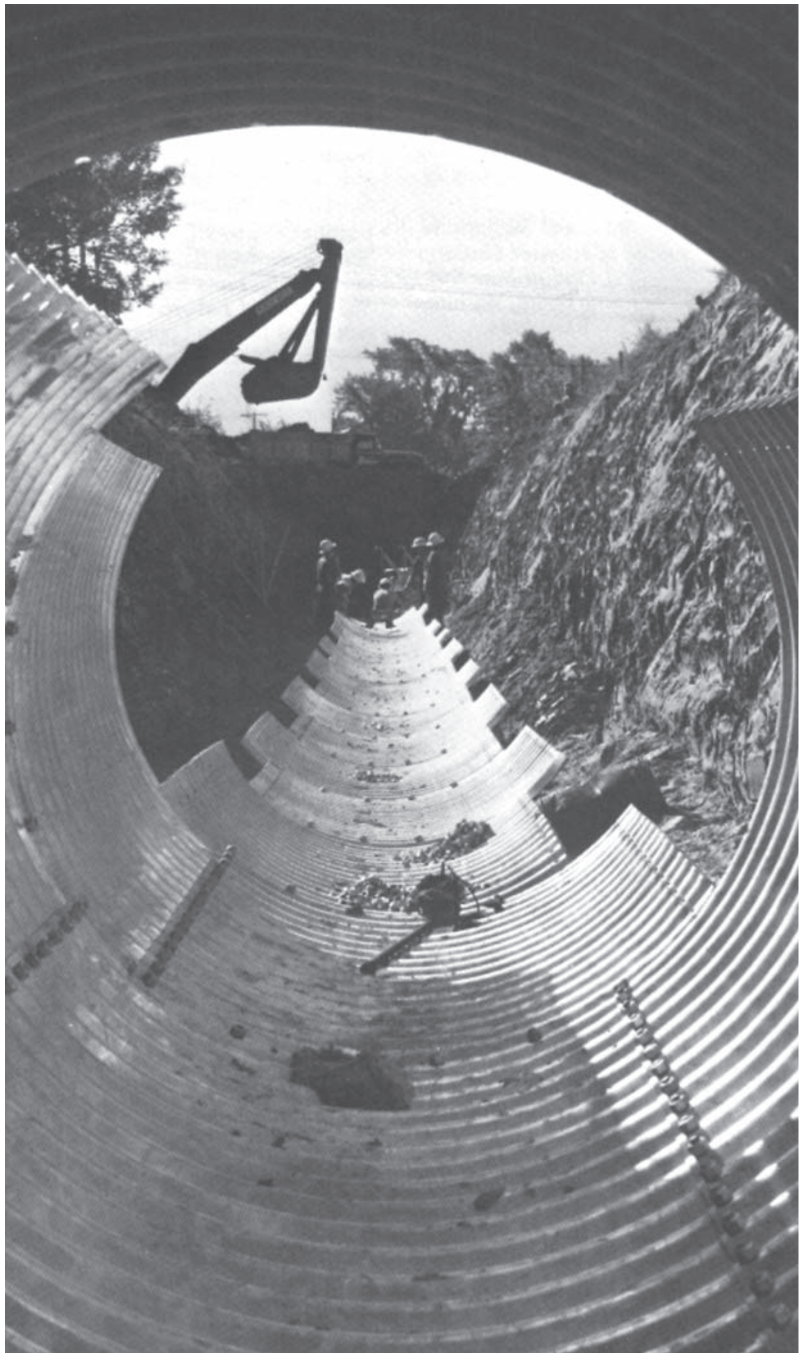


Trunk sewer mains for storm water runoff have proven particularly suited, and economical, in design with steel. Long lengths of helical CSP cut handling and installation costs and typical field assembly of large structural plate mains, as above, clearly optimize the use of municipal tax dollars.

CHAPTER 10 Construction

CONSTRUCTION PLANS

The excavation for corrugated steel drainage structures must be made in conformance with specific project construction plans. The construction plans should contain both plan and profile views of the project area and are intended to describe graphically the horizontal and vertical locations of the conduit.

The plan view depicts horizontal location and pertinent data for the proposed conduit, as well as other items such as utilities, structures, trees, etc., that fall within the construction limits. The profile shows the elevation or vertical location of the same items as situated in the plane immediately above and below the proposed conduit.

SUBSURFACE SOIL INFORMATION

Information regarding subsurface soil conditions is often included as a part of the construction plans. This information is used to facilitate the design of the project, and also to aid the contractor in planning his construction procedure. Often, soil information that is adequate for design does not contain sufficient detail to meet the needs of the contractor. For this reason, it may be advantageous to obtain additional subsurface information. This may be accomplished through tests performed by the contractor or by engaging the services of a soils engineer.

The purpose of a subsurface soils investigation is to determine:

- The types of soils that will be encountered in the construction area.
- The presence of rock.
- The thickness of various strata.
- The behavior of soils during and after excavation.
- The presence of ground water and the elevation of the ground water table.

Soils investigations can be performed by using several different procedures,depending upon the degree of sophistication desired.

Soil borings obtained through the use of hand or power driven augers provide continuous samples at increasing depths, but only in cohesive soils void of rock and gravel. Auger methods are also useful in determining the presence of rock strata and ground water.

More detailed analysis may be made from continuous core samples obtained by driving a hollow sampling device, such as a "split spoon." This method provides layer by layer information in relation to the surface. Soil density can also be determined by relationship to the number of blows required to drive the sampling device. Water table elevation can be measured after the water level in the bore hole is stabilized.

Soil and ground water information is graphically represented by plotting a vertical section of each sampling location on the project plan-profile or a separate profile sheet prepared to display soil information. The soil section should indicate not only the soil types and location of the ground water, but also information regarding relative density and elevations of various strata referenced to the same datum as the sewer project. A sample section of a soil log is shown in Figure 10.1.

