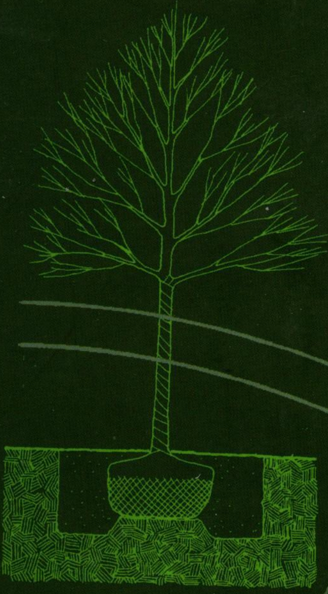
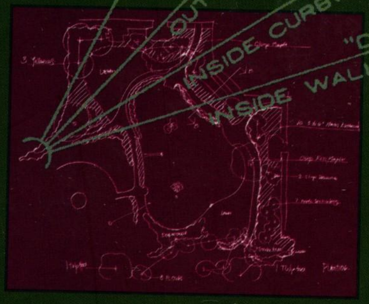
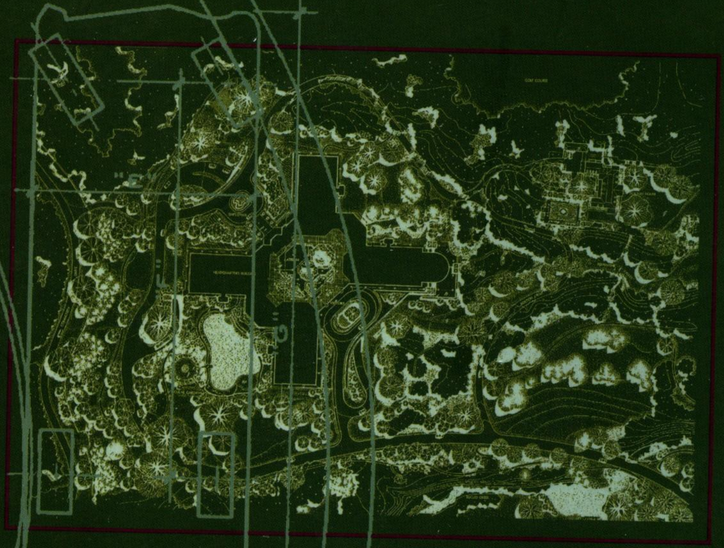
TIME-SAVER STANDARDS

FOR LANDSCAPE ARCHITECTURE

second edition







CHARLES W. HARRIS
NICHOLAS T. DINES

EXTENDED LENGTH VEHICLES
DIMENSIONS AND TURNING RADII

MAKE OF CAR	"A"	"B"	"C"	"D"	"E"	"F"	"G"
Cadillac	30'–0"	28'–6"	18'–11 1/2"	18'–9"	6'–11"	13'–0"	20'–10 1/4"
Dodge	23'–4"	21'–9"	13'–4 1/2"	12'–10 3/4"	6'–8"		18'–4"

Table of Contents

SECTION 240:

