CORRUGATED STEEL PIPE
Design Manual

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NCSPA
National Corrugated Steel Pipe Association

PREFACE

The First Edition of NCSPA's Corrugated Steel Pipe Design Manual is the result of an extensive review and update of products and methods that are currently used. This manual places emphasis on the many applications of corrugated steel products. It also focuses on special design considerations, rehabilitation, and maintenance of steel pipe. In addition, significant updates have been made to reflect the NCSPA's current durability guidelines.

The NCSPA actively promotes the use of corrugated steel pipe products in construction. Major credit is due to the members of the NCSPA Technical Advisory Committee (TAC) and others responsible for preparing this First Edition:

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Users of the Corrugated Steel Pipe Design Manual are encouraged to offer suggestions for improvements in future editions.

CSP detention systems can be made to fit any site configuration.

Corrugated steel structural plate bridge structure.

CHAPTER one

Applications

INTRODUCTION

Corrugated steel pipe continues to play a major role in modern engineering technology for drainage systems. The versatility of corrugated steel pipe allows a designer flexibility to match the right product with the application, whether drainage or non-drainage. This chapter will briefly describe just a few of the many ways in which this product is commonly utilized. Technical information on applications is more completely defined in the later chapters.

100+ Years of History and Service

Invented in 1896, corrugated steel pipe (CSP) has been successfully used for over 100 years. Millions of installations have shown CSP to be a product at the forefront of modern engineering technology, a proven material of choice in both drainage and non-drainage applications.

Versatility

Corrugated steel pipe is manufactured in a wide range of shapes and sizes, including diameters from 6 inches to over 50 feet, as well as arch and box designs in a multitude of span and rise dimension combinations, with spans exceeding 80 feet.

Fabrication in many configurations and designs allows CSP great versatility; lending itself to a virtually endless array of fittings for drainage systems such as wyes, tees, elbows, manholes, sediment pond risers and detention systems. Corrugated steel pipe is the choice of engineers in the development of innovative design.

Structural Strength

The mechanical properties of steel are controlled at the mill, and the finished product is fabricated to exacting specifications. The strength and integrity of steel-soil interaction structures is almost unlimited. CSP structures can handle fill heights in excess of 100 feet and the product's beam strength allows structures to be manufactured in lengths exceeding any alternative drainage product on the market.

Durability

Corrugated steel pipe is available with a wide variety of protective coatings that have proven to meet the requirements of demanding environments. No matter the location or application, CSP has a coating to meet the needs of the situation. This provides the engineer or contractor an end result of optimum service life for the structure at the lowest cost. Service life exceeding 100 years can be obtained using the proper coating, specific to location and application.

Economic Value

A cost-effective product that is easily and quickly installed, and one which can be manufactured in longer lengths, CSP provides a viable alternative to other materials. These efficiency attributes help lessen the amount of equipment and time required to complete the job. Corrugated steel pipe fabricating plants are located throughout the United States, resulting in quick delivery of the product. CSP is not sensitive to temperature or moisture extremes and can be installed even during inclement weather. Rapid installation and the inherent strength of steel enable the contractor to make more efficient use of equipment. Heavy earthmovers can operate over corrugated steel structures after a proper covering with soil, shortening the time trenches must be left open and allowing the project to progress quickly. Corrugated steel pipe is the choice of cost conscious contractors and project owners, combining a strong durable product with quick installation.

Recycled Content

Steel contains the highest percentage of recycled material among products used for drainage structures. The recycled content of corrugated steel pipe, up to 96%, is rated as significant. Accordingly, specifying CSP can greatly assist in earning LEED® points in the “Material & Resources Credit 4” category. Additionally, steel is certified to meet specifications even with recycled material. While other drainage products may claim to be eco-friendly, care should be taken to ensure that these products conform to the AASHTO drainage pipe design and product specifications. Corrugated steel pipe, while having a high recycled content, conforms to and is routinely certified for compliance to AASHTO specifications. NCSPA members, on request, can also certify the recycle content for LEED’s® qualification purposes.

