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H 500 FOUNDATIONS AND RETAINING STRUCTURES

H 510 PILES

The general construction specifications for pilings are published in the Standard Specifications, Section 205, including timber, steel, and concrete piles. Special Provisions should be included in the bid documents for additional control of materials, installation, and testing of piles. Standard Special Provisions are available from the Structural Engineering Division.

H 511 PILE TYPE SELECTION

The selection of foundation type should be a joint effort between the design engineer and the Geology and Soils Engineering Section, based on a soils investigation (refer to Subsection H 152.33, Geology and Soils Report).

When pilings are required, the following factors are among those to be considered in selecting the proper pile type:

a. **Economy of Section** - Comparing pile costs strictly on average costs per lineal foot might be misleading. The final cost will vary with the accessibility of the site, type of soil, required number of piles, and the total length of pile driven. The Utility and Estimating Division will provide comparative cost estimates.

b. **Type of Soil** - A good knowledge of the materials through which piles will penetrate and be founded is very important. The soil must be examined for its driving resistance, vertical load supporting capacity, lateral load supporting capacity, and the properties of the material to squeeze, cave, and heave.

c. **Required Load Capacity** - Most design problems will allow the engineer some flexibility to vary the spacing of piles and the required pile load capacity to obtain the most economical foundations. However, space limitations may determine the number of piles and, therefore, the required pile load capacity. The effect of group action of piles should be considered.

d. **Ground Water Level** - The elevation of the ground water table will vary with the amount of rainfall, ground water replenishment, and usage. Therefore, the elevations can only be assumed to be valid for the location and date observed, unless historical data from a nearby observation well is available and can be correlated.

e. **Proximity of Existing Structures** - It may be necessary to provide low displacement piles to prevent damage to existing structures. Damage may also be caused by foundation settlement or by heaving, or settlement from the driving operation.

f. **Pile Deterioration** - The major causes of pile deterioration are: Corrosion, insect attack, decay, marine-borer attack, mechanical wear, and fire. For completely buried foundation piles, only the first three factors need be considered. For waterfront structures, all factors must be considered.

g. **Pile Installation** - The installation of piling should be performed such that the technique used will maintain the structural integrity of the piling and also accomplish the desired interaction with the soil. The special provisions should include specific requirements for predrilling, prejetting, and jetting, including size of jet, depth of jet, water pressure, air pressure, volume of water, and final driving resistance. The special provisions should clarify the installation process and should be compatible with the minimum control requirements listed in the Standard Specifications or the Standard Special Provisions.

   General pile installation requirements are covered in Section 305-1 of the Standard Specifications. Standard Special Provisions with more specific requirements are available from the Structural Engineering Division.

Obtain Geology and Soils Engineering Section's recommendations as to type of pile and method of installation. Limit or exclude installation methods (such as jetting) if they would be harmful. The Contractor must install the piles in a way that will comply with the essential design requirements (e.g., jetting may reduce the intimate contact with adjacent earth necessary for resisting lateral force). Within these necessary limits, allow the maximum freedom of methods of installation. For example, as far as practicable, specify results, not methods, so that maximum economy and proper division of responsibility are maintained (see Reference 1).

During the preadvertising review, verify that such items as unit costs of piles and additional pile tests are included in the list of bid items.

H 512 PILE TYPES

H 512.1 CAST-IN-DRILLED-HOLE PILES

Under favorable conditions, CIDH (cast-in-drilled hole) piles (straight friction piles or belled-end bearing piles) are usually the most economical type. The concrete for these piles is placed in holes drilled in the soil to predetermined elevations. After the drilling operation is completed, all loose material and water existing at the bottom of the hole should be removed before placement of concrete. Casing may be required to prevent caving.

It may be difficult to cast concrete below the groundwater table without dewatering. Although placing concrete underwater can be successful if pumped with the slickline or tremie always below the level of rising concrete (and the concrete is not agitated so as to mix with the water above), the method is not recommended due to the difficulty of cleaning the drilled hole while wet, and the extra care required to obtain a satisfactory installation. (See reference 4 for procedure for placing CIDH piles where caving occurs.)

Due to caving and concrete placement difficulties, this type of pile should not normally be used as a batter pile. However, in some soils a small batter may be feasible.