Outdoor Accessibility

SECTION 252

Natural Hazards: Earthquakes

SECTION 253

Natural Hazards: Landslides and Snow Avalanches

SECTION 254

Natural Hazards: Land Subsidence

SECTION 255

Natural Hazards: Expansive Soils

DIVISION 300 Techniques

SECTION 320

Site Grading

SECTION 330

Stormwater Management

SECTION 340

Pedestrian Circulation

SECTION 341

Bicycle Circulation

SECTION 342

Vehicular Circulation

DIVISION 400 Structures

SECTION 410

Retaining Walls

SECTION 420

Small Dams

SECTION 440

Surfacing and Paving

SECTION 450

Fences, Screens, and Walls

SECTION 460

Wood Decks and Boardwalks

SECTION 470

Pedestrian Bridges

DIVISION 500 Improvements

SECTION 510

Site Furniture and Features

SECTION 520

Recreational and Athletic Facilities

SECTION 530

Pools and Fountains

SECTION 540

Outdoor Lighting

SECTION 550

Plants and Planting

DIVISION 600 Special Conditions

SECTION 610

Roof and Deck Landscapes

SECTION 620

Interior Landscapes

SECTION 640

Disturbed Landscapes

SECTION 660

Sound Control

DIVISION 700 Site Utilities

SECTION 710

Water Supply

SECTION 720

Sewage Disposal

SECTION 740

Recreational Water Bodies

SECTION 750

Irrigation

DIVISION 800 Materials

SECTION 810

Soils and Aggregates

SECTION 820

Asphalt

SECTION 830

Concrete

SECTION 840

Masonry

SECTION 850

Wood

SECTION 860

Metals

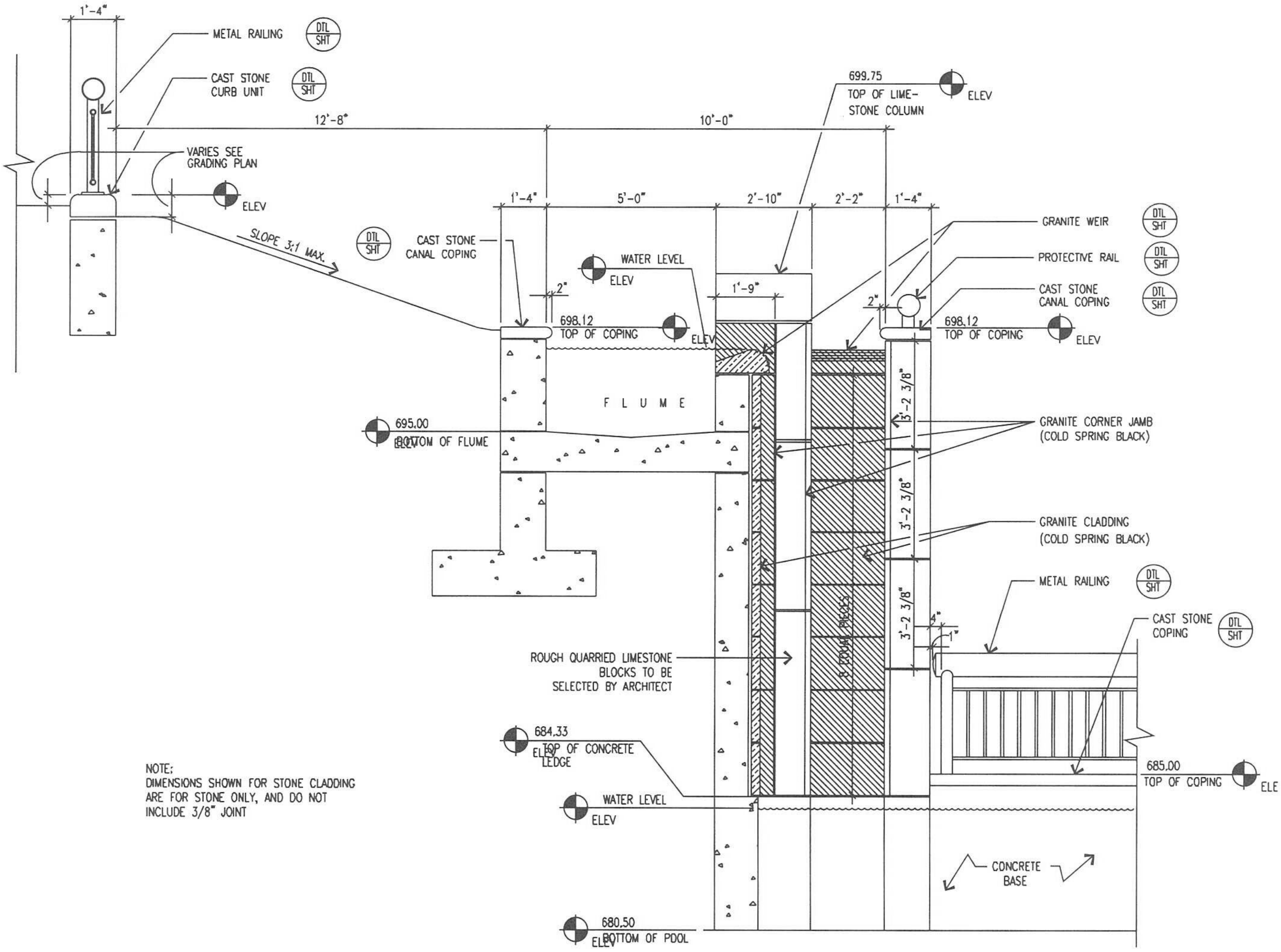
SECTION 870

Plastics and Glass

SECTION 880

Geotextiles

DIVISION 900 Details and Devises



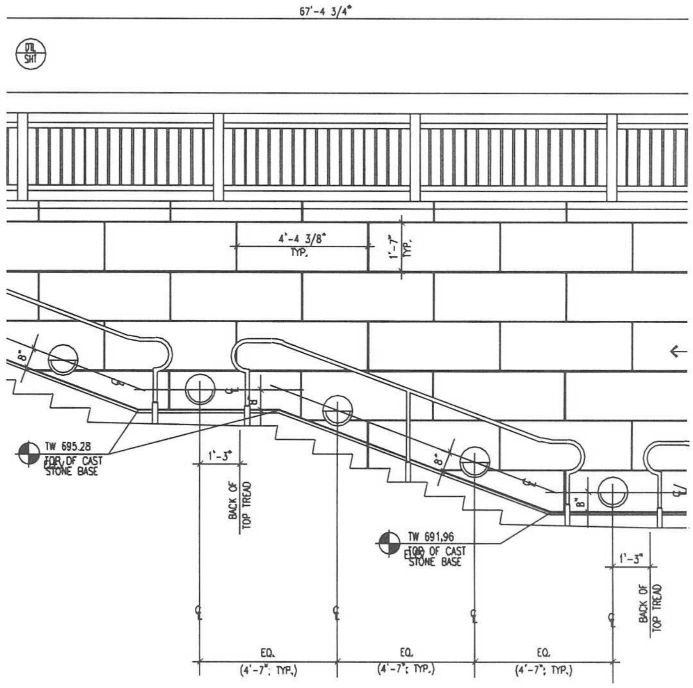


Figure 110-5. Site details and sections.

- ☐ *Earthwork sections*
- ☐ *Pavements, curbs and edgings*
- ☐ *Shelters, decks*
- ☐ *Screens, walls and steps*
- ☐ *Furnishings and features*
- ☐ *Utilities*
- ☐ *Plant installation*

SECTION 130

Site Construction Operations

CREDITS

Section Editor:
Nicholas T. Dines

Reviewer:
Mark J. Zarrillo, FASLA
Symmes, Maini, and McKee Associates
Cambridge, MA

Sarah Gronquist

CONTENTS

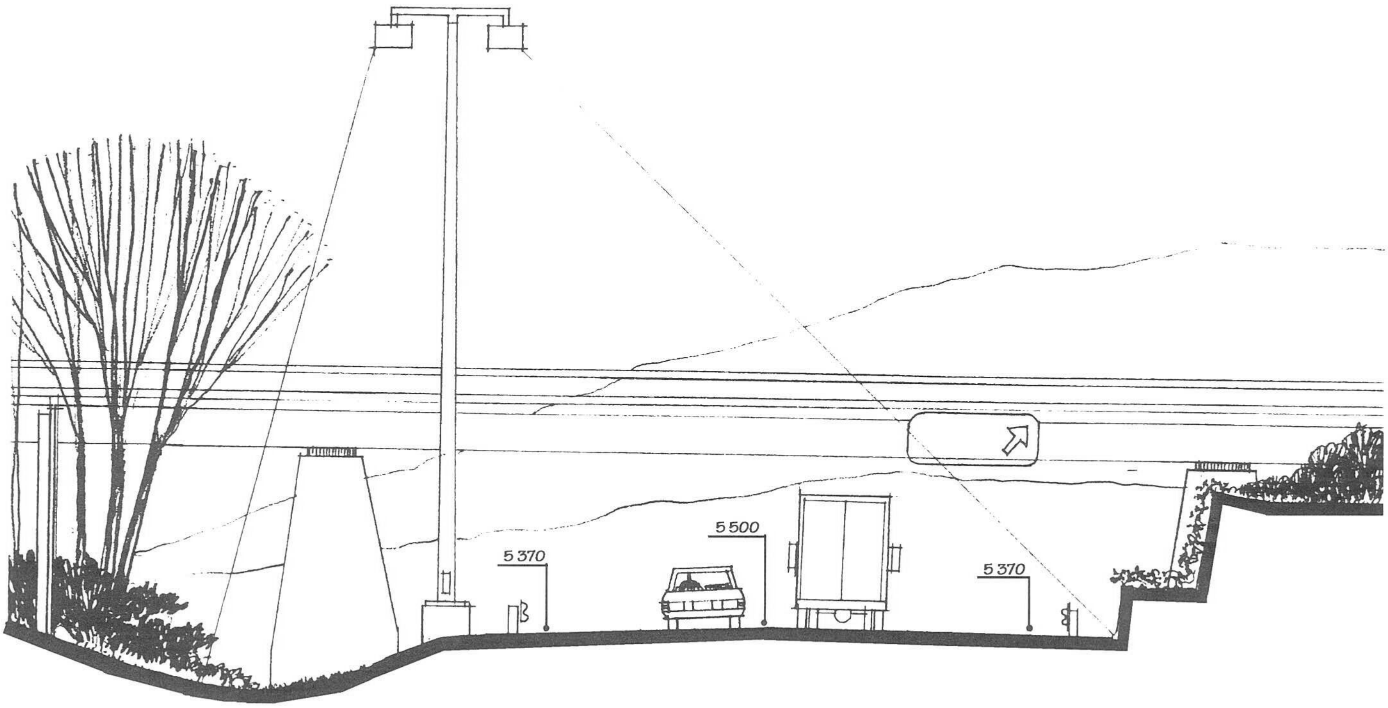


Figure 130-1 a. A typical design cross section emphasizing finished surface elevations.