Acceptance of Steel

Few if any construction materials are more universally recognized and accepted than steel. Steel has been used successfully in corrugated drainage structures for over 100 years throughout the world. For many years, corrugated steel pipe products have been included in the standard specifications of the American Association of State Highway and Transportation Officials (AASHTO), the American Society for Testing and Materials (ASTM), the Federal Highway Administration (FHWA), the American Railway Engineering and Maintenance-of-Way Association (AREMA), the Corps of Engineers (USACOE), the Federal Aviation Administration (FAA), the U.S. Forest Service (USFS), the Natural Resources Conservation Service (NRCS), the Canadian Standards Association (CSA), as well as state, county, township and municipal departments. The most recognized and respected consulting engineers worldwide specify corrugated steel pipe to meet design requirements.

DRAINAGE

Generally, drainage facilities can be classified as culverts, storm sewers, stream enclosures and bridges.

Culverts

The distinction between culverts and storm sewers is made primarily on the basis of length and type of inlets and outlets. A culvert is defined as a channel, serving as a continuation or a substitute for an open stream where that stream meets an artificial barrier such as a roadway, embankment, or levee. A culvert may be constructed in varying forms; round pipe, pipe arch, arch or box, and is usually less than 200 feet in length. CSP has dominated the culvert application market since it's emergence in the construction industry more than 100 years ago.

Multiple lines of CSP provide an effective low profile culvert crossing.

Storm Sewers

A storm sewer is a collection system for stormwater, surface water and street runoff, exclusive of domestic and industrial wastes. It is typically a series of tangent sections with manholes, inlets or bends at the junction points of the tangent sections. Stormwater is less, if at all, corrosive than rural watershed runoff. Erosion by stormwater flow through a CSP system is significantly less than in culverts.

As with CSP culverts, corrugated steel storm sewers have a service record of over 100 years. The strength, flexibility, positive joints and installation economies of steel storm sewers are assured by the use of rational corrosion design criteria and readily available coatings and linings. CSP storm sewers are also used to reline failing sewers of all sizes and shapes, with a minimum reduction in waterway area.

Many growing communities face the need for expansion in their storm sewer systems to accommodate residential, commercial and industrial development. Steel storm sewer pipe provides a ready solution. Its inherent long-term economic advantage to contractors and cost-conscious municipalities enables construction of projects that might not otherwise be built. Including CSP in the project specifications ensures these communities favorable bid prices, swift installation and a sound proven solution.

The use of corrugated steel pipe for storm sewers is common. Product data, design information and engineering considerations can be found in later chapters of this manual.

■ CSP storm sewers can be fabricated to fit any site.

Stream Enclosures

Large spans provided by CSP allow streams to be enclosed without disrupting the natural flow and stream bed. Often these enclosures protect the stream from new development or intrusions. Sizes, shapes and the capability with CSP to fabricate multiple angles allow the stream to take its natural course.

■ Structural plate structure following curvature of a natural stream.

Bridges and Bridge Replacements

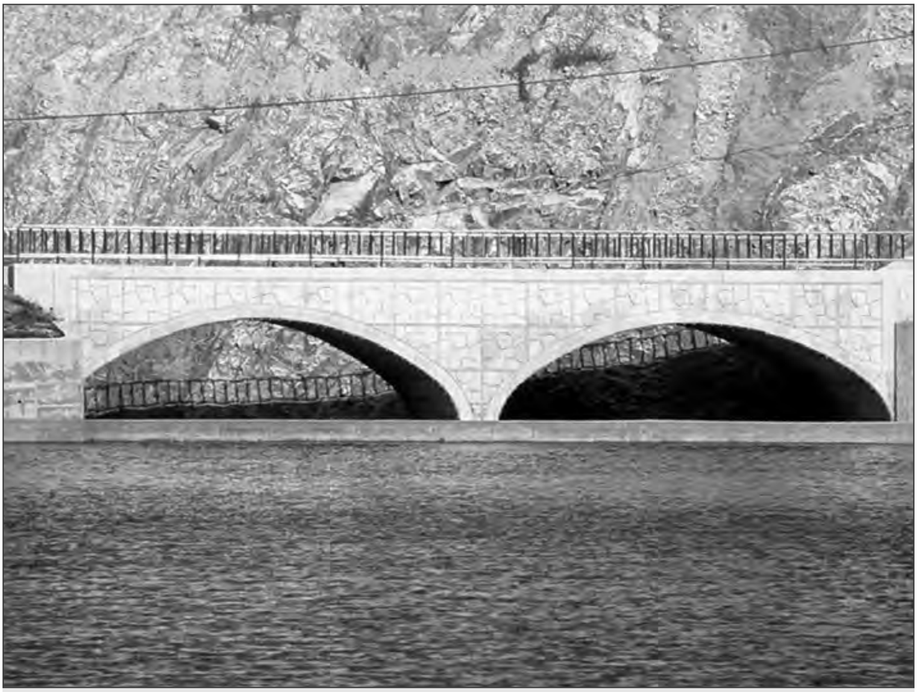
Currently, over 25% of the nation's bridges are structurally deficient. This situation is especially acute at county and municipal levels due to limited funds for maintenance and replacement on secondary roadways. Bridges can be economically replaced or rebuilt with corrugated steel structures; conventional corrugated steel pipe, structural plate pipe, pipe arches, arches and steel box culverts. The strength of corrugated steel allows spans that can exceed 80 feet, satisfying the majority of bridge installations.