Figure 10.1 Log of boring no. B-21

DATE **SURFACE ELEV. 28.7** **LOCATION**

DEPTH, metres	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	1	Topsoil (300mm)					
		Firm brown micaceous clayey silt (fill)					
1.5	2	Soft to very soft interbedded dark gray silty fine sandy clay/tan-brown fibrous peat		59.4	74	38	X
	P<50						
	1			77.6			X
3.0				89.5			
	P150			312.9	103	51	X
				26.5			
	1	Soft to firm tan-brown silty fine sandy clay					
	P800						
4.5	12	Medium to dense interbedded tan-brown silty medium to fine sand/gray-brown gravelly silty coarse to medium fine sand		24.9			M
6.0	6			16.9			
7.5	10			19.1			
9.0	16			8.2			
10.5	16			8.0			
12.0	16	Very stiff gray-red mottled fine sandy silty clay		23.9	41	23	
13.5	26			28.6			

COMPLETION DEPTH 19m WATER DEPTH 1500mm enc.

SAMPLER 51mm O.D. SPLIT BARREL SAMPLER

TRENCH EXCAVATION

The successful completion of a conduit installation project is dependent upon all involved individuals, including the designer, field engineer, and contractor, being familiar with surface and subsurface conditions.

Prior to the start of trench excavation or any other part of the contract, both the owner and contractor should thoroughly familiarize themselves with the latest OSHA requirements relating to the work specified.

Choice of excavation equipment by the contractor is predicated on conditions existing on any specific project. Bulldozers, backhoes, draglines, scrapers, and end loaders are only part of the myriad equipment available to contractors. Each particular item of equipment is designed to perform a certain function and the contractor must bear in mind items such as type and volume of material to be excavated, the width and depth of the trench, available working space, and the disposal of excavated material.

Regardless of the type of equipment selected to perform the work, trench excavation should proceed upstream. Most trenching equipment is more efficiently operated in this manner, and pipe sections are also easier joined when progressing in this direction. If excavated soil is to be used as backfill, it should be stockpiled in a windrow at a safe distance back from the edge of the trench.

Care should always be exercised in the operation of equipment in the vicinity of an open trench. As with the case of stockpiled excavation, the combination of equipment weight and vibration will cause a surcharge loading effect on the earth adjacent to the trench. These loads can reach such magnitudes as to cause the trench wall to fail, resulting in a cave-in.

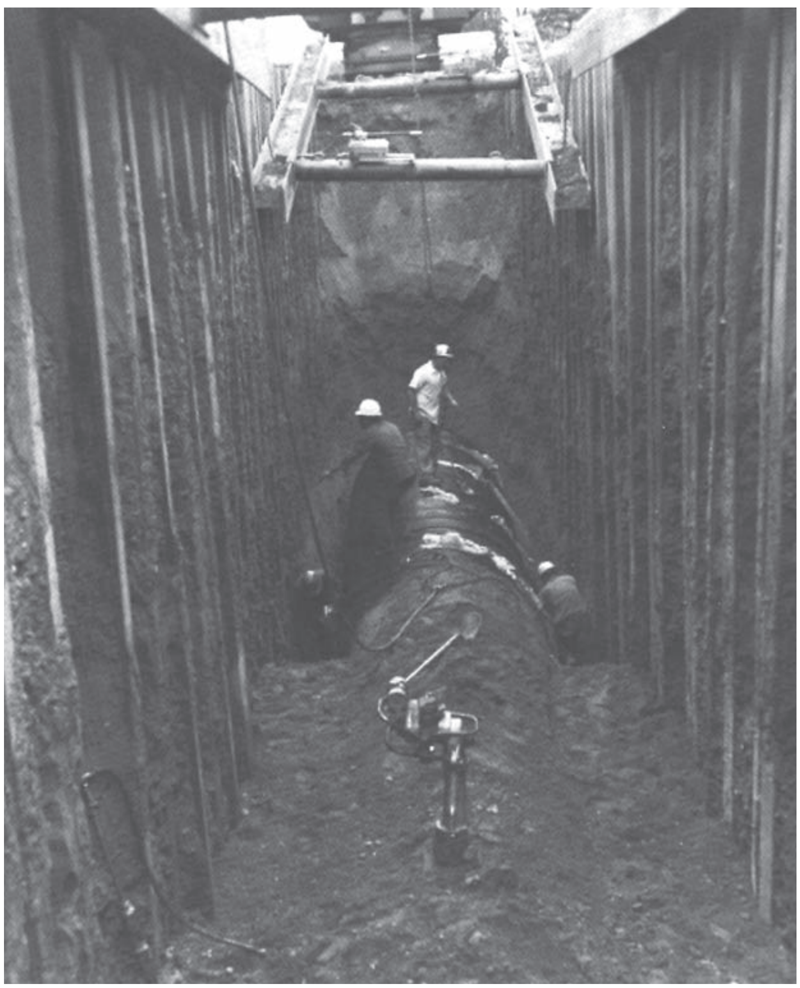
Pre-fabricated miter section of CSP is lowered into place to match bend in trench.

The three phases of a conduit construction project (excavation, pipe installation, and backfilling) should be scheduled in close sequence with each other. An open trench is dangerous and vulnerable to accidents. In addition to safety to workmen and the general public, the contractor must always keep in mind that an open excavation can result in damage to the project under construction. The two main hazards that must always be considered in trenching work are:

- Stability of trench walls.
- Water that may accumulate in the trench resulting from seepage and surface runoff.

To minimize the chance of accidents and losses resulting from trenching operations, the following procedures should be followed:

- Begin excavation only when installation of conduit materials can immediately follow.



76mm x 25mm full bituminous coated and full paved storm sewer, 820m, 2200mm diameter, 1.6mm.

- Protect trench walls to insure their stability throughout the construction period.
- Follow procedures that will keep the trench free of seepage and surface waters.
- Trench excavation should proceed at the same rate as conduit installation with a minimum of distance, as dictated by safety, separating the two operations.
- As soon as practicable after conduit installation, the trench should be backfilled.

In the interest of safety, it is suggested that all excavations deeper than 1.2m be equipped with ladders or steps located within 8m of the working area. Ladders or steps should be secured at the top of trench walls and for ease of access, such facilities should extend at least 1m above the top of the trench.

