CHAPTER 2
DRAINAGE PIPE

2-1. General.

A drainage pipe is a structure (other than a bridge) used to convey water through or under a runway fill or some other obstruction. Materials for permanent-type installations include plain or nonreinforced concrete, reinforced concrete, corrugated steel, asbestos cement, and day and aluminum corrugated pipe.

2-2. 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 designed economically, 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. Factors which should be considered in selecting the type of pipe include strength under maximum or minimum cover, bedding and backfill conditions, anticipated loadings, length of sections, ease of installation, corrosive action by liquids carried or surrounding soil, jointing methods, expected deflection, 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.

2-3. Selection of n values.

Whether the coefficient of roughness, n , should be based on the new and ideal condition of a pipe or on anticipated condition at a later date is a difficult problem. Sedimentation or paving in a pipe will affect the coefficient of roughness. Table 2-1 gives 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.

Table 2-1. Roughness coefficients for various pipes.

n = 0.012 for smooth interior pipes of any size, shape, or type*

n value for annular corrugated metal

Corrugation size	Unpaved	25% Paved
2 + 2/3 by 1/2 inch	0.024	0.021
3 by 1 inch	0.027	0.023
6 by 2 inch	0.028-0.033	0.024-0.028
9 by 2 + 1/2 inch	0.033	0.028

n values for helical corrugated metal (2 + 2/3 by 1/2 inch corrugations)

Pipe diameter	Unpaved	25% Paved
12-18 inches	0.011-0.014	X
24-30 inches	0.016-0.018	0.015-0.016
36-96 inches	0.019-0.024	0.017-0.021

* Includes asbestos cement, plastic, cast iron, clay, concrete (precast or cast-in-place) or fully paved corrugated metal pipe.

2-4. Restricted use of bituminous-coated pipe.

The installation of corrugated-metal pipe with any percentage of bituminous coating should be restricted where fuel spillage, wash rack waste, and/or solvents can be expected to enter the pipe.

2-5. Minimum and maximum cover.

a. Heliport and airport layout will typically include underground conduits which pass under runways, taxiways, aprons, helipads, and other hardstands. In the design and construction of the drainage system it will be necessary to consider both minimum and maximum earth cover allowable in the underground conduits to be placed under both flexible and rigid pavements as well as beneath unsurfaced airfields and medium-duty landing-mat-surfaced fields. Underground conduits are subject to two principal types of loads: dead loads caused by embankment or trench backfill plus superimposed stationary surface loads, uniform or concentrated; and live or moving loads, including impact.

b. Drainage systems should be designed to provide the greatest possible capacity to serve the planned pavement configuration. Additions to or replacements of drainage lines following initial construction are both costly and disrupting to aircraft traffic.

c. Investigations of in-place drainage and erosion control facilities at military installations were made during the period 1966 to 1972. The facilities observed varied from 1 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 failures of buried conduits were reported 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 in-place underground conduit, it is the contractor's responsibility to provide any additional cover during construction to avoid damage to the conduit.

d. Since 1940 gross aircraft weight has increased twenty-fold, from 35,000 pounds to approximately 700,000 pounds. The increases in aircraft weight have had a significant effect on design criteria, construction procedures, and material used in the manufacture and construction of buried conduits. Major improvements in the design and construction of buried conduits in the 2 decades mentioned include among other items increased strength of buried pipes and conduits, increased compaction requirements, and revised minimum and maximum cover tables.

e. For minimum and maximum cover design, H-20, 15-K, F-15, C-5A, C-141, C-130, B-I and B-52 live loads and 120 pounds per cubic foot backfill have been considered. Cover heights for flexible pipes and reinforced concrete pipes were based on an analysis of output (Juang and Lee 1987) from the CANDE computer program (FHWA-RD-77-5, FHWA-RD-77-6, FHWA-RD-80-172). Wall crushing, seam separation, wall buckling, formation of a plastic hinge, and excessive deflection, as functions of pipe size and stiffness, backfill conditions, fill height, and live load were considered for flexible pipes. Steel yield and concrete crushing, shear failure and tensile cracking, as functions of pipe size, backfill conditions, full height, concrete strength, steel content, and live load were considered for reinforced concrete pipe. Nonreinforced concrete and vitrified clay pipe design are based on the American Concrete Pipe Association's D-load design procedure based on a 0.01-inch crack.