■ CSP bridge replacement provides an economical installation with short road closure time.

CSP structures have been extremely popular for bridge replacement, providing the following advantages:

1. Economic value in production and installation costs.
2. Less design and construction time required than for conventional bridges, allowing earlier project completion.
3. Elimination of constant maintenance on bridge approaches and painting of superstructures.
4. No bridge deck deterioration problems.
5. Elimination of icy bridge deck problems.
6. Structures are readily available, shipped in one piece or easily field assembled.
7. In cases of future roadway expansion, lanes are easily widened by simply extending the ends of the structure.
8. Aesthetically and environmentally preferred, as they permit the use of a natural appearance in earth slope and vegetation.

For available shape configurations, sizes and waterway areas, see Chapter Two, Product Details and Fabrication. If an appropriate structure to meet project requirements is not shown, a design to meet specific site conditions can be provided by the manufacturers.



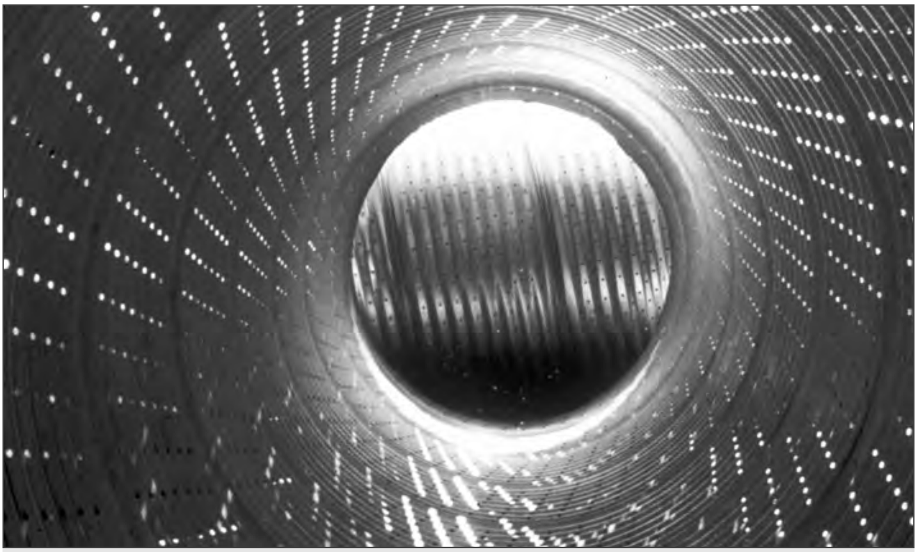
■ Low profile arch structural plate provides an aesthetic and economical stream crossing.

STORMWATER MANAGEMENT

The continuing spread of urbanization requires new drainage concepts to provide efficient and safe disposal of stormwater runoff. Existing storm drains in most areas cannot handle the additional volume at peak flow times. Severe flood damage can occur if good stormwater management tools, such as retention and detention systems, are not employed.

Retention Systems

Where stormwater runoff has no outlet for disposal, a retention system is a good solution. The stormwater is deliberately collected and stored, then allowed to dissipate by controlled infiltration into the ground. Additional benefits are found in the enhancement of ground water resources and filtration of stormwater through percolation. The use of fully perforated corrugated steel pipe for recharge wells and linear pipes is a very cost-effective way of disposing of unwanted stormwater.



Perforated CSP being used for underground retention system.

Detention Systems

In a situation where stormwater runoff has a restricted outlet due to downstream use, a detention system may be used. Temporary detention of stormwater in CSP storage tanks can be most economical and reliable. Stormwater is detained beyond the peak flow period and then is systematically released into the downstream storm drain. The demand for zero increase in the rate of runoff is very apparent in urban drainage design. Using corrugated steel pipe for retention and detention systems answers that need.