In addition to the cost advantage of a drilled foundation, there is no soil displacement or vibration that could damage adjacent structures, noise of installation is reduced, lengths can be adjusted readily to fit field conditions, there is no damage to piles due to handling, minimal handling equipment is required for placement of reinforcing cage, and placement is sometimes possible in types of soil that a driven pile could not penetrate (bedrock, boulders, hard layers, etc.).

H 512.2 PRECAST PRESTRESSED PILES

These piles are able to withstand hard driving. They are more resistent to deterioration in marine environments due to the absence of cracks. The disadvantages are the time for curing, storage space, and necessity to predetermine the lengths. Predetermined lengths are a major disadvantage for splicing and for cut off, especially if special reinforcement or connections are required at the pile butt.

H 512.3 PRECAST PILES

These piles require time for curing and storage space. The lengths must be predetermined and, therefore, the piles may sometimes need to be spliced or cut off to suit actual required depth of driving. Splicing is difficult. Spalling of concrete at the butt is sometimes a problem.

H 512.4 STEEL PILES

HP-piles have a low displacement and sometimes are the only piles that can be driven without jetting or predrilling. The low displacement makes it easier to penetrate cobbles, boulders and soft bedrock and less damaging when driving adjacent to existing structures. H-piles are easy to handle and compact for storage and shipping. They are generally more expensive than others and should be used only where conditions will not permit the use of concrete piles. They are readily spliced by welding. In some environments corrosion protection is advisable.

H 512.5 TIMBER PILES

In general, all timber piles should be treated with a preservative. Untreated timber piles may be used for permanent construction where the pile cutoff is permanently below the ground water table, and for most temporary construction. Untreated timber piles should not be used where they may be subject to either attack from marine-borers or wet and dry cycles.

H 513 PILE DESIGN

The design of pile foundations should conform to BPDM, Volume I, Sections 4 and 2-16, Seismic Forces, as supplemented in this Section.

Piles for building structures are designed in accordance with LABC, Division 28. Railroad bridge piling should meet the requirements of the AREA "Manual for Railway Engineering", Volume I, Chapter 8, Parts 3 through 6.

H 513.1 MAXIMUM DESIGN LOADS, AXIAL

The following design pile loads are recommended for normal conditions, but may be increased as required by analysis if soil conditions permit. They are intended for piles fully embedded in soils that offer lateral support and should be decreased when other conditions prevail.

a. **Concrete** - Optional pile construction for 45 ton (400 KN) and 70 ton (623 KN) capacities are shown on the standard "Pile Details" sheets which are available from the Structural Engineering Division for inclusion in the contract drawings. Precast and prestressed piles are included.

b. **Steel** - The recommended design capacity for H-piles should be specified on the plans as follows:

10	BP42	-	45 tons	(400 KN)
12	BP53	-	60 tons	(534 KN)
10	BP57	-	70 tons	(623 KN)

Details are shown on the standard "Pile Details" sheets.

c. **Timber** - The recommended design capacity is 35 tons (311 KN) for timber piles with a minimum butt diameter of 12 inches (305 mm)~

H 513.2 ALLOWABLE LATERAL RESISTANCE

Piles should be designed to carry the lateral loads expected. Piles not fully embedded in soil, or where scour may occur should be designed as laterally loaded columns. The point of fixity may be assumed 5 feet (1.52 m) below ground line for compact sand-clay soils and 10 feet (3.05 m) below ground line in loose sand or medium density silt and clay. The soil should be investigated as necessary to determine its ability to resist the lateral forces transmitted.

For piles fully embedded in soil, the assumed allowable lateral resistance may be as listed in BPDM, Volume I, Article 4-15.8, lateral loads on piles. Timber piles can resist only negligible lateral loads.

For seismic design criteria, see Subsection H 233.5, Pile Foundations, and BPDM, Volume I, Article 4-15.8(3), Earthquake Lateral Loads.

H 514 BATTER PILES

When the lateral resistance of the piles is inadequate to counteract the lateral forces transmitted to the foundation, batter piles should be used. The lateral deflection of piles varies with the pile type and size, foundation material, and amount of lateral load (see References 2 and 3). In structures such as rigid frames, where movement of the footing is critical, the allowable lateral deflection should be determined and the lateral load to each pile limited. Also, battered piles can be used to limit deflections.

Batter piles may be assumed capable of resisting the same axial load as vertical piles of the same type and size, driven to the same stratum. The horizontal component of pile load should be added to the lateral resistance.