f. The tables (B-I through B-23) in appendix B identify the recommended minimum and maximum cover requirements for storm drains and culverts. These cover depths are valid for the specified loads and conditions, including average bedding and backfill. Deviations from these loads and conditions significantly affect the allowable maximum and minimum cover, requiring a separate design calculation. Most pipe seams develop the full yield strength of the pipe wall. However, there are some exceptions which occur in standard metal pipe manufacture. To maintain a consistent safety factor of 2.0 for these pipes, the maximum ring compression must be one-half of the seam strength rather than one-half of the wall strength for these pipes. Table 2-2 shows cover height reductions for standard riveted and bolted seams which do not develop a strength equivalent to f_y = 33,000 pounds per square inch. The reduction factors shown are the ratios of seam strength to wall strength. The maximum cover height for pipes with weak seaming as identified in table 2-2 can be determined by multiplying the maximum cover height for a continuously-welded or lock seam pipe (app B) by the reduction factors shown in table 2-2.

Table 2-2. Maximum cover height reduction factors for riveted and bolted seams.

Thickness in.	Gage	5/16 in. Rivets 2-2/3 × 1/2 in. Single	5/16 in. Rivets 2-2/3 × 1/2 in. Double	3/8 in. Rivets 2-2/3 × 1/2 in. Single	3/8 in. Rivets 2-2/3 × 1/2 in. Double	3/8 in. Rivets 3 × 1 in. Double	7/16 in. Rivets 3 × 1 in. Double	3/4 in. Bolts 6 × 2 in. 4 bolts/ft
0.064	16	0.65	0.84			0.98		
0.079	14	0.57	0.93			0.97		
0.109	12			0.52				0.82
0.138	10			0.43	0.85		0.96	0.97
0.168	8			0.36	0.73		0.87	

g. Figures 2-1, 2-2, 2-3, and 2-4 indicate the three main types of rigid conduit burial, the free-body conduit diagrams, trench bedding for circular pipe, and beddings for positive projecting conduits, respectively. Figure 2-5 is a schematic representation of the subdivision of classes of conduit installation which influences loads on underground conduits.