Site configuration adaptability and economical storage are accomplished with this detention system.

For further details on stormwater management covering retention/detention and surface disposal please refer to other chapters of this manual.

Sheet Flow Drainage

Intercepting sheet flow drainage at highway intersections, driveways and at the elevated shoulder of curves has become a critical element in highway design. For example, snow pushed to the high side shoulder on a curve melts as sunlight heats the pavement and shoulder. The runoff from the snow flows back across the roadway and freezes as evening temperatures fall. The result is sheet ice in a very critical area, creating a dangerous traffic hazard and repetitive maintenance problems.

An effective and economic solution to many sheet flow and pavement drainage problems can be a continuous longitudinal slotted drain corrugated steel pipe. A narrow slot in the top of the culvert intercepts runoff and the pipe carries it away as a part of the storm drain system. The system provides an inlet, runoff pipe, and grate all in one installation.

CSP Water Quality Structures

Corrugated steel pipe water quality structures can be used where it is necessary to control the quality of the runoff. These systems work in a three stage process; settling out solids, separating floating oils and solids, and filtering small fines. The CSP system can be built with a convenient means for access, allowing the structures to be cleaned and maintained periodically.

Effective water quality is attained by using an underground CSP sand filter.

Subdrainage

Subdrainage is the control of ground water in contrast to surface water or storm drainage. The civil engineer considers soil as an engineering construction material for building foundations, retaining wall backfills, embankments, cut sections for roads, highways and channels. Concern focuses on the basic soil characteristics, the presence of ground water, and whether subdrainage is practical for the soils on the project. Subdrainage can be a practical, economical method used in the stabilization of various construction sites: maintaining firm subgrades and structure foundations, eliminating wet cuts, preventing frost heave, preventing sloughing of fill and cut slopes, keeping recreational areas dry and reducing saturation of backfill behind retaining walls.

With a little study and experience, many soil and ground water problems can be recognized and solved with subdrainage pipe. For the more difficult cases, utilizing a soils engineer and laboratory are indispensable.

OTHER CSP DRAINAGE APPLICATIONS

Erosion Prevention

Soil erosion by water is a common and destructive force that plagues many project sites. It makes unsightly gullies on roadways, cut slopes and embankments. It gouges out side ditches, fills culverts with sediment and is a costly nuisance.

There are three basic ways of preventing erosion. The first is to treat the surface by paving, riprap, or use of erosion-resistant turf, vines, or other vegetation. Second, the velocity of the water may be reduced by means of ditch checks. The third method is to intercept the water through inlets and convey it in corrugated steel flumes, pipe spillways, stream enclosures, or storm drains. Larger streams may be controlled by steel sheeting, jetties, or retaining walls.

Corrugated steel pipe, with its long lengths, positive joints and flexibility to conform to shifting soil, provides a most dependable means of solving erosion problems.

■ Installation of a corrugated steel pipe spillway. Note the anti-seep collars on the pipe.

Dams and Levees

Earth dams, levees and many other types of embankments require culverts or outlets for intercepted or impounded water. Corrugated steel pipes are particularly advantageous and have enviable records for this type of service.

Dams and levees impound water and ultimately need pipe for drains and relief structures. Soil conditions at these locations are seldom ideal; therefore strong, flexible pipes are needed to resist disjointing, settlement and infiltration of the surrounding soil. CSP meets the demanding durability and structural needs for dams and levees. A local or regional office of the Natural Resource Conservation Service (NRCS) can be helpful in suggesting suitable details, such as diaphragms, anti-vortex baffles and riser sections based on proven local practice.

Fish Passage

In many sites, the need to accommodate migrating fish passage is an important consideration in culvert design. Transportation and drainage designers should seek early coordination with environmental, fish and wildlife agencies to insure that stream crossings that require provisions for fish passage are identified before design commences. Extensive experience has shown clearly that culverts can be designed to provide for fish passage. Design criteria for the specific fish species should be clarified during project development.

CSP arch preserving natural stream bed for fish passage.

Several variations in design are possible to accommodate fish passage:

Open-Bottom Culverts or arch-type culverts on spread footings permit the use of the natural stream bed. This approach is favored in streams with rock or erosion-resistant channels. Selection of a wider arch span provides for the maintenance of natural stream velocities during moderate flows.