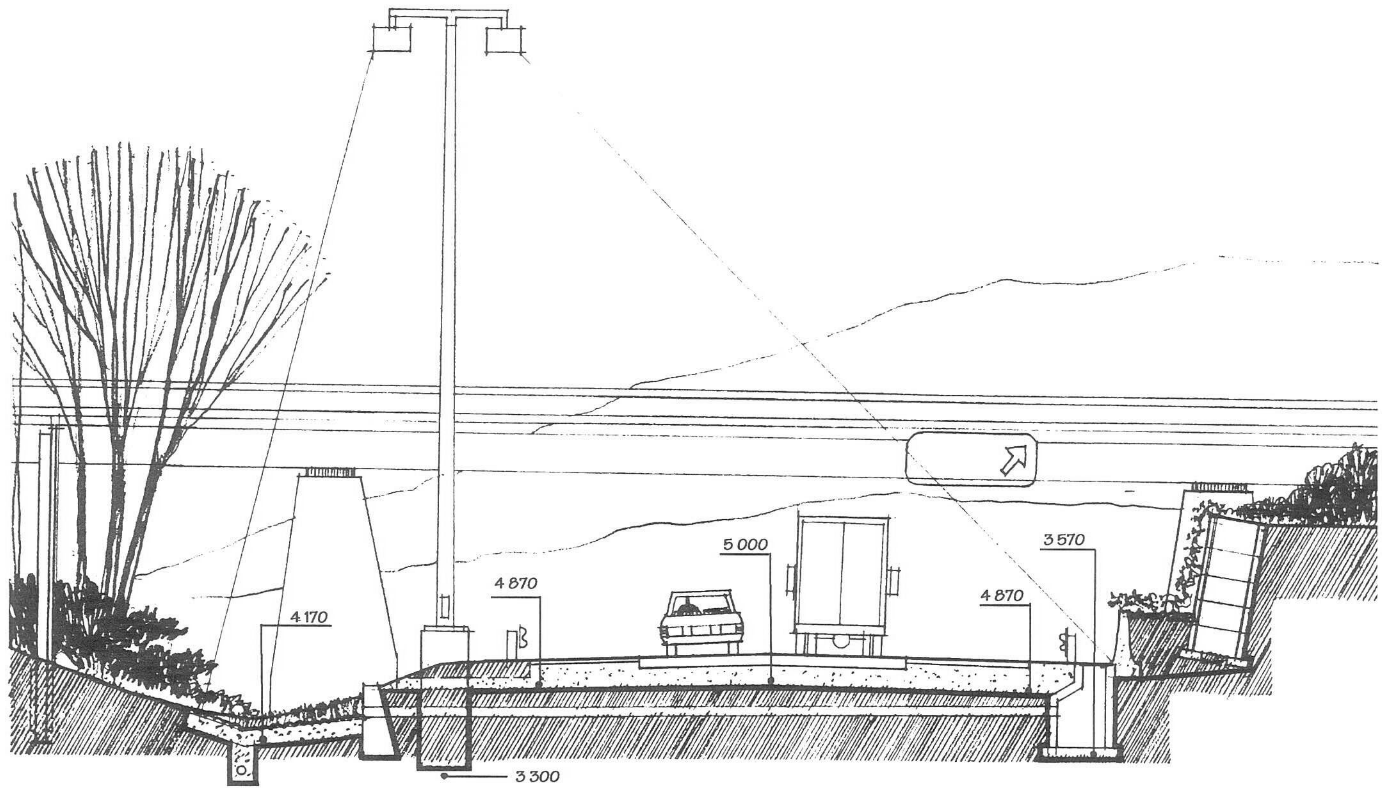


Figure 130-1 b. A contractor's analysis of the same design with emphasis on the subgrade elevations.

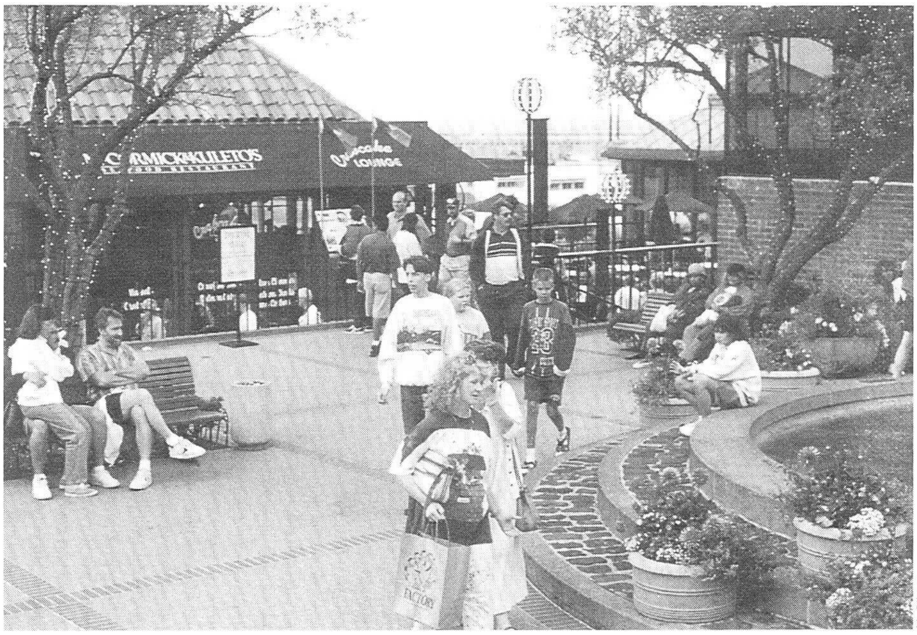
Spatial Standards

CREDITS

Contributor:
Nicholas T. Dines, FASLA

CAD Drawings:
Dou Zhang

Technical Review:
Vollmer Associates
New York, NY



N. Dines

CONTENTS

1.0 INTRODUCTION

Human spatial standards are derived from ergonomic and cultural data and vary widely across cultures and land-use settings. Standards are often established to provide:

1. Minimal safety clearances (ergonomic/legal)
2. Perceived user comfort (psychological/perceptual)
3. Ceremonial protocol (cultural/ritual)
4. Aesthetic choice (personal/cultural)

Most "normative" standards require cultural adjustment before being applied to a particular design setting. Cultural standards are often referred to as the "hidden dimension," and at times may contradict strictly

