadings are measured from the bottom of the tie to the top of the pipe.
7. If pipe produced by a manufacturer exceeds the strength requirements established by indicated standards then cover depths may be adjusted accordingly.
8. See table 9 for suggested minimum cover requirements.
### Table 9

#### Suggested Guidelines for Minimum Cover

**H-20 Highway Loading**

<table>
<thead>
<tr>
<th>Pipe Diameter, in.</th>
<th>Height of Cover During Construction, ft.</th>
<th>Minimum Finished Height of Cover (From Bottom of Subbase, to Top of Pipe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos-Cement Pipe</td>
<td>12&quot; to 42&quot; Diameter/2 or 3.0' whichever is greater</td>
<td>Diameter/2 or 2.0' whichever is greater</td>
</tr>
<tr>
<td>Concrete Pipe Reinforced</td>
<td>12&quot; to 108&quot; Diameter/2 or 3.0' whichever is greater</td>
<td>Diameter/2 or 2.0' whichever is greater</td>
</tr>
<tr>
<td>Non-Reinforced</td>
<td>11&quot; to 36&quot; Diameter/2 or 3.0' whichever is greater</td>
<td>Diameter/2 or 3.0' whichever is greater</td>
</tr>
<tr>
<td>Corrugated Aluminum Pipe 2-2/3&quot; x 1/2&quot;</td>
<td>12&quot; to 24&quot; Diameter 30&quot; and over 1.5' Diameter</td>
<td>Diameter/2 or 1.0' whichever is greater Diameter/2</td>
</tr>
<tr>
<td>Corrugated Steel Pipe 3&quot; x 1&quot;</td>
<td>12&quot; to 36&quot; Diameter 36&quot; and over 1.5' Diameter</td>
<td>Diameter/2 or 1.0' whichever is greater Diameter/2</td>
</tr>
<tr>
<td>Structural Plate Aluminum Alloy Pipe 9&quot; x 2-1/2&quot;</td>
<td>72&quot; and over Diameter/2</td>
<td>Diameter/4</td>
</tr>
<tr>
<td>Structural Plate Steel 6&quot; x 2&quot;</td>
<td>60&quot; and over Diameter/2</td>
<td>Diameter/4</td>
</tr>
</tbody>
</table>

**NOTES:**

1. All values shown above are for average conditions and are to be considered as guidelines only.
2. Calculations should be made for minimum cover for all individual pipe installations for pipe underlying roads, streets and open storage areas subject to H–20 live loads.
3. Calculations for minimum cover for all individual pipe installations should be separately made for all Cooper E–80 railroad live loading.
4. In seasonal frost areas, minimum pipe cover must meet requirements of table 2–3 of TM 5–820-3 for protection of storm drains.
5. Pipe placed under rigid pavement will have minimum cover from the bottom of the subbase to top of pipe of 1.0 ft. For pipe up to 60 inches and greater than 1.0 ft. for sizes above 60 inches if calculations so indicate.
6. Trench widths depend upon varying conditions of construction but maybe as wide as is consistent with space required to install the pipe and as deep as can be managed from practical construction methods.
7. Non-reinforced concrete pipe is available in sizes up to 36 inches.
8. See tables 1 through 8 for suggested maximum cover requirements.