The maximum horizontal resistance of a battered pile consists of the horizontal component of force resulting from the batter and the lateral bearing resistance of the soil. In some cases, the passive soil resistance against the pile cap may also be used.

Soil friction at the bottom of the pile cap should not be used to resist lateral loads, due to possible settlement of the soil beneath the pile cap.

The slope of batter piles should not exceed one horizontal to three vertical. Consideration should be give to the possibility of encroachment on property outside of the right-of-way lines.

H 515 SPACING, CLEARANCE AND EMBEDMENT

Pile spacing should not be less than 3'-0" (0.91 m) center to center. A minimum of 1'-6" should be provided from edge of footing to centers of piies. Concrete piles should be embedded 3 inches (76 mm) into concrete footings. Steel piles should be embedded 5 inches (127 mm) and timber piles 8 inches (203 mm) into concrete footings.

H 516 PILING ADJACENT TO EXISTING STRUCTURES

When driving piling adjacent to an existing structure, restrictions may be required to avoid damage. These restrictions may include maintaining a clear distance between the piling and the structure and placing the piling in a hole predrilled to a sufficient depth prior to driving. When the existing structure belongs to another department or agency, their requirements should be complied with.

H 516.1 PILING IN U.S. CORPS OF ENGINEERS' RIGHT-OF-WAY

The minimum clearance and predrilling requirements when placing displacement or non-displacement piles within the Corps of Engineers' right-of-way is shown in Figure H 516.1. The depth of predrilling may vary depending on the pile spacing, pile size, and type of foundation soils encountered. The depths of predrilling indicated are conservative for some pile and soil combinations and may be reduced with sufficient justification.

The following requirements should be used in conjunction with Figure H 516.1:

a. When piles are driven in Zones A and B and several rows are to be driven, the row closest to the channel should be driven first.

b. When predrilling is required, to produce an annular space around the pile, the hole should have a diameter equal to the butt diameter of the pile plus 6 inches (152 mm).

c. After driving the pile, the annular space around the pile should be filled to the ground surface with dry sand or pea gravel.

H 516.2 PILING ADJACENT TO EXISTING SEWERS AND STORM DRAINS

H 516.21 SHEET PILING

The driving of sheet piling closer than a clear distance of 15 inches (381 mm) to unreinforced concrete, brick, or clay sewers or storm drains should not be permitted.

H 516.22 VERTICAL SUPPORT BEAMS

When steel HP-piles or other single vertical support beams are used as supports for trench sheeting alongside existing sewers and storm drains, they should be placed in drilled holes, without driving, to at least the following depths below the subgrade of the existing conduit. The predrilled holes should have a diameter not greater than the Major dimension of the pile at ground surface.

Reinforced Concrete Pipe or Structures - Predrill to the pipe or structure subgrade if the pile is less than 2 feet (0.61m) clear of the conduit.

Unreinforced Concrete, Brick, or Clay Pipes or Structures - If less than 2 feet (0.61 m) clear of the conduit, predrill to 2 feet below the subgrade.

If between 2 feet (0.61 m) and 5 feet (1.52 m) clear of the conduit, predrill to a line extending upward at a slope of 1-1/2 horizontal to 1 vertical from a point located 2 feet (0.61 m) below the conduit subgrade and at least 2 feet (0.61 m) distant from the outer face of conduit.

H 517 PILE LENGTH DESIGNATIONS

Pile lengths should be designated as follows on the "Foundation Plan":

Cast-in-drilled-hole piles - Designate the required tip elevation of the piles.

Driven piles - Designate the following, if known:

a. Minimum pile length, and

b. Estimated pile length and/or

c. Design pile length.

(Note: It is possible to have all three lengths equal.)

H 517.1 MINIMUM PILE 1ENGTH

Minimum pile length is that length of pile required to ensure adequate penetration to fully develop both the vertical and lateral capacities of the pile.

The minimum pile length should not be less than 12 feet (3.66 m) in hard material and 20 feet (6.1 m) in soft material. Greater minimum lengths should be determined jointly by the designer and the Geology and Soils Engineering Section and should be equal to or greater than those required by the following three criteria:

Horizontal Capacity of the Pile - A minimum pile length should be calculated to resist the design lateral force. This length is seldom critical, except in the case of very short piles or piles in soft material.