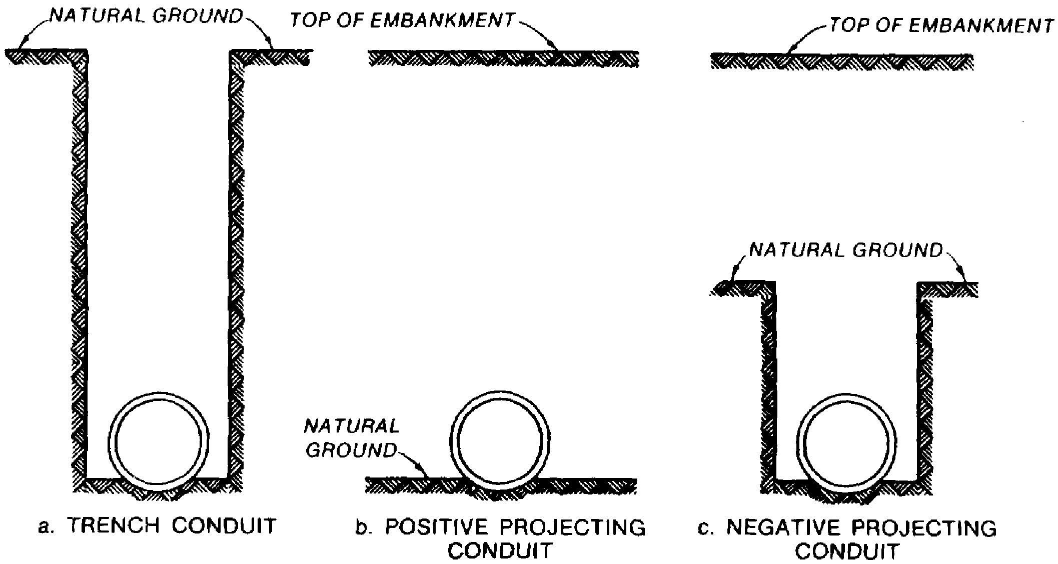


Figure 2-1. Three main classes of conduits.