Trench Shape

The cross-sectional shape of the trench is dependent upon several factors, including:

- The design depth below surface.
- The shape of the conduit structure.
- The type of soil encountered.
- Foundation material present in the bottom of the trench.
- Procedures used in placement of backfill around the conduit structure.

Corrugated steel pipe is designed structurally to withstand the formal full loading of the overburden. This means that no restriction of C.S.P. trench width is necessary beyond those considerations listed above. Other conduit materials may require a restricted trench width as this is commonly the basis for their design.

Using steel trench shield to install CSP sewer.

Trench excavation should be carried to a depth below the corrugated pipe structure to allow for the placement of bedding materials. The depth of bedding should be 75 mm for ordinary soils and a minimum of 300 mm when rock excavation is encountered. Soft foundation materials should always be excavated to a sufficient depth to allow for the placement of granular backfill that will provide adequate support for the structure.

Trench Stability

As mentioned in earlier sections, trench wall stability is of prime importance in maintaining a safe working area and providing protection to the work in progress. The stability of a trench wall is dependent upon the type of soils present and the treatment given these soils. Materials encountered in trenching operations may be classified into two general groupings—cohesive soils and cohesionless soils. It is important to understand the difference between these two types and how stability failures occur in each.

Cohesive soils are fine-grained materials, such as silts and clays, that owe the greater part of their strength to a complicated molecular interaction between individual soil particles. The stability of a cohesive soil is measured by its shearing resistance strength—the amount of force required to destroy the bonding action between the soil particles. Failure in these soils occur along a curved surface, or "slip-circle," as shown in Figure 10.2, and are the result of a stress "build-up" which exceeds the shear resistance capability of such soils. The development of excessive stresses along the "slip-circle" can be attributed to several factors, including:

- The removal of lateral support through the excavation of the trench.
- The placement of a surcharge loading (soil excavation or equipment) adjacent to the trench.

Cohesionless soils are composed of coarse, weathered rock materials that depend upon an interlocking of the angular surfaces of one soil particle with another in order to maintain stability of the soil mass. Sands and gravels are typical examples of cohesionless soils. The degree of stability of this type of soil is dependent upon the soil's internal angle of friction. While not theoretically correct, the angle of internal friction of a cohesionless soil can roughly be assumed as equal to its angle of repose the maximum angle with the horizontal at which an excavated trench wall can be expected to remain stable. Table 10.1 contains a listing of various cohesionless soils with their corresponding angle of repose and slope ratios.

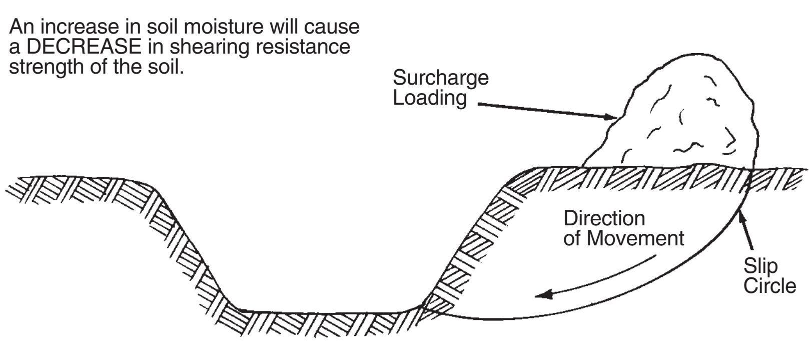


Figure 10.2 Typical trench wall failure in cohesive soil

Table 10.1 Stable slope angles for various cohesionless materials

Material description	Angle of repose	Slope ratio (horizontal to vertical)
Rock and cemented sand	90ϒ	Vertical
Compacted angular gravels	63ϒ	$\frac{1}{2}$:1
Compacted angular sands	34ϒ	$1\frac{1}{2}$:1
Weathered loose sands	27ϒ	2:1

The prediction of the degree of stability for any given trench wall usually defies theoretical analysis. Investigative methods available require assumptions to be made that result in only general guidelines regarding the stability of a sloped soil surface. This is quite understandable, since most soils are not truly cohesive or cohesionless but are mixtures containing some of the properties of both general groupings.

To further complicate the situation, trenching operations can change the behavior properties of a soil as work progresses. The soil can dry out, develop cracks, and portions of the wall slough off. Rock surfaces that appear stable upon initial excavation can soften and become hazardous upon exposure to air. Consequently, all trenches should be considered as dangerous and treated with great respect.

Safety requirements dictate that all except very shallow trenches be protected by either the use of sloping trench walls or the adoption of shoring or bracing systems.

Trench Stabilization Systems

Often, it is not practical to stabilize trench walls by the use of sloping procedures. This situation may arise due to:

- Unstable soil conditions.
- The presence of ground water.
- Nearby underground structures.
- A restricted surface work area.
- An excessively deep excavation.
- Surcharge loadings adjacent to the trench resulting from soil placement or the presence of construction equipment and/or vehicular traffic.

Systems most often used for trench stabilization, Figure 10.3, are:

- Open sheathing.
- Closed sheathing.
- Tight sheathing.
- Trench shields.

Closed and tight sheathing are similar to each other, the difference being that tight sheathing uses interlocking vertical members to impede the passage of ground water into the trench area. Either timber or steel sections can be used as the sheathing members. When working in a dry, cohesionless soil, closed sheathing may be adequate; but where ground water control operations are being conducted, tight sheathing should always be used.

In some soil conditions where a trench will be open for only a short period of time, a trench shield (also referred to as a trench box) can be utilized in lieu of a sheathing system. The shield is usually constructed of steel with reinforcing cross members at each end. OSHA regulations permit the use of a shield provided that protection equal to other forms of shoring is achieved. The shield supplies a safe work area while trench bedding is prepared and conduit sections are placed. After installation and backfilling around the pipe, the shield is pulled forward. Trench shields can be constructed in various widths and heights. When a trench shield is used, and as the shield is moved forward, void areas may develop between previously placed backfill and the trench wall. Therefore care must be taken to prevent problems if voids are excessive.