Geology of the Foundation - A minimum pile length should found the pile in favorable bearing material.

Percentage of the Estimated or Design Length - A percentage of the estimated or design length may be used to compensate for the possible variation between the actual and calcualted soil supporting capacity (85 percent is commonly used).

H 517.2 ESTIMATED PILE LENGTH

Estimated pile length is shown on the plans as a guide for estimating the work only if a pile load test is specified on the plans or Special Provisions.

This length of pile is determined from analysis of soil tests to provide the required load capacity.

The actual length of pile to be driven is determined by a dynamic formula, but should not be less than the "minimum pile length" shown on the plans. Standard Special Provisions which include a dynamic formula for calculating bearing values are available in the Structural Engineering Division.

H 517.3 DESIGN PILE LENGTH

Design pile length is the length shown on the plans to which piles must be driven unless "practical refusal" and "minimum pile length" requirements are satisfied at a lesser depth. "Practical Refusal" is defined as a bearing value of 150 percent of the required allowable load capacity as determined by dynamic formula.

This length is determined by the Geology and Soils Engineering Section and is based on soil strength criteria. The pile should be checked for structural strength, buckling, etc. Design lengths are generally presented in the soil report as a family of curves in which the allowable load is plotted versus the depth below pile cap.

H 518 TEST PILES

When the Geology and Soils Engineering Section recommends load testing of piles, the location and length of test piles should be shown on the plans.

Load testing should be in accordance with Subsection 305-1.7 of the Standard Specifications, as supplemented by the project's Special Provisions. Copies of load testing requirements for inclusion in the Special Provisions are available from the Structural Engineering Division.

H 519 JETTING

The general requirements for jetting are included in Section 305 of the Standard Specifications. Jetting is usually effective and practical in sands or fine silty cohesionless soils. It should not be permitted in clay soils or in coarse gravel, boulders, hardpan, and bedrock.

The influence of jetting on soil density as it affects lateral and vertical capacity and the interaction of soil and pile after installation must be considered from the soils mechanics aspect. All soils must be reconsolidated after jetting by driving the pile with a hammer. It is desirable to specify a minimum number of blows in addition to a minimum distance to be driven after jetting in order to achieve the expected pile capacity. Jetting should not be carried below this intermediate capacity, Jetting should not be carried below this intermediate pile tip elevation. The effect of jetting on adjacent structures and previously driven piles should be considered. Particular attention should be given to piles designed for high lateral loadings and the final condition of soil adjacent to the pile over its full length in the zone of jetting.

Following are some jetting techniques and uses:

Spuddin or Prejetting is the technique of forcing down a weighted jet of air and water at the pile location, breaking up hard layers, cemented strata, etc. The jet is then withdrawn and the pile installed in the same location. The jetting opens up a passage and also leaves the soils in a temporarily suspended or liquified condition which permits easier penetration of the pile.

Jetting is the technique of penetrating with a jet of air and water during pile driving, using a separate external pipe beside the pile (side jetting) or a pipe cast into the pile (center jetting). It is very effective in silty and sandy materials. The air and water flow up along the pile, lubricating the surface and reducing skin friction.

Side jets are sometimes used in pairs, or three or more as a ring, to provide uniform distribution of water around the pile. Center jets may have multiple nozzles to distribute the water around the pile.

In gravel soils, jetting may result in the collection of rock at the bottom of the jetted hole, making it difficult to drive the pile the required distance.

Driving in some water-bearing soils with a hammer may be difficult because the pore water pressure prevents forcing the soil away from the sides and tip of the pile, giving very high temporary resistance. Jetting may be beneficial in such cafes.

The **use of air** along with water aids in displacing soil and reducing skin friction. However, much jetting is done using water alone or with air in varying amounts at various pressures from high to low. Pressure build-up should be avoided to prevent "blow-out" which can displace large volumes of earth along tha pile and reduce its resistance to lateral loads.

H 520 FOOTINGS

The design of footings is outlined in BPDM, Volume I, Subsection 4-6. Minimum top reinforcement in spread footings and pile caps should be provided (see Subsection H 233.3, Footings).

H 530 ABUTMENTS

The design of abutments is discussed in BPDM, Volume I, Subsection 4-10 which may be supplemented by the design loads outlined in Subsection H 373.