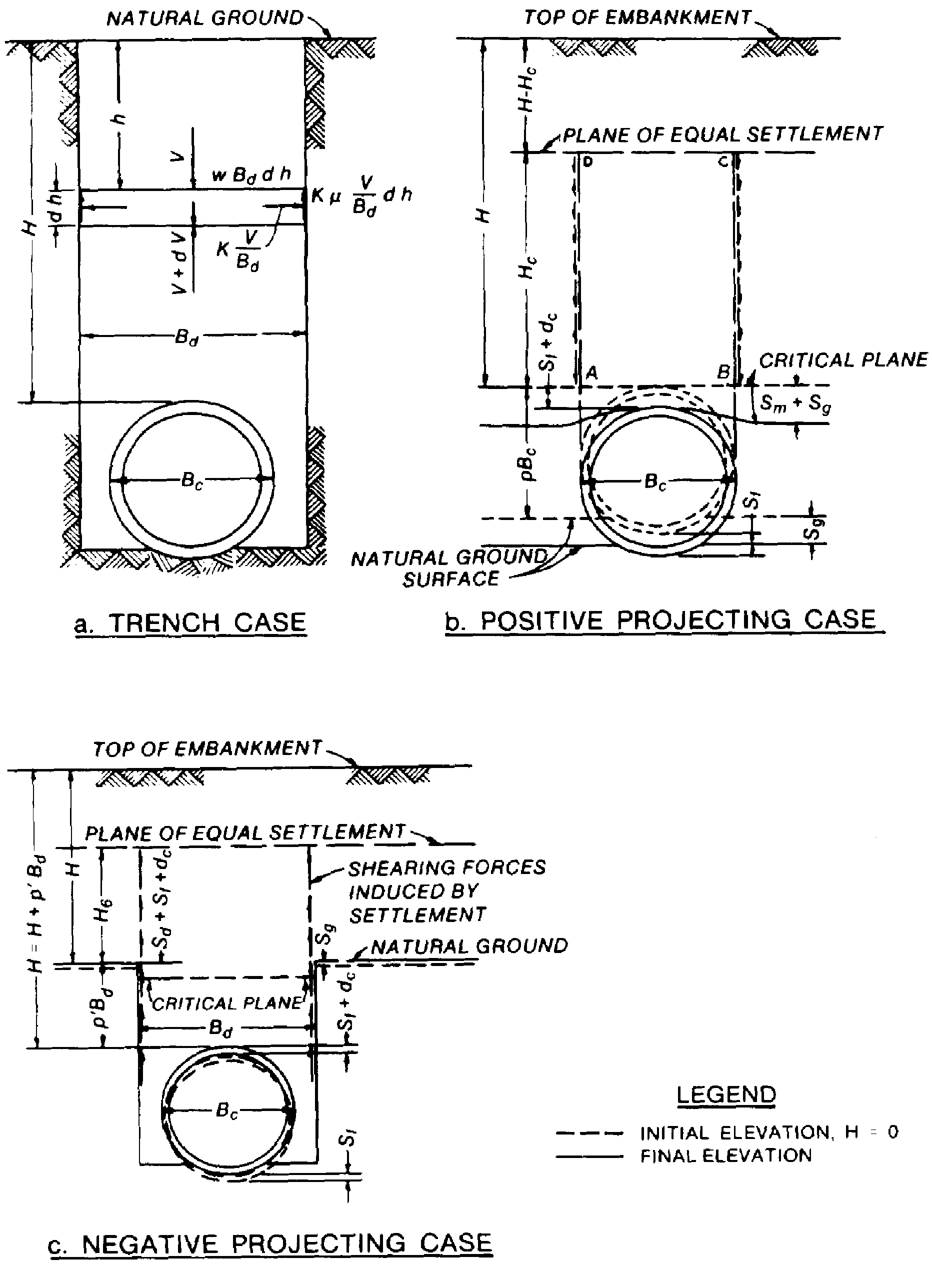