Tailpond Control Weirs have proven to be the most practical approach to meet a minimum water depth requirement in the culvert barrel. A series of shallow weirs with a notch or small weir for low-flow passage have proved extremely effective. Larger weirs of more substantial design may require provision for separate fish ladder bypasses.

Oversized Culverts may be used when it is desirable to maintain a natural stream bed. Oversizing and depressing the culvert invert below the natural stream bed permits gravel and stone deposition, resulting in a nearly natural stream bed within the culvert. Numerous velocity profiles taken during floods indicate that wall and bed friction permit fish passage along the wall. In effect, the roughness of the steel barrel assists in fish passage.

Culverts with baffles attached to the invert may be used to control water velocities and depths. Considerable laboratory and field research has indicated that baffles or spoilers do significantly aid fish passage. The use of baffles in the barrel of a drainage structure may also be successful at sites where energy dissipation may be desirable. Additionally, baffles (sometimes called sill plates) will retain rock in a high velocity situation.

Multiple barrel installations have proven to be particularly effective in wide shallow streams. One barrel can be specifically designed with orifice plates inside the barrel to provide for fish passage.

Conversely, prevention of fish migration into upstream spawning grounds can also be accommodated through the incorporation of suitable weirs or barriers into the culvert design.

Power Plant Cooling Water Lines

Power plants require vast amounts of cooling water. Structural plate steel pipes over 18 feet in diameter have been used for water intake and outlets. These lines are typically subaqueous, requiring special underwater construction by divers. Corrugated steel is especially suitable for this type of construction and has been used for such lines in the Great Lakes region.

NONDRAINAGE APPLICATIONS

Steel conduits serve many practical purposes other than for drainage. Several of these are noted below.

Underpasses and Overpasses for Pedestrians and Animals

Pedestrian underpasses find their principal use in protecting people, including school children, who would otherwise be forced to cross hazards such as railway tracks, streets or highways.

Both domestic animals and wildlife benefit from the use of steel conduits as well. Frequently, large farms and ranches are divided by a highway or railroad, forcing livestock and native wildlife to make repeated dangerous crossings. An opening or underpass is often the most satisfactory solution to this problem. In some cases, large steel plate structures have been used to provide wildlife and ski trail crossings either over or under busy roads.

Safety is not the only advantage. Where a business, industry, or institution is divided by a busy street or railroad, a structural plate underpass is often the most convenient, direct and economical means of access.

Pedestrian and golf cart underpass.

Vehicular & Rail Grade Separations

Large underpasses serve as grade separations for automotive and railway traffic. For example, a county or local road can be carried under or over an interstate highway or railroad, often at less cost than by building a bridge. Smaller underpass structures are also used to provide passage for golf carts, snowmobiles, bicycles and other small vehicles.

■ Structural plate grade separation between railroad and highway.

Conveyors, Tunnels and Granaries

When a plant property is divided by a roadway or other barrier, a tunnel or an aerial bridging conduit may serve to join the property economically. In some cases a conveyor cover for short or long distance can serve to protect products from the elements while en route. Tracks, conveyor belts, or walkways may be used in these tunnels, bridging conduits, and conveyor covers.

■ Conveyor crossing and walkway access for aggregate handling facility.

Conveyor tunnels of heavy-wall thickness corrugated steel pipe are commonly used under storage piles of aggregates and other materials. Additionally, storage bins of heavy curved corrugated steel plates are used on construction jobs, as well as in plant material yards.

Utility Conduits

Water, steam and gas lines, sewers, or power cables must often pass between buildings or beneath embankments or other surface obstacles. Good engineering practice calls for placing them within a conduit to protect against direct loading, impact, corrosion, temperature extremes, and against sabotage or vandalism.

For encasing sewers or high pressure lines, a corrugated steel conduit helps minimize damage to the fill and surface installations caused by sudden breaks. A conduit large enough to walk through provides better access for inspections and repairs. Brackets, hangers, or cushioning bases are easily installed.

Utility conduits or tunnels may also double as air ducts. In the case of mines, munitions plants and other hazardous activities, these conduits may serve as ventilation overcasts and escapeways.

■ Corrugated steel utility conduit.

Bent Protection Systems

Corrugated steel pipe is utilized to reinforce and protect bridge piers, bents and foundations. Examples are applications such as roads and parking lots under elevated roadways or piles of aggregate from conveyors that accumulate against conveyor bents.

Bridge bent protection.