In addition, refer to BPDM, Volume III, Section 1, for earthquake design aids and details. For bridge widenings, refer to Subsection H 247.32, Pier and Abutment Settlement, which indicates design features to use when extending an existing abutment to minimize differential settlement.

H 540 RETAINING WALLS

Generally, a structural element that provides lateral support to a mass of soil is considered a retaining wall and is designed to withstand earth pressure, including surcharge.

H 541 USES

Some of the more common uses of retaining walls are:

a. Hillside roads.

b. Elevated or depressed roads.

c. Terrace landscaping or planter boxes.

d. Canals and locks.

e. Erosion protection.

f. Flood control channel walls.

g. Bridge abutments.

h. Shorings for excavation.

i. Basement walls.

H 542 TYPES

The more common types of walls are illustrated in Figure H 542 and are as follows:

H 542.1 GRAVITY WALLS

A gravity retaining wall depends entirely upon its own weight to provide the necessary stability. Plain concrete, masonry or confined earth materials are used. (Also see Section 542.6). Lateral earth pressures do not produce significant stresses in the wall.

H 542.2 CANTILEVER WALLS

The cantilever retaining wall consists of thin reinforced concrete stressed in bending to resist lateral earth pressure. Stem, toe, and heel are designed as cantilever slabs. For small walls, reinforced concrete blocks may be used for the stem.

The walls can be T-shaped (as shown) or L-shaped. An L-shaped wall usually requires less excavation, but a larger footing to offset overturning forces. L-shaped walls are often used to avoid placing a wall footing on private property.

H 542.3 COUNTERFORT WALLS

The counterfort retaining wall resembles a cantilever wall and uses the weight of the soil for stability. The stem and heel are intersected at intervals by counterforts (bracing walls) over the heel slab. These act as tension ties and supports for the stem and heel slabs which span horizontally between counterforts and are supported on three sides. This type of wall is more economical than the cantilever type for height in excess of 25 to 30 feet (7.6 to 9.1 m).

H 542.4 BUTTRESSED WALLS

A buttressed wall is similar to a counterfort wall except that the buttresses (bracing walls) are on the toe side of the stem and act in compression. Stem and toe slabs span horizontally and are supported on three sides. Buttresses interfere with the use of space at the wall face and are rarely used.

H 542.5 TIEBACK WALLS

A tieback wall is a retaining wall tied horizontally to a deadman earth anchor embedded behind the wall. The wall spans both horizontally and vertically between tiebacks. Support at the base of the wall is from passive soil pressure on the footing. Tiebacks and deadmen may be installed in trench or in holes drilled from the face of the wall. Installation may proceed from the top down in the latter case, eliminating the need for temporary shoring or underpinning of existing adjacent structures.

H 542.6 CRIB WALLS

A crib wall is an earth filled box made of timber, precast concrete, or structural steel members of sufficient combined mass to form a gravity retaining wall. It may be economical for heights in excess of 30 feet (9.1 m).

H 543 FACTORS TO CONSIDER IN TYPE SELECTION

Following are some specific items to consider in addition to those listed under Subsection H 152.4, Project Type Selection.

H 543.1 RIGHTS-OF-WAY

Rights-of-way and easement acquisition may constitute a major portion of the total project cost and often govern the design and layout of retaining walls. It may be better to minimize the acquisition of easements by selection of a more costly type of wall.

H 543.2 SHORING

Shoring or slot cutting and stage construction may be required during construction of a wall due to conflicting use of rightof-way, existing structures, or soil problems. Both are expensive methods of construction when compared with temporary slopes, and should usually be minimized by selecting the proper wall type.

H 543.3 MAINTENANCE

Walls should be designed to minimize maintenance of earth slopes and wall finish. Common sources of maintenance problems include inadequate height of wall, settlement of fill behind wall, eroding of slopes behind wall, plugged weep holes, and deterioration of untreated or improperly treated timber or uncoated steel materials.

H 543.4 CONSTRUCTION DIFFICULTIES

Some construction difficulties that should be minimized by the design include: unusual configuration; complex special architectural effects; difficult accessibility to the work site; lack of room to maneuver heavy equipment; poor soil quality and difficulty of excavation; poor topography of site; and traffic hazards.

H 543.5 CONSTRUCTION PERIOD

If possible, projects in flood plains, with large excavations or high unprotected slopes, should be scheduled so that the construction can take place during the dry season (April 15 to October 15).