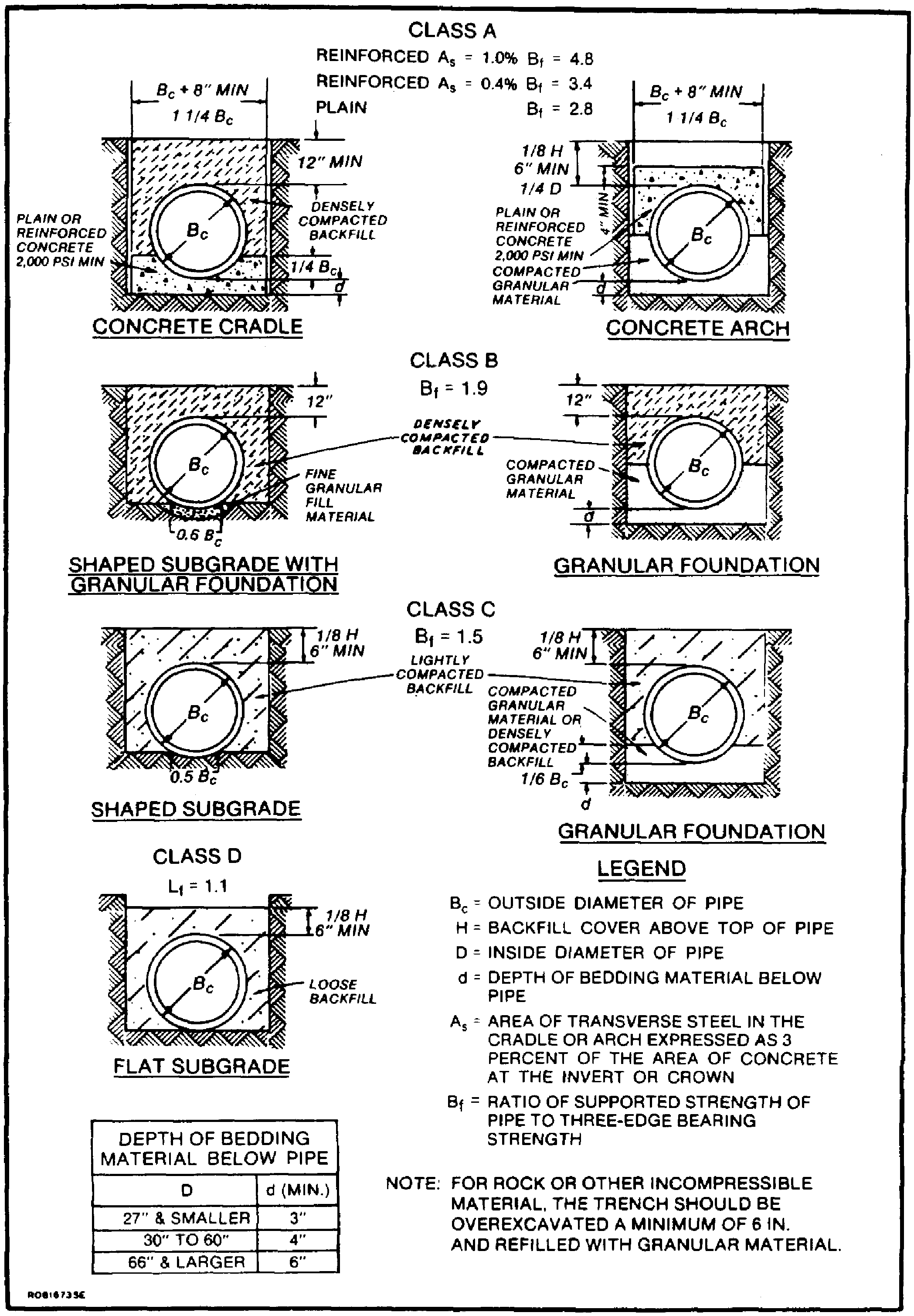