Backfill should be placed around the conduit while the sheathing is still in place. If wooden sheathing is removed from the trench area adjacent to

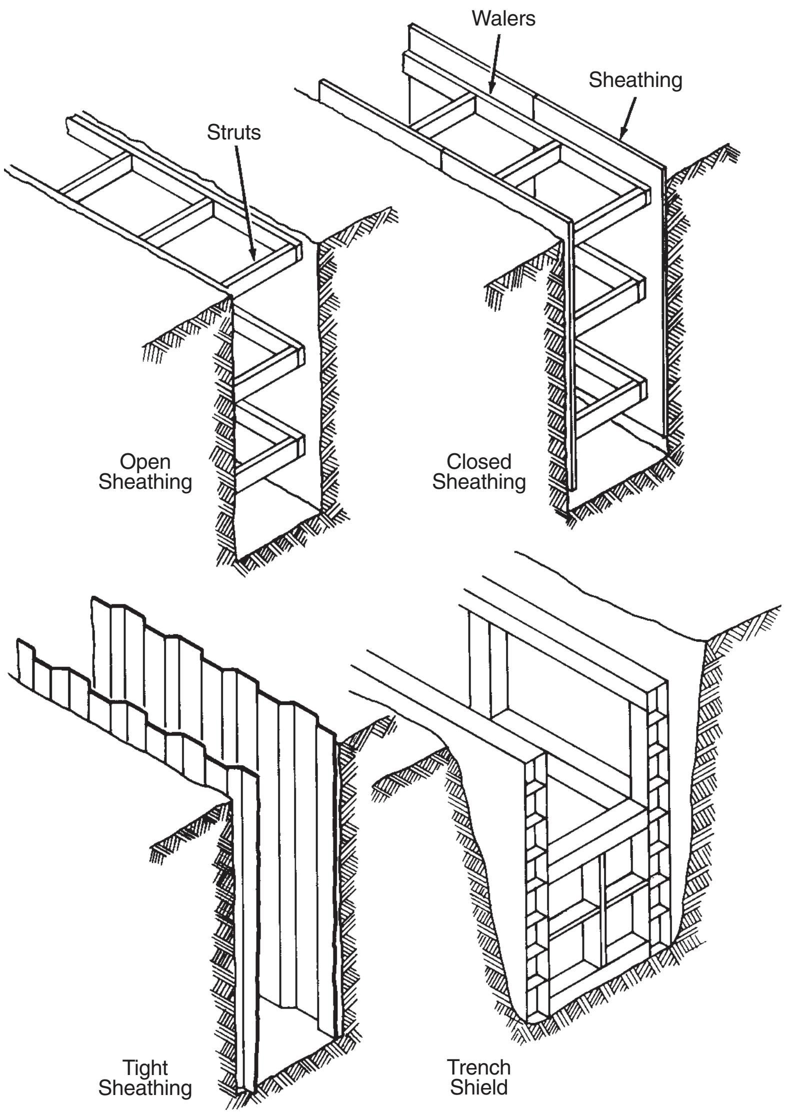


Figure 10.3 Four systems most often used for trench stabilization

the conduit, voids will develop that can reduce the effectiveness of the backfill material. For this reason, all wooden sheathing and bracing should be cut off at a point 450 mm above the conduit top and the supports below this point left in place.

Steel sheathing has the capability of being reused many times. For this reason, and due to the small thickness of the member, steel sheathing can be carefully removed without seriously reducing the effectiveness of the backfill material.

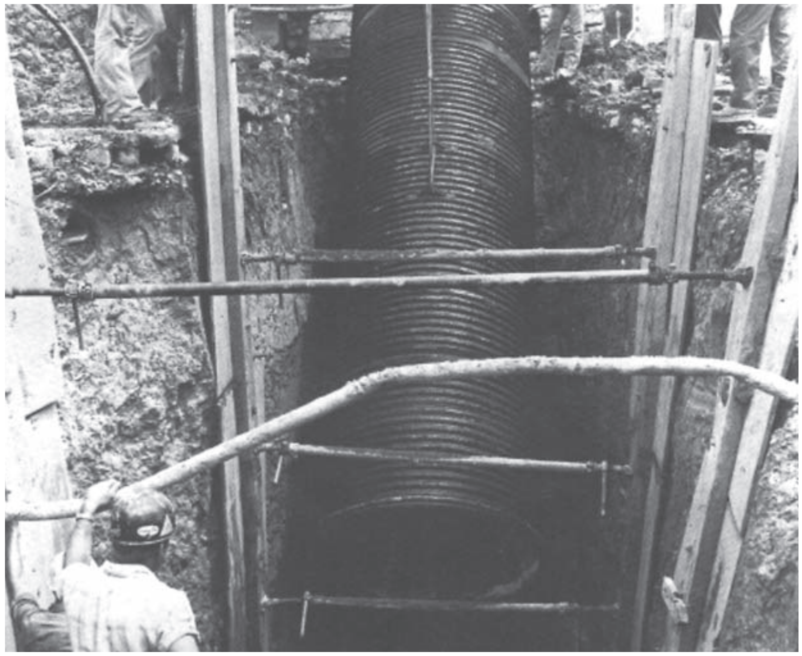
Several methods are commonly used to prevent and control the intrusion of ground water into the trench area. The system selected, of course, is directly dependent upon both local conditions and the quantity of water that must be removed. Systems available include:

- Tight sheathing.
- Pumping from sumps placed in the trench base.
- Wells placed along the trench alignment.
- A system of continuous well points installed along the trench route.

In most instances, tight sheathing alone will not provide effective ground water control. If ground water levels are allowed to build up behind the sheathing, increased pressures will develop on the bracing system. This additional force is caused by two factors—the hydrostatic pressure of the collected ground water and behavorial changes that occur in the soil due to saturated conditions. For these reasons, some form of pumping operations should be carried out in conjunction with tight sheathing.

Water collection sumps can be placed in the trench bottom and filled with crushed stone or washed gravel to control relatively small amounts of ground water that may accumulate in the trench. This method of direct pumping is particularly effective in cohesionless soils or where granular bedding material has been placed in the trench bottom, thus allowing water to flow to the sump area.