H 543.6 PUBLIC CONVENIENCE DURING CONSTRUCTION

Safe and adequate vehicular and pedestrian access through the construction area should be considered. Construction areas near schools should be protected with barriers.

H 543.7 PHYSICAL LIMITATIONS

Most utility lines in City-owned right-of-way are under revocable permit and can be relocated if the lines interfere with wall construction. Relocation of lines is expensive, however, and should be avoided wherever economically possible.

Oftentimes, trees are to be planted in the sidewalk area. When a footing extends under the sidewalk, the necessity for providing openings to accommodate the trees should be determined.

Walls should be designed to provide access to intersecting walkways and driveways.

H 543.8 RETAINING WALLS VERSUS SLOPES

If the designer has a choice between constructing a retaining wall or sloping the earth, he should study the two alternatives, taking into consideration the costs, aesthetics, maintenance, and function. It may be better in some cases to demolish or relocate an existing structure to avoid wall construction.

H 544 DESIGN CRITERIA

H 544.1 ALLOWABLE STRESSES

Design stresses are referenced in Chapter H 400.

H 544.2 REINFORCEMENT COVER

The minimum cover for reinforcement should conform to Subsection H 410. Vertical elements single formed against earth should be designed with 3-inch cover.

H 544.3 SAFETY RQUIREMENT

Walls subject to overturning should be designed using the following factors of safety:

Factor of safety against overturning = 1.75

Factor of safety against sliding = 1.50*

The resultant force should fall within the kern (middle 1/3) of Footing.

*The sliding friction coefficient between concrete and earth may be assumed 0.4, unless the soil report establishes a more accurate value. A factor of safety against sliding is included in this value and need not be added.

Earth above the top of the footing should not be assumed to develop passive resistance against sliding, except in the case of unusually deep footings.

H 544.4 WALL DESIGN

Minimum Thicknesses:

Thickness	**Design Condition**
6" (152 mm)	Walls and slabs with a single curtain of reinforcing.
8" (203 mm)	Walls and slabs with two curtains of reinforcing,
8" (203 mm) to 12" (305 mm)	For embedment of railing posts as necessary

Wall Joints - For reinforced concrete walls, joints in stems at 96-foot (29,26 m) intervals, maximum should be provided as shown on Standard Plan 5-505.

H 544.5 FOOTING DESIGN

Minimum Thickness - The minimum footing thickness should be 8 inches (203 mm).

Footing Steps - The maximum height of footing steps should not exceed 2' -0" or 1/3 the height of the shorter adjacent wall section. The location of steps should be shown on the plans. For typical footing step details, see Standard Plan S-505, Sloping Footings - For economy, retaining wall footings may be placed on a longitudinal slope in lieu of footing steps. The maximum slope should not exceed six percent.

H 544.6 DESIGN LOADS

H 544.61 DEAD LOAD

Dead loads are specified in Section H 320.

H 544.62 EARTH PRESSURES AND BACKFILL DRAINAGE

Earth Pressures - Vertical and lateral earth pressures for use in design are specified in Section H 370.

Backfill Drainage - Backfill drainage must be provided unless walls are designed to support saturated soils or the wall is founded entirely on highly permeable soil such that water cannot be contained behind it. Drainage is accomplished using weepers or curb drains, or continuous perforated pipe subdrains embedded in a crushed rock blanket. Curb drains are used whenever an existing or future sidewalk will be located at the wall face. Weepers are used for discharge onto landscaped or natural grade. Continuous subdrains are used exterior to basements of buildings or other structures unable to receive drainage at the wall face. Where structures are submerged or where water pressure buildup is unavoidable, design loadings should be based on submerged or saturated soils. (For typical drainage details, see Standard Plan S-505.)

H 544.7 ADDITIONAL DESIGN CRITERIA

H 544.71 EXCAVATION AND BACKFILL

Maximum height and slope of excavation and backfill should be noted on the Plans or in the Special Provisions as required by the soils report or by proximity of adjacent structures. Type of backfill material, method of excavation, method of shoring, and limits of excavation should be shown if needed.

H 544.72 TOP OF WALL DRAINS

Standard Plan S-503, "Top of Wall Gutters and Drain Details" provides details of gutters for removal of surface water collected at the top of retaining walls. Gutters should be provided when the horizontal area of runoff tributary to the top of wall is greater than 1,500 square feet (139.4 m2) for a single section of wall. Gutters are also provided when the surface water would otherwise discharge onto a sidewalk or in an area that would cause damage to public or private property.