Figure 2-2. Free body conduit diagrams.



DEPTH OF BEDDING MATERIAL BELOW PIPE	
D	d (MIN.)
27" & SMALLER	3"
30" TO 60"	4"
66" & LARGER	6"

Figure 2-3. Trench beddings for circular pipe.

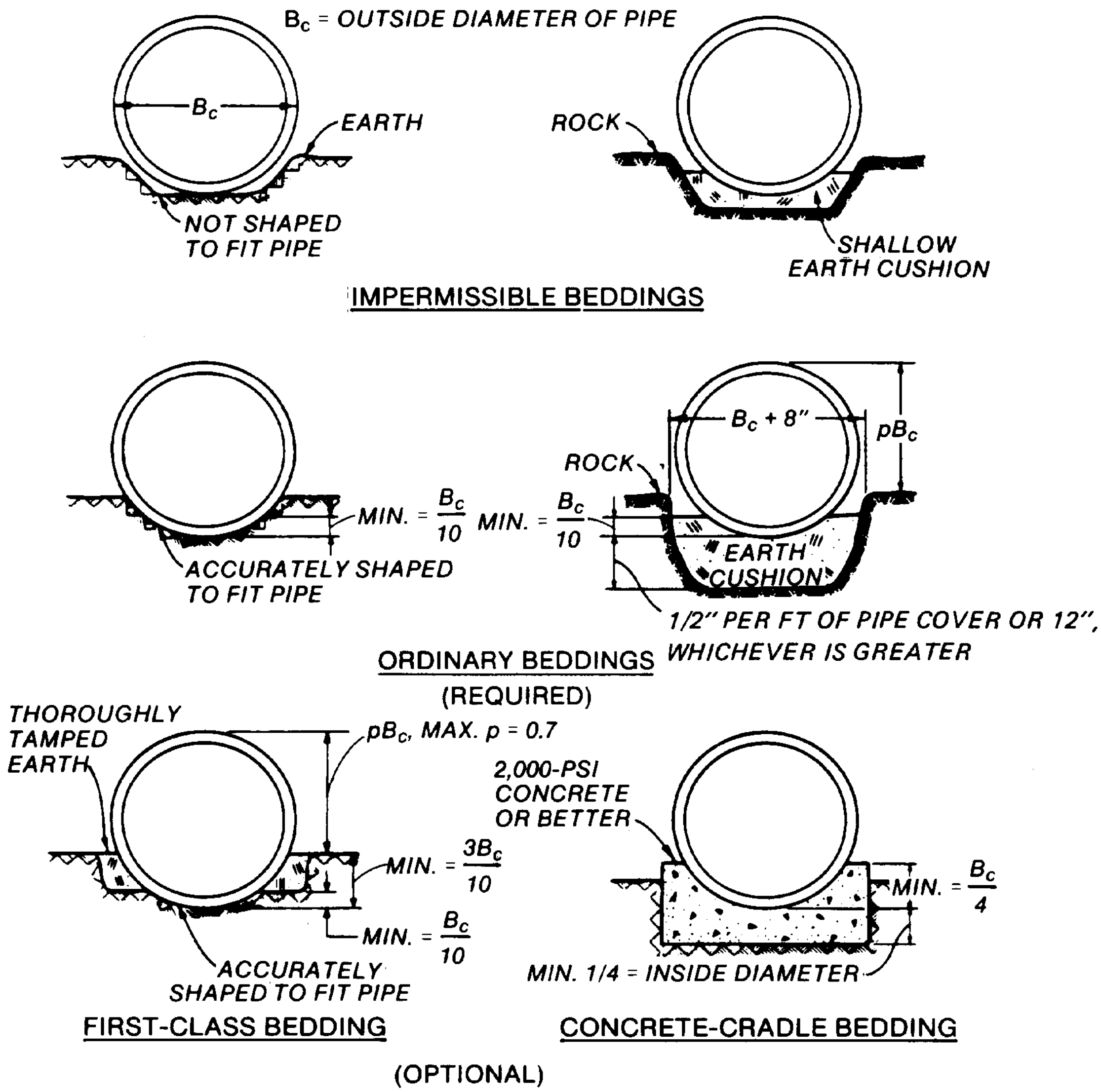


Figure 2-4. Beddings for positive projecting conduits.