Installation of CSP sanitary sewers.



Full bituminous coated and full paved, 76 x 25 mm corrugation, approximately 940 m of 300 - 1800 mm for storm sewer.

When it is desired to lower the ground water table prior to trench excavation, wells or a system of continuous well points should be utilized. These methods can be used quite successfully on cohesionless soils that readily allow the passage of ground water. If individual wells placed along the proposed trench alignment will not sufficiently lower the water table, a system of well points will be required.

A well point system consists of a series of small diameter vertical pipes driven or jetted into the water-bearing strata adjacent to the proposed trench. Each pipe is equipped with a perforated well point head that allows for the passage of ground water. The well point pipes, in turn, are connected by flexible couplings to a horizontal header pipe at the ground surface. A negative pressure or suction is created in the system by use of either a vacuum or centrifugal pump that has the capability of passing both air and water.

Typical arrangements for dewatering operations are shown in Figure 10.4. The purpose of such systems is to provide a safe working area and an environment that will enable the corrugated steel structure to be installed and backfilled properly. Dewatering, however, must be conducted with care. If ground water is pumped at an excessive rate or over too prolonged a period of time, soil particles may be removed from the ground. This can result in the subsidence of trench walls and damage to nearby structures due to settlement.

COUPLINGS

During the construction of a corrugated steel pipe system, care should be given to the treatment of joints to prevent both infiltration and exfiltration. Both processes will have an effect upon backfill materials, since soil

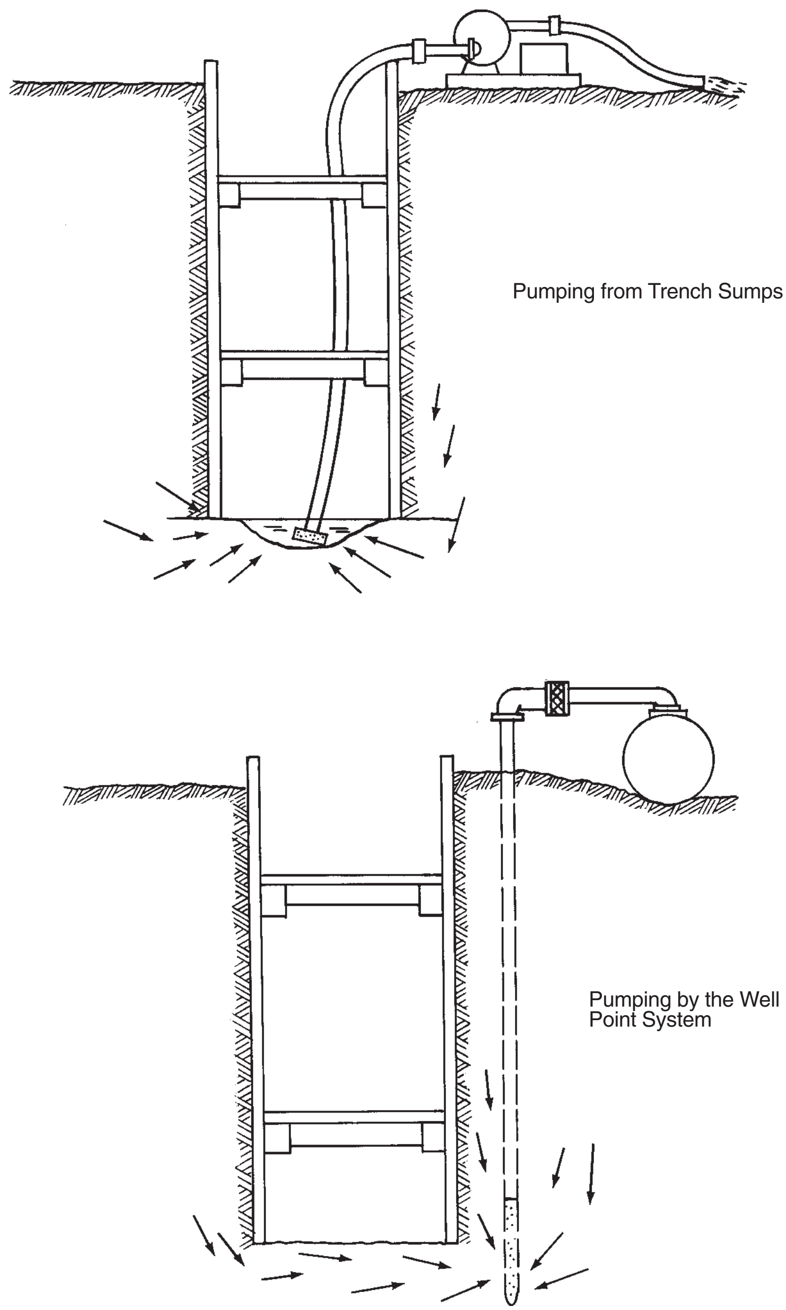


Figure 10.4 Typical arrangements for dewatering operations

particle migration can occur. This is particularly true when fine grained soils (silt and clay) are present in the backfill material.

A wide variety of couplings are used for joining sections of corrugated steel pipe. To control leakage, gaskets are available for placement between the outer surface of the conduit and the connecting band.

When infiltration or exfiltration is anticipated, the owner agency may incorporate minimum pressure requirements into the project specifications.

TESTING

Due to the conduit sizes involved in corrugated steel pipe structures, an air testing system is a relatively convenient method for checking the pressure integrity of joints. Flexible bags are placed on either side of a joint and inflated to provide a tight seal. Compressed air is pumped into the isolated area until the desired pressure is achieved. The pressure is then monitored to check for leakage. The flexible bags are then deflated and moved to the next adjacent joint for a similar check. By following this procedure, the entire conduit system can be pressure tested. Joint testers such as the Cherne Joint Tester, developed particularly for corrugated steel pipe, will give accurate low pressure air testing of large diameter pipe joints.