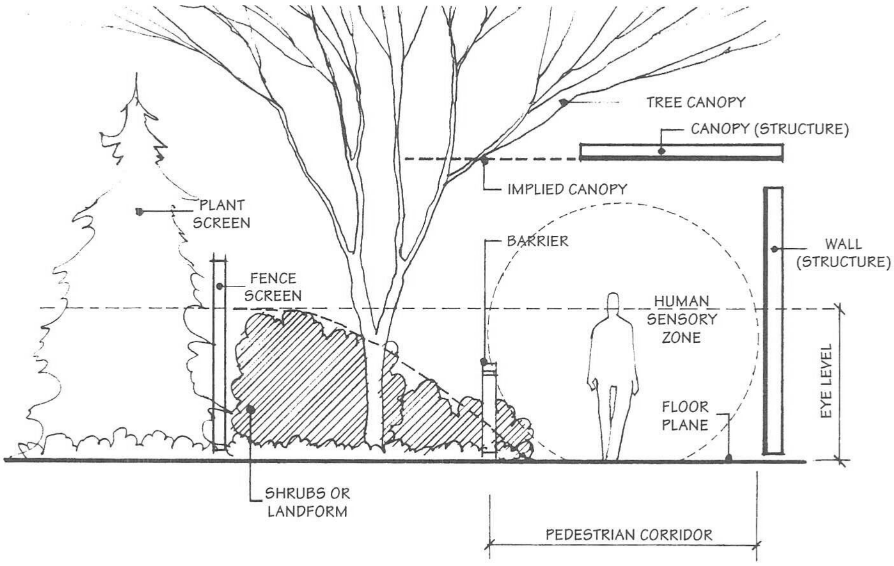


Figure 210-1. Elements of spatial enclosure: floor, wall, canopy, modified by time, light, climate, and intensity of activity.

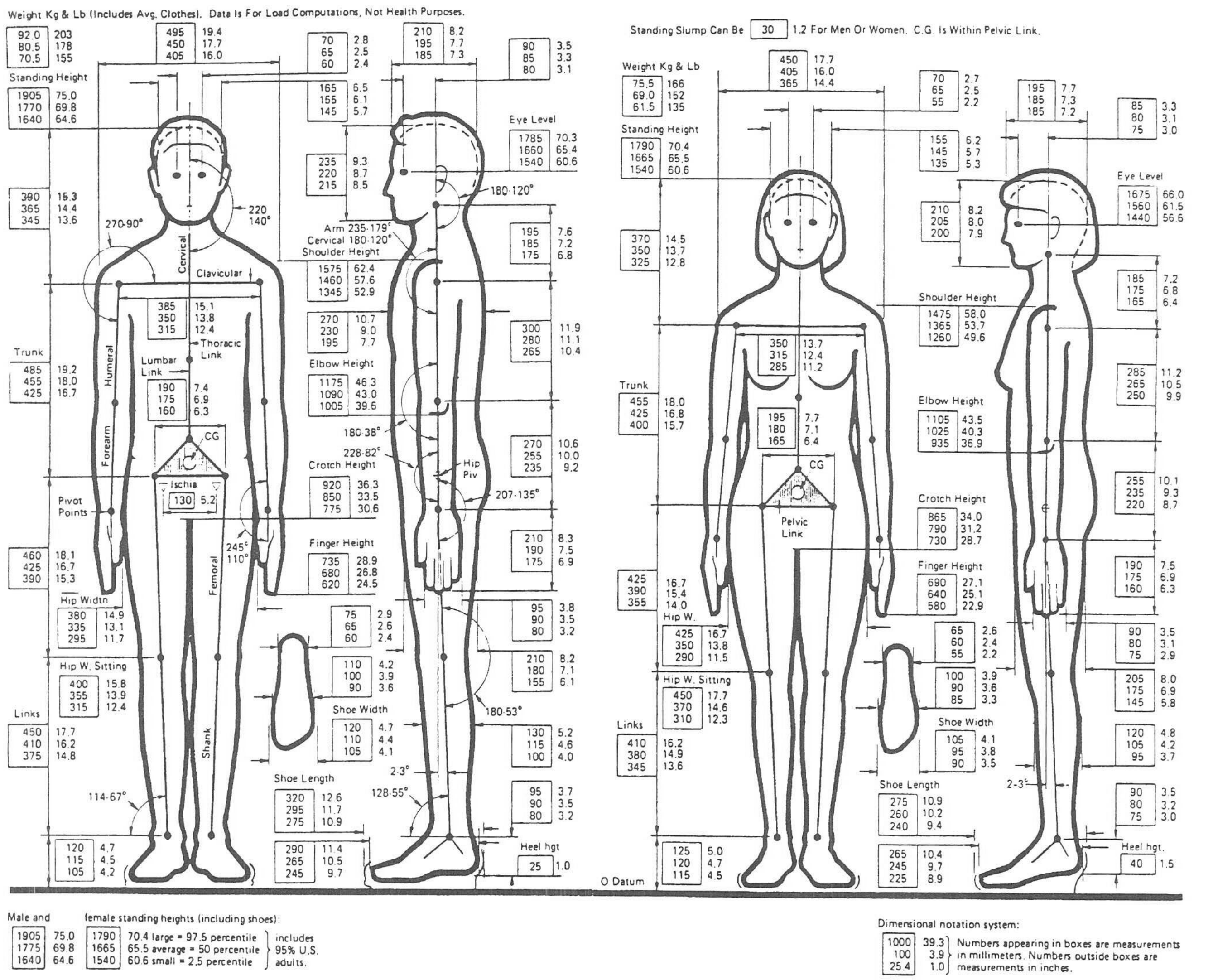


Figure 210-2. Standing adult male and female dimensions. *(Anthropometric data provided by Henry Dreyfuss Associates).*