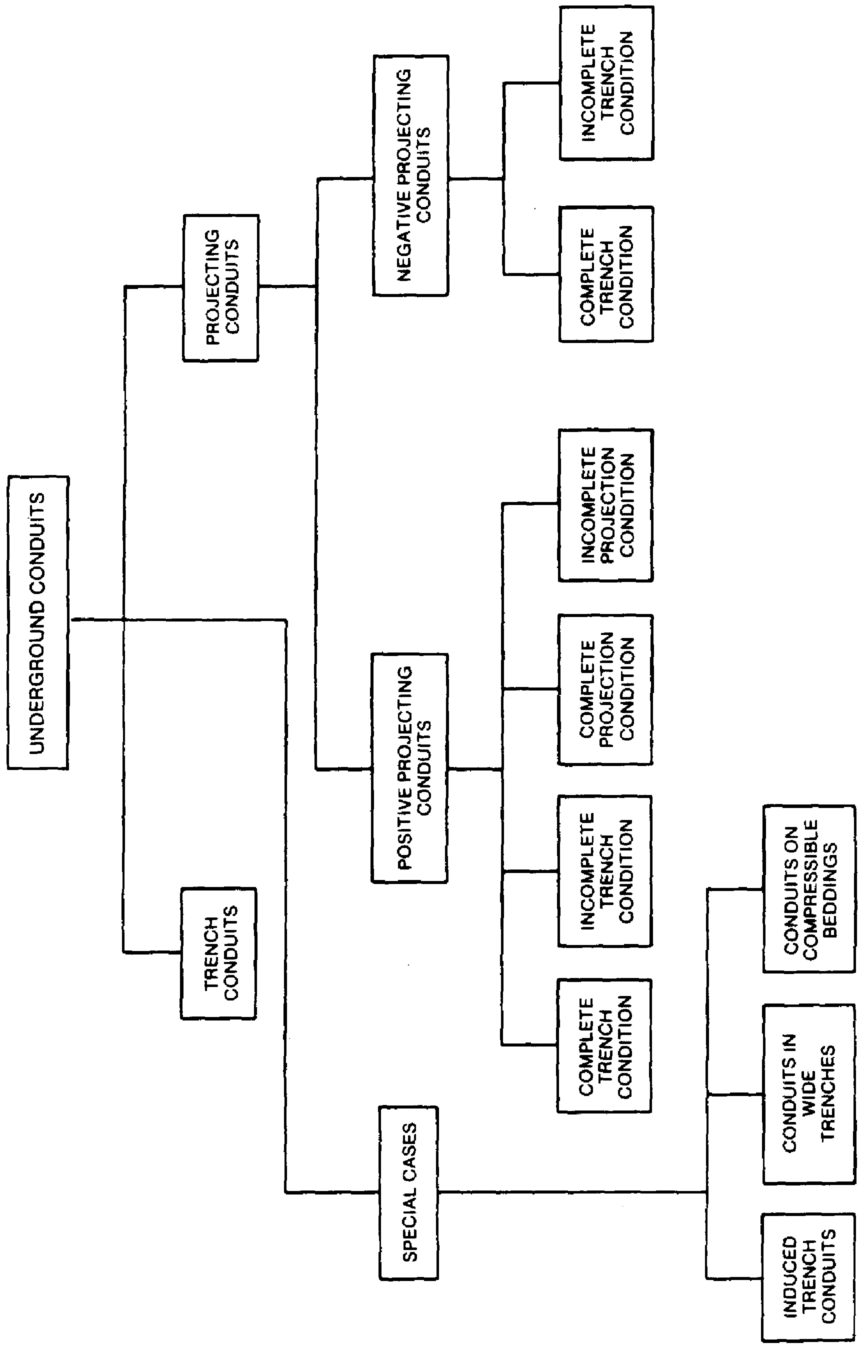


Figure 2-5. Installation conditions which influence loads on underground conduits.

2-6. Frost condition considerations.

The detrimental effects of heaving of frost-susceptible soils around and under storm drains and culverts are principal considerations in the design of drainage systems in seasonal frost areas. In such areas, freezing of water within the drainage system, except icing at inlets, is of secondary importance provided the hydraulic design assures minimum velocity flow.

a. Drains, culverts, and other utilities under pavements on frost-susceptible subgrades are frequently locations of detrimental differential surface heaving. Heaving causes pavement distress and loss of smoothness because of abrupt differences in the rate and magnitude of heave of the frozen materials. Heaving of frost-susceptible soils under drains and culverts can also result in pipe displacement with consequent loss of alignment, joint failures, and in extreme cases, pipe breakage.

Placing drains and culverts beneath pavements should be minimized to the extent possible. When this is unavoidable, the pipes should be installed before the base course is placed in order to obtain maximum uniformity. The practice of excavating through base courses to lay drain pipes and other conduits is unsatisfactory since it is almost impossible to attain uniformity between the compacted trench backfill and the adjacent material.

b. No special measures are required to prevent heave in nonfrost-susceptible subgrades. In frost-susceptible subgrades where the highest ground-water table is 5 feet or more below the maximum depth of frost penetration, the centerline of the pipe should be placed at or below the depth of maximum frost penetration. Where the highest ground-water table is less than 5 feet below the depth of maximum frost penetration and the pipe diameter is 18 inches or more, one of the following measures should be taken:

(1) Place the centerline of the pipe at or below the depth of maximum frost penetration and backfill around the pipe with a highly free-draining nonfrost-susceptible material.

(2) Place the centerline of the pipe one-third diameter below the depth of maximum frost penetration.

c. To prevent water from freezing in the pipe, the invert of the pipe should be placed at or below the depth of maximum frost penetration. In arctic and subarctic areas it may be economically infeasible to provide sufficient depth of cover to prevent freezing of water in subdrains; also, in the arctic, no residual thaw layer may exist between the depth of seasonal frost penetration and the surface of permafrost. Subdrains are of little value in such areas because, unless protected from freezing, they are usually blocked with ice during the spring thawing period. Water freezing in culverts also presents a serious problem in arctic and subarctic regions. The number of such structures should be held to a minimum and should be designed based on twice the normal design capacity. Thawing devices should be provided in all culverts up to 48 inches in diameter. Large diameter culverts are usually cleaned manually immediately prior to the spring thaw. Drainage requirements for arctic and subarctic regions are presented in TM 5-852-7/ AFM 88-19, chapter 7.

d. The following design notes should be considered for installations located in seasonal frost areas.

(1) *Note 1*. Cover requirement for traffic loads will apply when such depth exceeds that necessary for frost protection.

(2) *Note* 2. Sufficient granular backfill will be placed beneath inlets and outlets to restrict frost penetration to nonheaving materials.

(3) *Note* 3. Design of short pipes with exposed ends, such as culverts under roads, will consider local icing experience. If necessary, extra size pipe will be provided to compensate for icing.