FIELD LAYOUT, ALIGNMENT AND INSTALLATION

Of critical importance in the process of constructing a sewer project is the correct placement of the conduit in its intended location. This is accomplished by an application of basic surveying procedures. The project is first located or “laid out” on the ground surface by the placement of a series of reference points. Next, the horizontal and vertical position of the conduit relative to the various reference points is determined. These measurements, along with the reference points, are then used by the contractor as guides for trench excavation and conduit installation.

Manhole risers can be built into the sewers with CSP pipe.

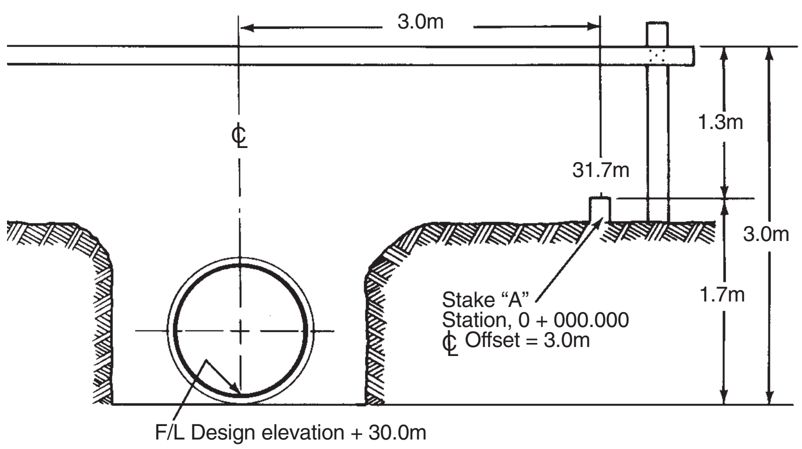
Field layout and installation must consider both the line and grade of the project. Line refers to the horizontal location and direction of a conduit while grade is a measure of its vertical elevation and slope. Slope is usually given as a percent of grade on the construction plans and denotes the change in conduit elevation per 100m. Hence, a 1.5 % grade simply means 1.5m of "fall" in each 100m of conduit length. Complete line and grade information should always be incorporated as a part of the construction plans.

One reliable method used to install conduit piping systems is known as the batter board or grade board system. This method consists of establishing a series of measurement points along a reference line parallel to the conduit alignment. Through the use of elementary surveying procedures, the vertical distance, or "cut," between each reference point and the conduit flowline adjacent to the reference point is determined. With this information, a series of boards can be established at a constant distance above the proposed conduit flowline. This procedure is illustrated in Figure 10.5.

A stringline is attached to the top of each grade board and positioned directly above the centerline of the proposed conduit. Alignment is transferred to the trench bottom by use of a plumb-bob attached to the stringline, while the conduit flowline grade is determined by a vertical measurement from the stringline.

Since the erection of boards essentially creates a measurement plane above, and parallel to, the proposed flowline, extreme care should be exercised to minimize the chance of error. The tops of any two boards, no matter how haphazardly placed, will define a plane. For this reason, a minimum of three grade boards should always be erected in series to minimize the chance of errors.

Calculations for grade board placement can be checked by visually aligning the tops to ensure that they are in a single plane.



1. Layout engineer determines elevation Stake "A" is 31.7m.
2. F/L design elevation at station 0 + 000.000 is 30.0m
3. Engineer then marks Stake "A" cut.
4. Erect "Grade Board" (Batter Board) some convenient distance above existing ground, 1.3m in this example. "Grade Board" cut is then 3.0m.
5. Repeat at 10m stations.

Figure 10.5 Pipe alignment using a grade board

In recent years, the board system to transfer line and grade has been supplanted by the use of laser generators. However, boards are employed on small projects and owner-agencies often require that when lasers are used, the initial alignment of the generator be through the use of a board system.

Various laser generators are available that are specifically designed for conduit installation. These generators project a concentrated low wattage light beam of such quality that little diffusion (or light spread) occurs in distances usually encountered in sewer conduit installation. The light beam essentially replaced the stringline in the transfer of line and grade. Input power is supplied by either an AC or DC source and output power is in the low range of 1 to 5 milliwatts. Care should always be exercised, however, when laser equipment is in use, since eye injuries can result from staring directly at the light source.

Laser generating equipment is adjusted and positioned in a manner similar to surveying instruments with the exception that an adjustment is provided to incline the beam at a slope equal to the grade of the conduit. A variety of accessories are available from manufacturers, such as tripods, poles, braces, and clamps, to facilitate the set-up of the laser generator. Two basic locations are generally used for the positioning of the laser equipment—in the trench bottom or on the ground surface.

When the equipment is placed in the trench, it is usually positioned in such a manner that the laser beam will describe the center of the conduit. The initial alignment of the laser generator should be accomplished by the erection of several grade boards as previously described. As each pipe section is installed, a special target or template is placed in the pipe's end and the vertical and horizontal alignment checked. The beam projected through previously placed conduit sections is also used to provide line and grade for trench excavation and the placement of bedding materials. The light

Quick installation of CSP sewer keeps pace with modern trenching equipment.

3000 mm diameter, 76 x 25mm full bituminous coated and full paved 1500m installed as stream enclosure for runway extension.

beam should be periodically checked against surface control points to insure its correct horizontal and vertical alignment. It must also be realized that, like any light beam, a laser is subject to refraction as it passes through the atmosphere. This is primarily a function of humidity, and, for this reason, the conduit line should be ventilated as work progresses.

When a surface set-up is used, the laser generator is positioned on the conduit centerline and the light beam functions in the same manner as the stringline in a grade board system. A grade pole is then used to transfer line and grade to the trench bottom. This method has the advantage of providing a quick check against grade reference points, but the beam is not available for continuous checks in the trench.

Whenever laser equipment is used, the generator must be protected against receiving an accidental bump. A slight shift in alignment of the light beam may not be noticeable at first, but any errors will be magnified as conduit installation progresses.

Underground Construction

When it becomes necessary to install a sewer under a city street, highway, or railroad, without interrupting traffic, the following underground construction methods can be used:

- Jacking
- Tunneling
- Boring

Underground construction can offer many advantages over open-cut methods, such as:

- Work can be carried out in any weather or season.
- Detours that might dangerously congest traffic may be eliminated as well as most traffic liability.
- Less pavement or other restoration is needed after the sewer is completed.