SECTION 220

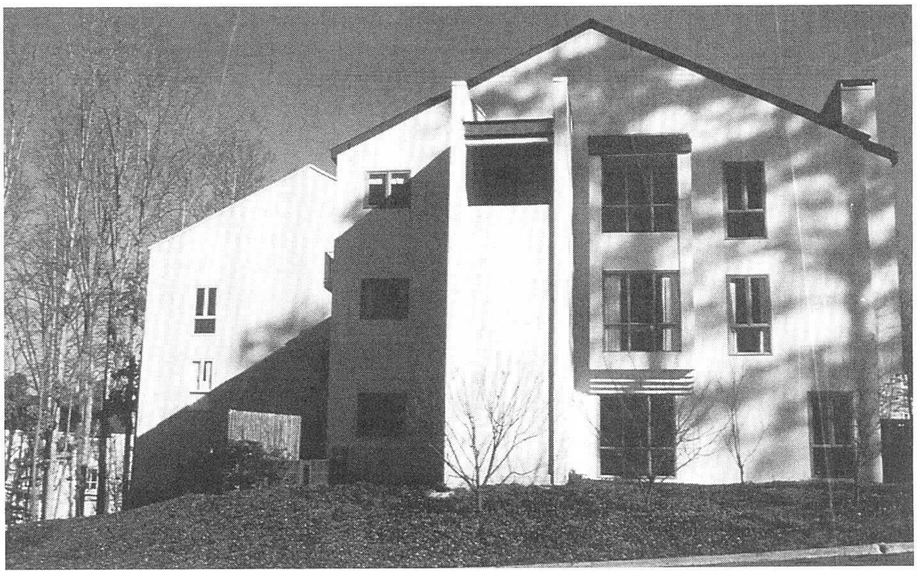
Energy and Resource Conservation

CREDITS

Contributor:
Nicholas T. Dines, FASLA

Technical Writer:
Kyle D. Brown

Reviewer:
John Furlong
Coordinator
Landscape Design Program
Radcliffe College
Cambridge, MA


N. Dines

CONTENTS

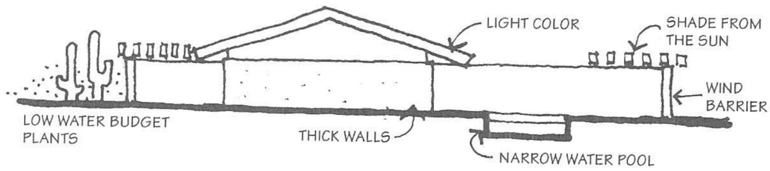


Figure 220-5. General site design strategies for hot arid regions.

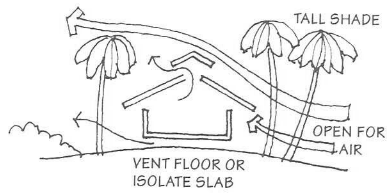


Figure 220-6. General site design strategies for hot humid regions.

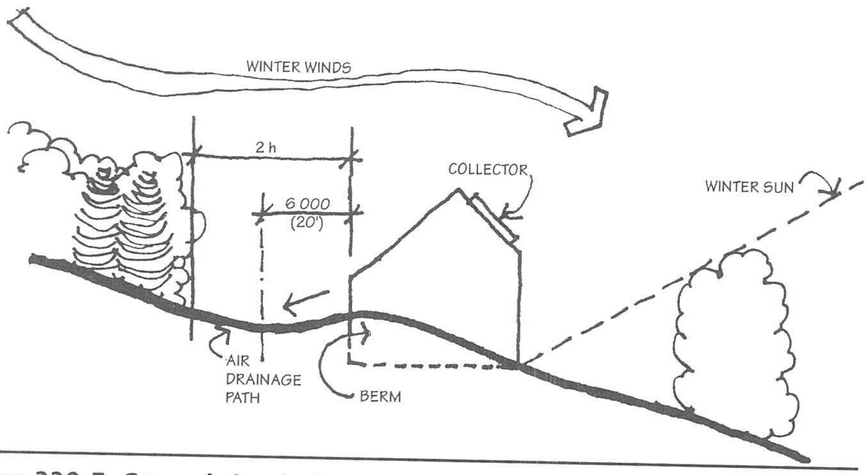


Figure 220-7. General site design strategies for temperate and cold regions.

Table 220-01. SUMMARY OF REGIONAL BIOCLIMATIC STRATEGIES

Factors Modified by Landform, Vegetation, and Structures	Climate Zones			
	Hot Arid	**Hot Humid**	**Temperate**	**Cold**
Sun	• Avoid heat absorbing materials use; thick walls or earthshelters • Use pergola and trellis structures for shade • Provide large overhangs on buildings • Avoid large area of exposed glass	• Maximize shade through the use of plantings • Use pergola and trellis structures for shade • Screened terraces provide relief from direct heating of main structure • Provide large overhangs on buildings • Use high ceilings and vent all roof systems	• Site structures on southerly slopes for solar gain in winter • Avoid northern entrances to buildings • Plant deciduous trees for afternoon shade • Use earthshelters to protect from summer sun	• Site structures on southerly slopes for solar gain in winter • Cold climate siting benefits from steeper slopes for better solar access • Avoid northern entrances to buildings • Plant deciduous trees for afternoon shade • Use earthshelter to protect from summer sun
Wind	• Site structures at toe of slopes for exposure to cold air flows at night • Use plant material to block desiccating winds • Deflect hot winds with walls and screens	• Site structure at top of slope for exposure to breezes • Avoid excessive earthmounding that may trap moist air • Maximize breezes through use of high canopy trees and with a loose open planting pattern • Avoid tall solid walls that block wind	• Site structure on middle to upper slope for access to light winds, but protection from high winds • Landforms, plants, and structures can be used to divert northerly winter winds while allowing cooling summer breezes • Use earthshelters to protect from winter winds	• Site structure on middle to lower slope for wind protection • Plant coniferous shelter belts to block cold winds • Avoid topographic depressions that collect cold air • Use earthshelters to protect from winter winds
Water	• Use moisture conserving plants-xeriscape • Limit impervious surface to minimize runoff-porous paving can be used	• Avoid siting next to stagnant bodies of water • Maximize infiltration of stormwater runoff	• Use of retention/ detention ponds for stormwater provides for evaporative/cooling of the site • Foundations for structures and pavement must drain well to prevent damage from frost/thaw action	• Use of retention/ detention ponds for stormwater provides for evaporative cooling of the site • Foundations for structures and pavement must drain well to prevent damage from frost/ thaw action

storing energy, increasing humidity, and diverting desiccating winds.

Hot Humid Regions: Characterized by hot summer temperatures [>20°C (68°F)] and mild to cool winters [>0°C (32°F)]. Annual precipitation and humidity are high, with frequent rain showers. Freezing temperatures are uncommon, and relatively minor diurnal temperature fluctuations are typical. Site planning and design should seek to increase shade, cooling from evaporation, and breezes.

Temperate Regions: Characterized by hot, often humid, summers [>20°C (68°F)] and cold winters [<0°C (32°F)]. Annual precipitation is fairly high. The region is subject to repetitive freezing/thawing action, and significant seasonal temperature fluctuations are common. Site planning and design should seek to promote shade and evaporative cooling in warm periods, and block winds and promote heat gain in cool periods, without disrupting favorable summer wind pattern.

Cold Regions: Characterized by mild summer temperatures [>10°-20° C (50°-68° F)] and very cold winters [<0° C (32° F)]. Annual precipitation is typically low. Region is subject to extreme freezing/thawing action. Site planning and design should seek to control winter winds, and promote solar gain and storage.