(4) *Note 4*. Depth of frost penetration in well-drained, granular, nonfrost-susceptible soil beneath pavements kept free of snow and ice will be determined from data found in figure 3-5 of TM 5-818-2/AFM 88-6, chapter 4. For other soils and/or surface conditions, frost penetrations will be determined by using conservative surface condition assumptions and methods outlined in TM 5-852-6/ AFM 88-19, Volume 6. In all cases, estimates of frost penetration will be based on the design freezing index, which is defined as the average air-freezing index of the three coldest winters in a 30-year period, or the air-freezing index for the coldest winter in the past 10-year period if 30 years of record are unavailable. Further information regarding the determination of the design freezing index is included in TM 5-818-2/AFM 88-6, chapter 4 and TM 5-852-6/AFM 88-19, Volume 6.

(5) *Note 5*. Under traffic areas, and particularly where frost condition pavement design is based on reduced subgrade strength, gradual transitions between frost-susceptible subgrade materials and nonfrost-susceptible trench backfill will be provided within the depth of frost penetration to prevent detrimental differential surface heave.

2-7. Infiltration of fine soils through drainage pipe joints.

a. Infiltration of fine-grained soils into drainage pipelines through joint openings is one of the major causes of ineffective drainage facilities. This is a serious problem along pipes on relatively steep slopes such as those encountered with broken back culverts or stilling wells. Infiltration is not confined to non-cohesive soils. Dispersive soils have a tendency to slake and flow into drainage lines.

b. Infiltration, prevalent when the water table is at or above the pipeline, occurs in joints of rigid pipelines and in joints and seams of flexible pipe, unless these are made watertight. Watertight jointing is especially needed in culverts and storm drains placed on steep slopes to prevent infiltration and/or leakage and piping that normally results in the progressive erosion of the embankments and loss of downstream energy dissipators and pipe sections.

c. Culverts and storm drains placed on steep slopes should be large enough and properly vented so that full pipe flow can never occur, in order to maintain the hydraulic gradient above the pipe invert but below crown of the pipe, thereby reducing the tendency for infiltration of soil and water through joints. Pipes on steep slopes may tend to prime and flow full periodically because of entrance or outlet condition effects until the hydraulic or pressure gradient is lowered enough to cause venting or loss of prime at either the inlet or outlet. The alternating increase and reduction of pressure relative to atmospheric pressure is considered to be a primary cause of severe piping and infiltration. A vertical riser should be provided upstream of or at the change in slope to provide sufficient venting for establishment of partial flow and stabilization of the pressure gradient in the portion of pipe on the steep slope. The riser may also be equipped with an inlet and used simultaneously to collect runoff from a berm or adjacent area.

d. Infiltration of backfill and subgrade material can be controlled by watertight flexible joint materials in rigid pipe and with watertight coupling bands in flexible pipe. Successful flexible watertight joints have been obtained in rigid pipelines with rubber gaskets installed in close-tolerance tongue-and-groove joints and factory-installed plastic gaskets installed on bell-and-spigot pipe. Bell-and-spigot joints caulked with oakum or other similar rope-type caulking materials and sealed with hot-poured joint compound have also been successful. Metal pipe seams may require welding, and the rivet heads may have to be ground to lessen interference with gaskets. There are several kinds of connecting bands which are adequate both hydraulically and structurally for joining corrugated metal pipes on steep slopes.

e. A conclusive infiltration test will be required for each section of pipeline involving watertight joints, and installation of flexible watertight joints will conform closely to manufacturers' recommendations. Although system layouts presently recommended are considered adequate, particular care should be exercised to provide a layout of subdrains that does not require water to travel appreciable distances through the base course due to impervious subgrade material or barriers. Pervious base courses with a minimum thickness of about 6 inches with provisions for drainage should be provided beneath pavements constructed on fine-grained subgrades and subject to perched water table conditions. Base courses containing more than 10 percent fines cannot be drained and remain saturated continuously.