Containment Rings and Tanks

Corrugated steel pipe or structural plate rings in conjunction with a liner are used around storage vessels as a means to contain the contents of a spill. Similar structures are used to build large ponds for fish hatcheries. Many other applications in containment and storage can also be found.

Corrugated steel rings used for spill containment.

Agricultural Ventilation Systems

Corrugated steel pipe can be used in ventilation for corn, potato, onion, sugar beet and various grain stockpiles. In these cases, perforated CSP is placed under the stockpile. Air pumped through the pipe ventilates the stockpile, keeping the stored products fresh for longer periods of time.

CSP ventilation system for sugar beet storage facility.

Foundation Structures

Corrugated steel pipe has many uses in foundation applications; it can be used as encasement pipe in the construction of bridge piers, building foundations and towers. While these structures differ in end use and in construction methodology, CSP offers similar cost/benefit advantages for all of the above applications.

The primary advantage to CSP encasement is in the cost-control of concrete in the pier pour. Diameters commonly used range from 18 to 144 inches and lengths range from 7 to 75 feet. This type of installation technique is preferred in all but deep-water pier construction.

CSP form for wind turbine generator footing.

Aerial Conduits

Aerial conduits include at least two classes of structures. The first is exposed sewers, such as gravity water lines and service tunnels or bridges. The second class includes ducts for air and various gases used for ventilation or circulation. Aerial access bridges for safe movement of personnel or intra-plant materials handling have also proved useful.

Service Tunnels

Rather than ground level crossings or subterranean passageways, aerial conduits can be a good choice in industry. Bridging between adjacent buildings of a manufacturing plant may be desirable for more direct access for employees, materials, finished products, or utility lines. Other applications are seen at mine tipples, quarries, or docks, where the aerial lines may be quite lengthy.

Architectural Design

Corrugated steel pipe has clean symmetrical lines that have long drawn architects to apply CSP both in aesthetic and structural uses. Common uses are supports and free standing columns.

CSP entry columns for commercial building.

Ventilation and Fan Ducts

Mining, industry and construction operations require various degrees of ventilation to protect against health hazards arising from toxic gases, excessive heat, moisture, dust and possible explosions. Ventilation conduits or fan ducts extend from the ventilating fan to the portal of the fresh air tunnel or air shaft. Corrugated steel pipe ducts have been widely used for years due to their high strength-to-weight ratio. Further, they are fully salvable if a change of operations is necessary. They resist destruction from explosions, are fire resistant, and contribute to mine safety through confining explosion and fire in the event of disaster.