Figure 220-2 illustrates a topographic section showing the theoretical "most favorable" microclimate location for each climate region. Hot Arid climates favor the eastern slope base to avoid harsh sun and to receive cool diurnal air drainage for the upper slope. Hot Humid climates favor the top of the eastern slope to avoid harsh west sun and to receive the evaporative cooling effect of winds due to turbulence at the hilltop. Temperate climates are most favorable at the south-east "military crest" to receive both sun and breezes, but to avoid cold winds at the true crest. Cold climates are ideal on the south to south-western lower slope to receive solar radiation and be protected from winter winds, but high

Outdoor Accessibility

CREDITS

Section Editor:
Nicholas T. Dines

Contributor:
Gary M. Fishbeck

Technical Writer:
Jeffrey D. Blankenship

Research Assistant:
Amy Ansell

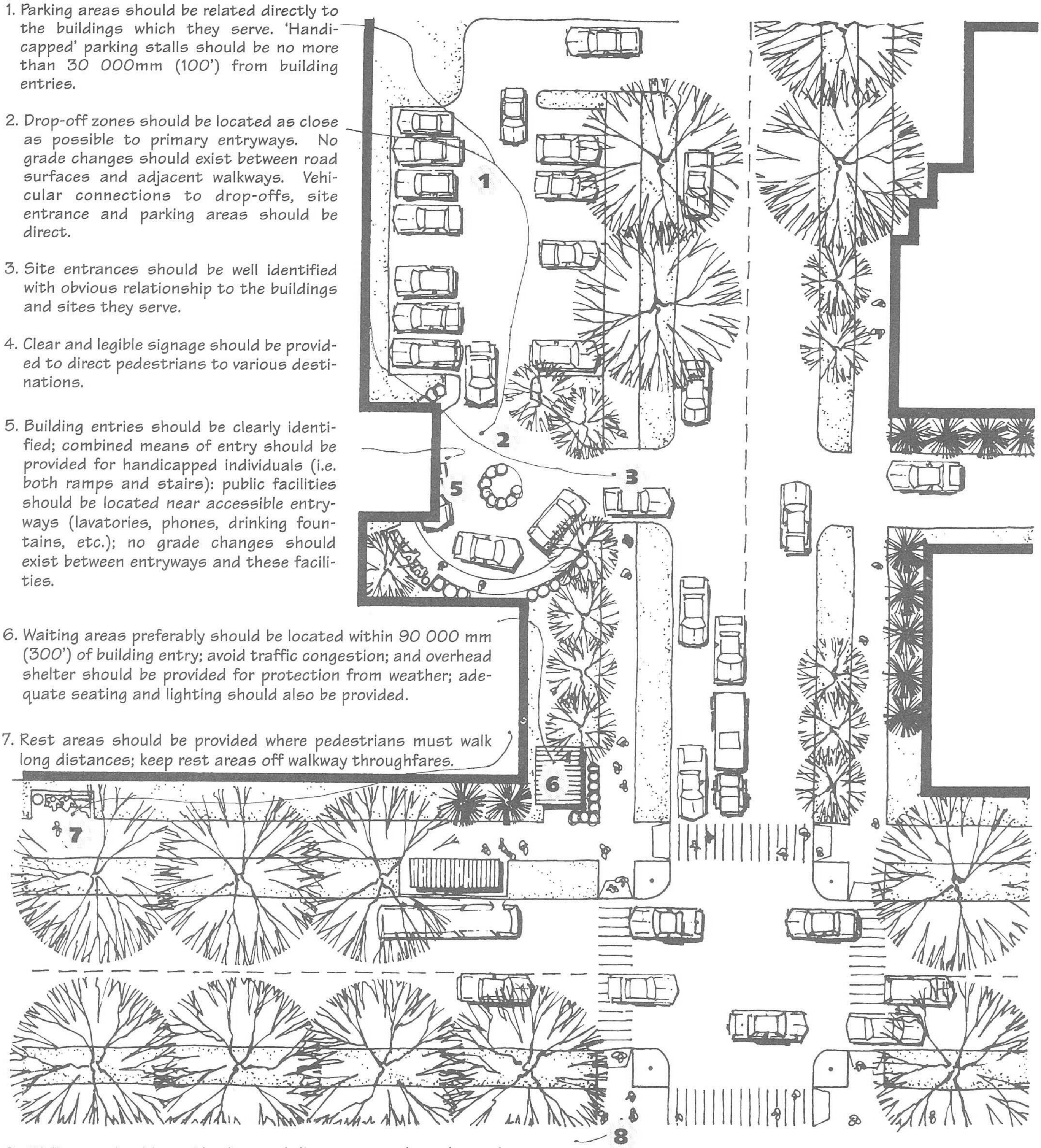
Graphics:
Laura Burnett, ASLA
Wallace, Roberts and Todd
San Diego, California

Reviewers:
John P.S. Salmen, AIA
National Center for a
Barrier-Free Environment
Washington, DC

Jay L. Jorgensen, ASLA
Annandale, Virginia


Kyle D. Brown

CONTENTS



1. Parking areas should be related directly to the buildings which they serve. 'Handicapped' parking stalls should be no more than 30 000mm (100') from building entries.

2. Drop-off zones should be located as close as possible to primary entryways. No grade changes should exist between road surfaces and adjacent walkways. Vehicular connections to drop-offs, site entrance and parking areas should be direct.

3. Site entrances should be well identified with obvious relationship to the buildings and sites they serve.

4. Clear and legible signage should be provided to direct pedestrians to various destinations.

5. Building entries should be clearly identified; combined means of entry should be provided for handicapped individuals (i.e. both ramps and stairs): public facilities should be located near accessible entryways (lavatories, phones, drinking fountains, etc.); no grade changes should exist between entryways and these facilities.

6. Waiting areas preferably should be located within 90 000 mm (300') of building entry; avoid traffic congestion; and overhead shelter should be provided for protection from weather; adequate seating and lighting should also be provided.

7. Rest areas should be provided where pedestrians must walk long distances; keep rest areas off walkway throughfares.

8. Walkways should provide clear and direct routes throughout sites: surfaces should be firm and level; curb cuts and ramps should be provided where necessary; accessible walkways should consist of closed loops rather than dead ends.

Figure 240-1. Accessible route. *An accessible route ensures that all people will have uninterrupted access to facilities.*

SECTION 252

Natural Hazards: Earthquakes

CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
Kyle Brown
Tess Canfield

Reviewers
Susan Tubbesing, Executive Director
Earthquake Engineering
Research Institute
Oakland, California

Michael Kukla, Librarian, (library search)
National Center for Earthquake
Engineering Research
State University of New York,
Buffalo, New York

Natural Hazards Research and
Applications Information Center
Boulder, Colorado

Daniel L. Schodek, Professor
Harvard Graduate School of Design
Cambridge, Massachusetts

CONTENTS

1.0 INTRODUCTION

Earthquakes are essentially vibrations of the earth's crust caused by subterranean ground faults or movements. They can cause injury or death to people and animals, damage or destruction to structures and landscapes. They create primary hazards such as surface rupturing, displacement of land, ground shaking, earthquake-induced ground failures, and oscillation of water surfaces. Secondary hazards are landslides, fires, floods, subsidence, and tsunamis (large sea waves) [Refer to Sections 253 through 255 for information on other types of natural hazards].