Only contractors with suitable experience and equipment should attempt underground installation.

Alignment Changes

Changes in horizontal and vertical alignment of a corrugated steel pipe can be accomplished by any one or several of the following methods:

- Field construction manholes.
- Shop fabricated corrugated steel manholes.
- The use of special fittings such as wyes, laterals, tees, and saddle fittings for branch lines.
- Special corrugated steel pipe and pipe arch elbow sections.

Manholes are multipurpose in function. They provide access for maintenance, serve as junction chambers where several conduits are jointed together, and are used to facilitate a change in horizontal or vertical alignment. Monolithic concrete holes are usually square or rectangular in shape. Structures of this design have the distinct disadvantage of causing turbulent flow conditions that, in effect, reduce the carrying capacity in upstream portions of the conduit system.

Shop fabricated corrugated steel manholes are available for all shapes of corrugated steel pipe structures. They are designed to receive standard cast iron appurtenances such as manhole covers and grates. Corrugated steel manholes have the advantage of quick installation and backfilling, thus reducing the possibility of damage to the pipeline due to flooding caused by unexpected weather conditions.

It is frequently desirable to change the horizontal or vertical alignment of large diameter corrugated steel drainage structures without the use of a manhole or junction chamber. Shop fabricated elbow sections are available for this purpose and, in most instances, the additional fabrication cost is more than offset by the elimination of the manhole or junction chamber.

Elbow pipe sections can be prepared by manufacturers to provide gradual changes in flow direction. Such fittings are prepared from standard pipe and pipe arch sections and have the advantage of providing a change in direction without interrupting the flowline. Figure 10.6 graphically indicates the form of these sections that are available in any increment between 0ϒ and 90ϒ. Elbow fittings can be used in conjunction with each other, thus providing a custom design to accommodate required field conditions. For example, a horizontal alignment change of 90ϒcould be negotiated through the use of three 30ϒ or four $22^1/_2$ϒ sections. A horizontal shift in alignment can easily be accommodated by the use of two elbow fittings…with the second fitting simply installed in reverse orientation to the first.

Saddle Branches

Saddle branches are fittings available for field connecting laterals and other lines entering a corrugated steel pipe structure. Any line at any angle may be joined to the main or line simply by cutting or sawing the required hole. The saddle branch is fitted over this opening and the incoming line is then attached to this fitting. See Chapter 1, page 25.

The use of special fittings and elbow sections required precise surveys both in the design and layout stages. The accurate location of special items must be predetermined in order for the manufacturer to supply fittings and straight pipe sections that will conform to field conditions. Layout and installation must be done with care to insure proper positioning of all portions of the corrugated steel pipe system. The field layout procedure for elbow pipe sections involve geometry similar to that of a standard highway curve. It should be noted, however, that only the center points at the end of each elbow section lie on the path of the circular curve.

BACKFILLING PROCEDURE

The performance of a corrugated steel pipe in retaining its shape and structural integrity is dependent upon the quality, placement, and degree of compaction of the backfill placed between the trench walls and the structure. The reader is encouraged to consult the following references for further detail on soils and installation requirements:

(1) ASTM A798, "Standard Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications"

(2) ASTM A807, "Installing Corrugated Steel Structural Plate for Sewers and Other Applications"

As vertical loads are applied to the conduit, the sides will tend to move outward in the horizontal direction. A properly placed backfill will resist this outward movement creating the soil-steel interaction system upon which the design was based.

In addition to providing support to the pipe, the backfill adjacent to the pipe must also support a portion of the trench loading. Good backfill around the pipe must, therefore, be provided to insure good results in pipe performance and to prevent damage to surface structures from trench fill subsidence.

Corrugated steel pipe may be placed directly on the fine-graded foundation for the pipe line. The bedding material should not contain rock retained on a 76mm ring, frozen lumps, chunks of highly plastic clay, organic matter, or other deleterious material. It is not required to shape the

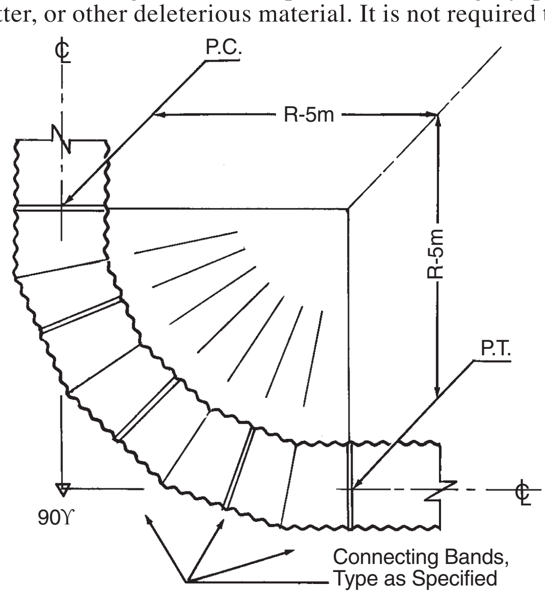


Figure 10.6 Alignment for pipe elbow sections
The above is a design to negotiate a 90ϒalignment change through the use of four 22 1/2ϒsections

bedding to the pipe geometry. However, for pipe arches, it is recommended to either shape the bedding to the relatively flat bottom arc or fine-grade the foundation to a slightly v-shape. This avoids the problem of trying to backfill under the difficult area beneath the invert of pipe arches. When rock excavation is encountered, it must be excavated and replaced with a layer of soil.

A properly developed foundation will:

- Maintain the conduit on a uniform grade.
- Aid in the maintenance of the desired cross-sectional shape.
- Allow for uniform distribution of loading without development of stress concentrations in the pipe wall.

Good bedding foundations can be viewed as a "cushion" for the conduit and should be relatively yielding when compared to compacted material placed between the trench wall and the pipe. In this manner, an earth arch can develop over the pipe, thus reducing the load transmitted to the conduit.