The spacing and size of outlet channels should be based on the physical conditions at the site. The following guidelines may be used to determine these values, but should not supplant the judgment of the designer:

a. The maximum spacing of outlet conduits should be 200 feet (60.96 m). A larger conduit is preferred to two or more smaller conduits of an equivalent combined capacity in order to minimize the possibility of plugging at the inlet and internally.

b. The size of conduit may be calculated from the equation Q = CA (square root 2gh), or determined from the table below.

Inlet capacity Q should be at least the tributary drainage area times rainfall intensity. C = 0.62, A = 1/2 of the cross sectional area of the vertical pipe, h = 6" head (152 mm), 9 = acceleration due to gravity.

All units must be consistent in the above equation.

Conduit Size Diameter		**Isohyetal in./hr.**		**Maximum Horizontal Projected Drainage Area Per Conduit**	
in.	**(mm)**			**sq. ft.**	**(sq. m.)**
4	(102)	1.33	(Valley area)	1900	(176.5)
		1.55		1600	(148.6)
		1.77		1450	(134.7)
		1.98	(Mounain area)	1250	(116.1)
6	(152)	1.33	"	4450	(413.3)
		1.55	"	3800	(353.0)
		1.77	"	3350	(311.5)
		1.98	"	3000	(278.7)
8	(203)	1.33	"	7650	(710.7)
		1.55	"	6550	(608.5)
		1.77	"	5750	(534.2)
		1.98	"	5100	(473.8)

The above table is based on the following criteria:

a. Drainage area is 100 percent impervious.

b. Maximum head on the conduit is 6 inches (152 mm).

c. Design storm frequency is 10 years.

d. Time of concentration of runoff is 55 minutes.

H 544.73 HANDRAILS

Fences or railings should be placed on top of or adjacent to retaining walls whenever "reasonable" access to the top of wall will exist. It is generally not necessary to provide them when backfill slope exceeds 2:1 and it usually is necessary if backfill slope is 2:1 or less or children are expected to frequent the site and gain access of the top of wall. Some types of handrails commonly used are shown in Figures H 243A, B, C, Railing; also, see Standard Plan 546-3. Guidelines for use of handrails are shown in Figure H 5442732

H 544.74 RETURN

Return walls extend into the backfill at right angles to the main wall. They provide a finished appearance in lieu of slope run-out at ends of walls or where wall offsets are used or when the top of wall is stepped at changes in finished grade of backfill. The availability and cost of any additional right-of-way should be included when considering the use of return walls.

H 544.75 WINGWALLS

Wingwalls are retaining walls placed at slope transitions at the ends of other retaining structures such as box culverts or bridge abutments. Wingwall structures may be supported separate from or built monolithic with the main structure. Differential settlement can result in unpleasant appearance and extra maintenance at railing, curb, or sidewalk and should be avoided. Cantilevering wingwalls from the main structure, placement of wingwall footings on piles and use of shear keys at the interface are methods used to prevent differential settlement.

H 545 STANDARD PLANS

The following City of Los Angeles Standard Plans for retajning walls are available:

S-500 Reinforced Concrete Retaining Wall Type 3
S-501 Reinforced Concrete Retaining Wall Type 4
S-502 Reinforced Concrete Retaining Wall Type 5

S-503 Top of Wall Gutters and Drain Details

S-504 Reinforced Concrete Return Wall Details

S-505 Retaining Wall Miscellaneous Details

B-3251 Metal Bin-Type Retaining Wall

B-3669 Bulkhead for Retaining Street Fills

B-3704 Reinforced Concrete Cribbing

B-3760 Reinforced Concrete Retaining Wall (H=6'-0" (1.83 m) max.)

B-3761 Concrete Block Retaining Wall (H=6'-0" (1.83 m) max.)

H 546 COMPUTER PROGRAMS

Computer programs are available for design or analysis of retaining walls and tieback or cantilever shoring systems (see Section H 190, Computer Applications).

H 547 CULTURAL AFFAIRS DEPARTMENT APPROVAL

Cultural Affairs Department approval for retaining walls is discussed in Section H 600, Architecture.

REFERENCES

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