The data presented in this section is not a general discussion of earthquakes. It seeks to focus on how the potential risks associated with earthquakes should influence (a) land use planning and (b) design and engineering of landscapes, structures and infrastructure systems. Some of the references listed at the end of this section contain additional general and technical information. In all cases, it is assumed that professional expertise will be needed to determine the detailed design and engineering requirements for all large man-made structures and major earthworks.

2.0 CAUSES OF EARTHQUAKES

2.1 Plate Tectonics

The earth's crust and upper mantle are composed of a mosaic of 80- to 100-km- (50- to 60-mile) thick rigid plates which move slowly and continuously over the interior of the earth resulting in pressure, separation or sliding at plate edges. As these plates move, strain accumulates, eventually causing faults along boundaries when the plates slip abruptly. The resultant release of stress, which usually occurs within a few cubic kilometers of the earth's crust, is called an earthquake. Figure 252-1 shows the major tectonic plates of the world. Figure 252-2 shows the world-wide distribution of earthquakes occurring in the mid- to late-20th century, up to 1987.

2.2 Other Causes

Other causes of earthquakes include volcanic activity, injection of liquid wastes into susceptible rock strata, and the weight of new large dams and their associated reservoirs.

Table 252-1. MODIFIED MERCALLI INTENSITY SCALE

I.	Not felt except for a very few under exceptionally favorable circumstances.
II.	Felt by persons at rest, on upper floors, or favorably placed.
III.	Felt indoors; hanging objects swing; vibration similar to passing of light trucks; duration may be estimated; may not be recognized as an earthquake.
IV.	Hanging objects swing; vibration similar to passing of heavy trucks, or sensation of a jolt similar to a heavy ball striking the walls; standing motor cars rock; windows, dishes, and doors rattle; glasses clink and crockery clashes; in the upper range of IV wooden walls and frames creak.
V.	Felt outdoors; direction may be estimated; sleepers wakened, liquids disturbed, some spilled; small unstable objects displaced or upset; doors swing, close, or open; shutters and pictures move; pendulum clocks stop, start, or change rate.
VI.	Felt by all; many frightened and run outdoors; walking unsteady; windows, dishes and glassware broken; knickknacks, books, etc., fall from shelves and pictures from walls; furniture moved or overturned; weak plaster and masonry D* cracked; small bells ring (church or school); trees and shrubs shaken (visibly, or heard to rustle).
VII.	Difficult to stand; noticed by drivers of motor cars; hanging objects quiver; furniture breaks; damage to masonry D, including cracks; weak chimneys break at roof line; fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments); some cracks in masonry C*; waves on ponds; water turbid with mud; small slides and caving in along sand or gravel banks; large bells ring; concrete irrigation ditches damaged.
VIII.	Steering of motor cars affected; damage to masonry C or partial collapse; some damage to masonry B*; none to masonry A*; fall of stucco and some masonry walls; twisting and fall of chimneys, factory stacks, monuments, towers and elevated tanks; frame houses moved on foundations if not bolted down; loose panel walls thrown out; decayed piling broken off; branches broken from trees; changes in flow or temperature of springs and wells; cracks in wet ground and on steep slopes.
IX.	General panic; masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged; general damage to foundations; frame structures, if not bolted, shifted off foundations; frames racked; serious damage to reservoirs; underground pipes broken; conspicuous cracks in ground; in alluviated areas sand and mud ejected, earthquake fountains and sand craters appear.
X.	Most masonry and frame structures destroyed with their foundations; some well-built wooden structures and bridges destroyed; serious damage to dams, dikes, and embankments; large landslides; water thrown on banks of canals, rivers, lakes, etc.; sand and mud shifted horizontally on beaches and flat land; rails bend slightly.
XI.	Rails bent greatly; underground pipelines completely out of service.
XII.	Damage nearly total; large rock masses displaced; lines of sight and level distorted; objects thrown into the air.

***Masonry A, B, C, and D as used in MM Scale above:**
Masonry A: Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.
Masonry B: Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C: Ordinaryworkmanshipandmortar;noextremeweaknesseslikefailingtotieinatcorners, but neither reinforced nor designed against horizontal forces.
Masonry D: Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally

3.0 MEASUREMENT

Intensity and magnitude are two types of measurement that are used to determine the severity of earthquakes.

Intensity describes the degree of shaking at a specified place. The most widely used intensity scale is the modified Mercalli scale (MM) (Table 252-1). Other scales in international use are shown in Table 252-2.

Magnitude indicates the size of an earthquake, independent of the place of observation. It is calculated from amplitude measurements and is expressed in decimal numbers on a logarithmic scale. The most used magnitude scale is the Richter scale (M). Figure 252-3 shows energy release equivalents on the Richter scale and illustrates the magnitude of several well-known earthquakes.

4.0 EFFECTS OF EARTHQUAKES

Earthquakes create several separate, but often related actions and reactions. These are described briefly below. Data about each of their impacts on land uses, site and building planning, design and construction is provided in subsection 5.0.

4.1 Faults and Fault Displacements

A fault is a fracture within the earth's crust. Fault displacement is the movement of two sides of a fault caused suddenly during an earthquake, or develops slowly as a tecton-

SECTION 253

Natural Hazards: Landslides and Snow Avalanches

CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
Kyle D. Brown

Reviewers:
Professor Tuncer B. Edil
Department of Civil and Environmental Engineering
University of Wisconsin-Madison
Madison, Wisconsin

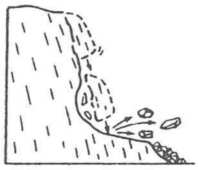
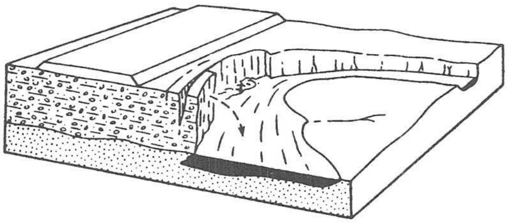
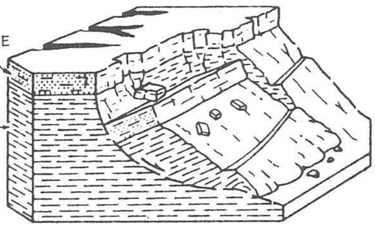
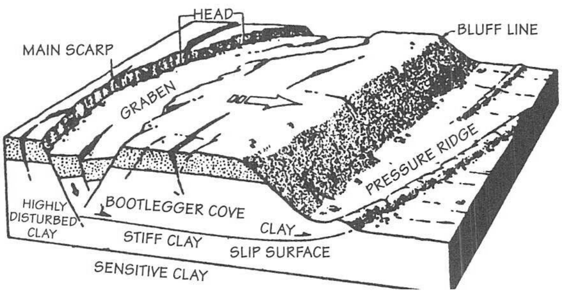
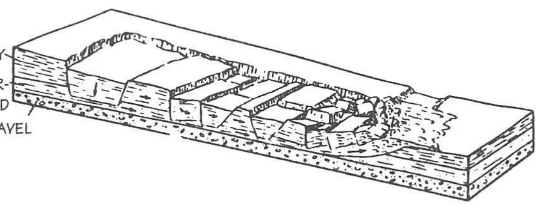
James E. Hough
James E. Hough and Associates
Cincinnati, Ohio