Backfill placed around the pipe structure should be granular. A small amount of silt or clay material may aid in the compaction process. Truly cohesive soils, such as heavy clays, should usually be avoided. This type of material can provide an effective backfill, but compaction must be performed at optimum moisture conditions for the particular soil.

Pit-run (or bank-run) sands and gravel compacted to 90% of AASHTO T-99 or ASTM 698 density provide excellent backfill for corrugated steel pipe. These materials exhibit good shear strength characteristics and are stable under varying moisture conditions.

To achieve the desired soil envelope around the corrugated steel pipe, the fill material should be placed in layers, uniformly from both sides, and compacted to the specified density. Care must be taken to ensure that the

Compacting backfill is required for proper installation of all sewers.

structure's alignment, grade, and cross-sectional shape are maintained. If excessive height differential exists between backfill from side to side, a rolling or eggshaped distortion may occur. Likewise, over compaction can cause vertical elongation or distortion.

When backfilling around the sides of the pipe-arch, particular care should be given to those areas around the pipe-arch haunches. Maximum pressure will be exerted on the soil backfill at these points. The backfill adjacent to the pipe-arch haunches must have a bearing capacity that will allow for a safe transfer of loading between the structure and the trench walls. It is important in pipe-arch installation to insure a favorable relative movement of the haunches with respect to the pipe bottom. For this reason, a slightly yielding foundation under the bottom, as compared to the haunches, is desirable. This factor is illustrated in Figure 10.7.

Quality backfill can be achieved by the use of a variety of tamping and vibrating equipment. Hand tamping is recommended for the filling of void areas beneath corrugated pipe structures. To achieve proper compaction it is often necessary to use a 51mm x 102mm timber for work in confined areas. Hand tampers can also be used to compact horizontal layers adjacent to the pipe. Hand tamping equipment should weigh at least 10 kg and have a surface no larger than 150mm x 150mm. Mechanical tamping and vibrating equipment may also be used where space permits. However, care should be exercised to avoid damaging the pipe during the compaction process. The most important factor in the backfilling operation is the exercise of care to insure that proper soil density is achieved between the conduit and trench walls. The greatest single error in backfilling is the dumping of piles of material into the trench and then attempting to compact the backfill without spreading. Material should be carefully placed alongside the conduit and distributed in layers prior to the compaction operation.

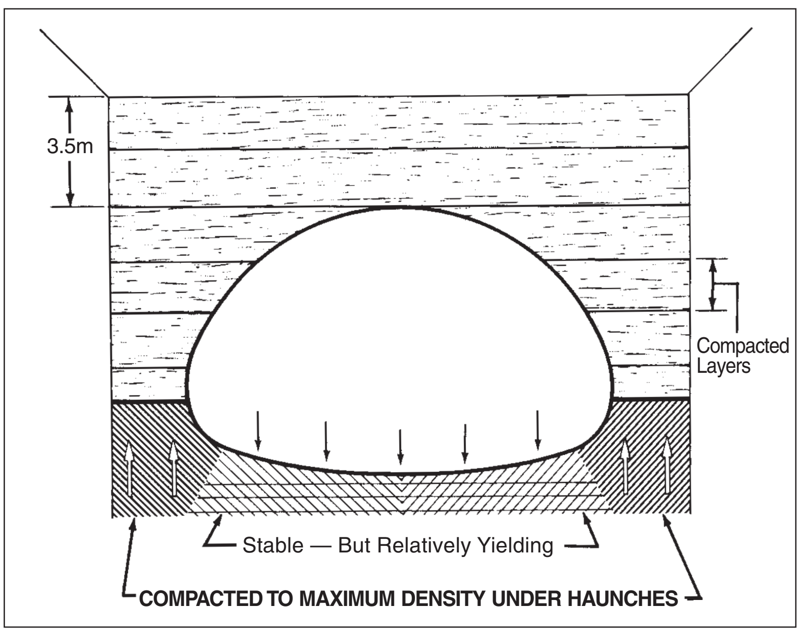


Figure 10.7 Pipe-arch loads are carried at the corners. Arrows show the direction of favorable relative motion of all pipe arches.

Philadelphia Airport expansion again calls for CSP storm sewers. Corrugated steel pipe was installed 25 years before in an earlier expansion.

Waterjetting can be accomplished with a length of small diameter pipe attached to a small pump with a long length of flexible hose. Granular material placed in lifts on each side of the pipe can be worked in under haunches and consolidated. Such methods can only be used on free-draining soils, and care must be taken to avoid floatation of the pipe.

Slurry backfill can provide a viable alternative to the usual soil backfill, particularly where the native soil is not suitable or installation speed is critical. Typical specifications describe a slurry with 40kg of cement per meter, 10mm maximum size aggregate, and a 130mm maximum slump, to achieve a minimum compressive strength of 690kPa. The slurry backfill can be placed in the trench around the pipe directly from the transit mix chute without vibrating.

Care must be taken to raise the level of the slurry on either side of the pipe at about the same rate. Also, it is important to estimate and control the pipe uplift to avoid damage. Uplift can be controlled by limiting the rate of placement, and by placing weights such as sand bags, internally or externally along the pipe. Further information may be found in "CSP Structure Backfill Alternatives," NCSPA, August, 1987.

Special Note

Pipe Construction may involve hazardous materials, operations, and equipment. This manual does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this manual to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

SUMMARY

Proper installation of any drainage structure will result in longer and more efficient service. This chapter is intended both to call attention to good practice and to warn against possible pitfalls. The principles discussed apply to most conditions. It is not intended to be a specification but merely a supplement to individual experience.

The following operations should be performed to insure a proper installation:

(1) Check alignment and grade in relation to streambed.

(2) Make sure the length of the structure is correct.

(3) Excavate to correct width, line, and grade.

(4) Provide a uniform, stable foundation.

(5) Unload and handle structures carefully.

(6) Assemble the pipe properly.

(7) Use a suitable backfill material.

(8) Place and compact backfill as recommended.

(9) Protect structures from heavy, concentrated loads during construction.

(10) Backfill subdrains with properly graded filter material.

A twin run of 1200 mm diameter CSP provide an underground stormwater detention system for a site in Southern Ontario.