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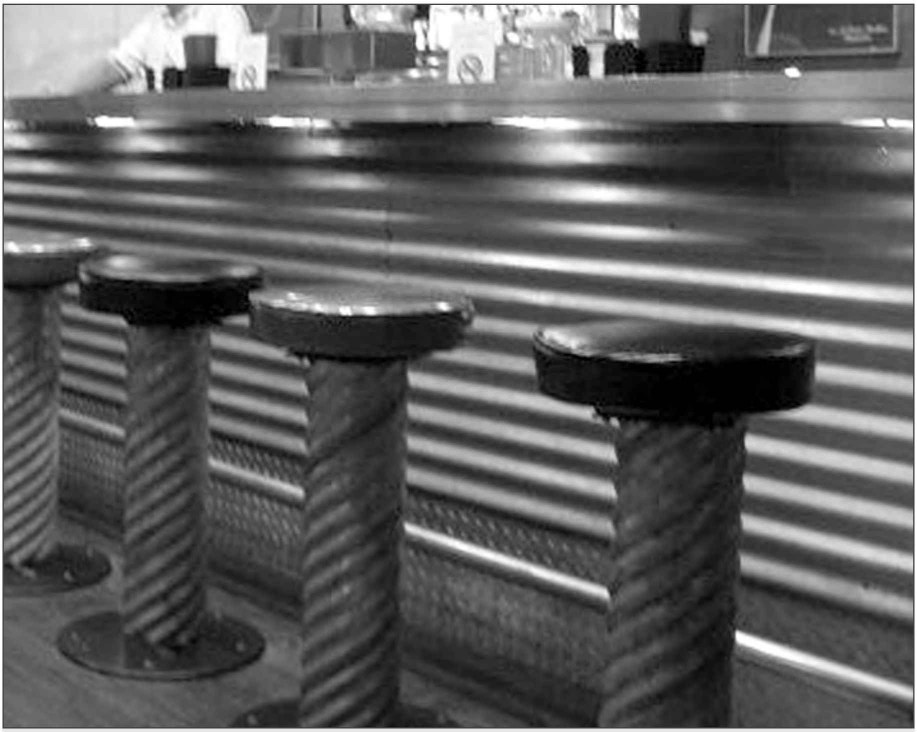
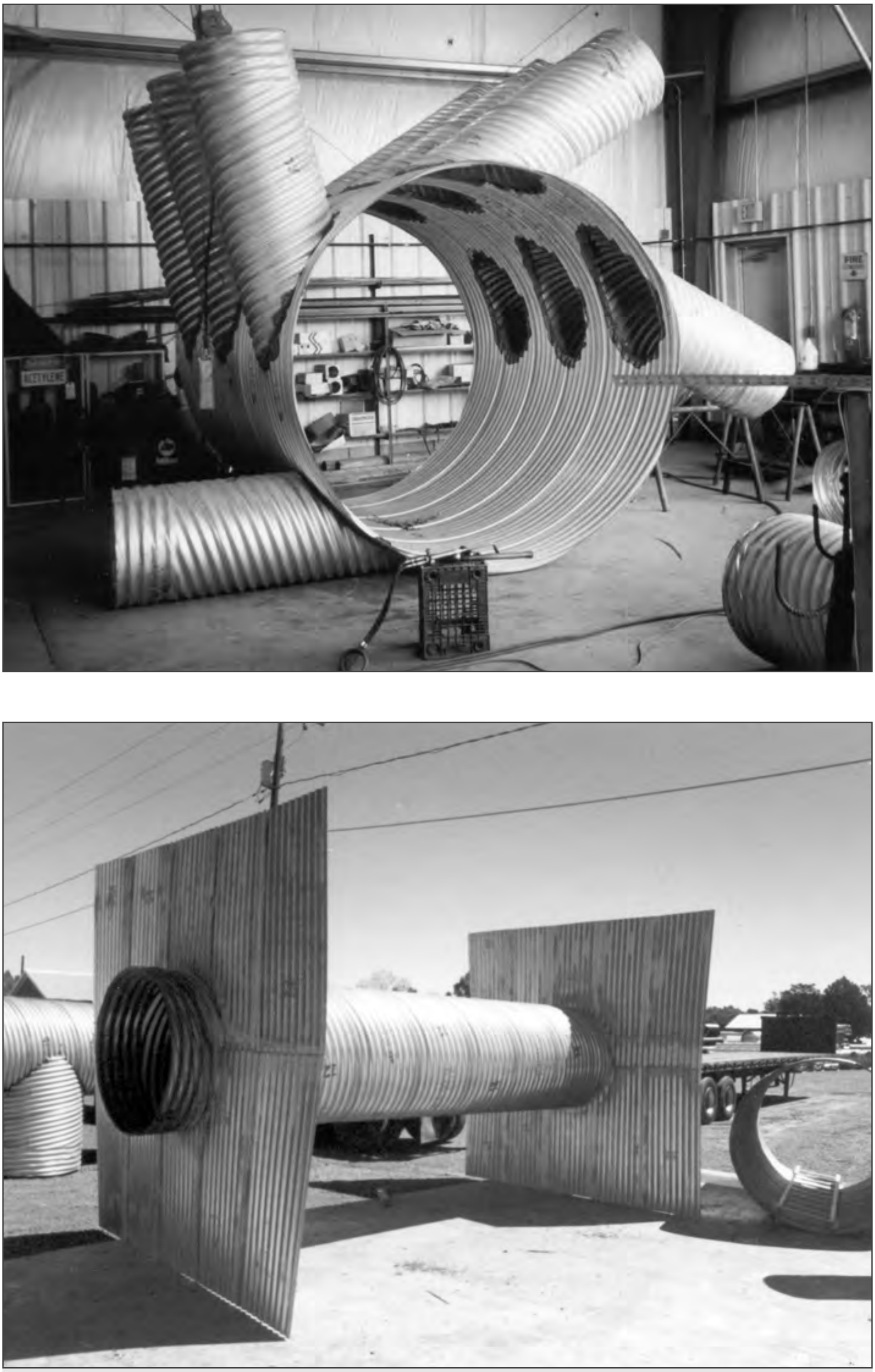


CSP and structural plate used in interior design.

A section of CSP used for an entry way.



Examples of the flexibility of CSP fabrication.