Jack D. Ives
International Mountain Society
Boulder, Colorado

Kyle D. Brown

CONTENTS

Table 253-1. CLASSIFICATION OF LANDSLIDES

TYPE OF MOVEMENT	RATE	DESCRIPTION
FALLS 	Very rapid to extremely rapid	Material travels most of the distance through the air.
TOPPLES 	Extremely slow to extremely rapid	Material tilts forward over a pivot point, resulting in a fall or slide.
SLIDES Rock Slump 	Extremely slow to moderate	Rotational (slumps): concave surface of rupture. Material moves along one or more identifiable surfaces.
Earth Block Slide 	Very slow to rapid	Translational (slides): generally planar or undulating surface of rupture. Frequently these are caused by structural weaknesses related to faults, bedding planes, etc.
LATERAL SPREADS 	Very rapid to slow	Material in a fractured mass moves laterally, often as a result of liquefaction or plastic flow in subadjacent material.

SECTION 254

Natural Hazards: Land Subsidence

CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
Kyle D. Brown
Tess Canfield

Reviewers:
James E. Hough
James E. Hough and Associates
Cincinnati, Ohio

Gilbert White, Susan Tubbesing,
Jacquelyn L. Monday, and Sarah Nathe
Natural Hazards Research and
Applications Information Center
University of Colorado
Boulder, Colorado

Richard Zoino
Goldberg-Zoino and Associates
Newton, Massachusetts


Kat Hardesty

CONTENTS

Natural Hazards: Expansive Soils

CREDITS

Section Editor:
Charles W. Harris

Technical Writers:
Kyle Brown
Megan Gardner
Tess Canfield

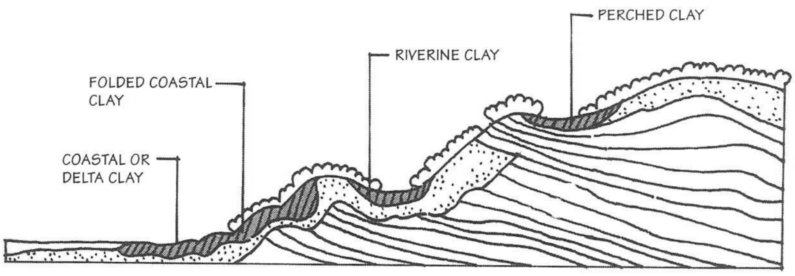
Special Consultants:
Richard Myrick and H. Rowland Jackson
Myrick-Newman-Dahlberg Partnership
Dallas, Texas

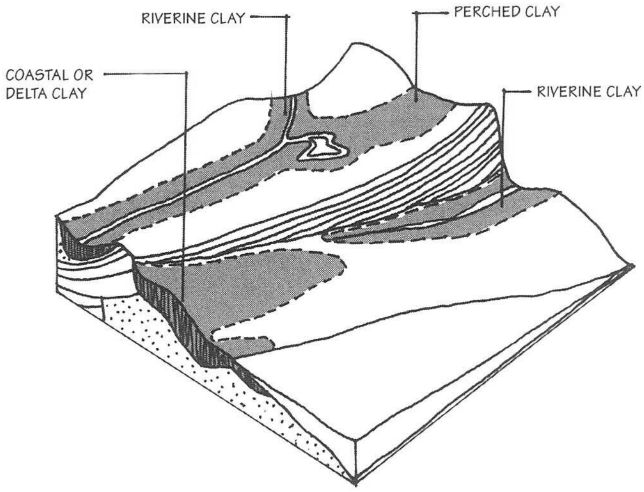
Patrick Buckley
Yandell and Hiller
Dallas, Texas

Reviewers
Ernest L. Buckley, Dean
School of Engineering
South Dakota State University
Brookings, South Dakota

James E. Hough
James E. Hough and Associates
Cincinnati, Ohio

Natural Hazards Research and
Applications Information Center
University of Colorado, Boulder, Colorado





CONTENTS

Site Grading

CREDITS

Section Editor:
Nicholas T. Dines

Contributor:
D. Lyle Aten and
John Dudley Scruggs
Scruggs and Hammond, Inc.
Landscape Architects-Planning Consultants
Lexington, Kentucky

Technical Writer:
Jeffrey D. Blankenship

Graphic Designer:
Douglas L. Sharp

Reviewers:
Horst Schach, Chairman
Department of Landscape Architecture
University of Kentucky
Lexington, Kentucky
David M. DuTot
The Delta Group, Landscape Architects
Philadelphia, Pennsylvania
Eugene West
L. E. Gregg & Associates,
Consulting Engineers
Lexington, Kentucky


N. Dines

CONTENTS

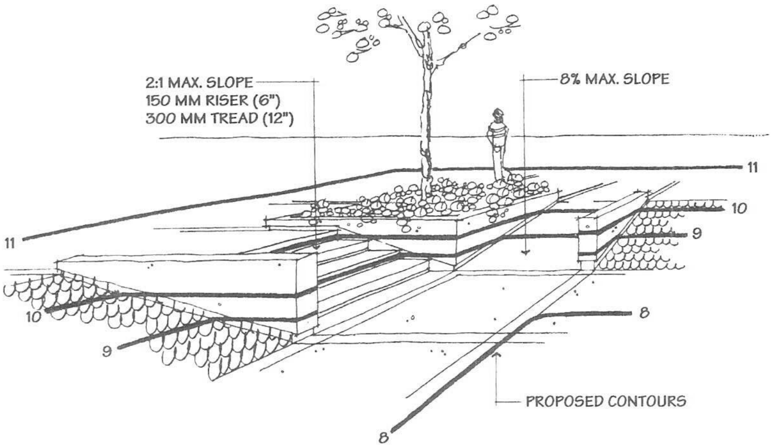


Figure 320-58. Grading of stairs and ramps. *Note that tread/riser ratios greater than 2:1 are advisable whenever possible.*

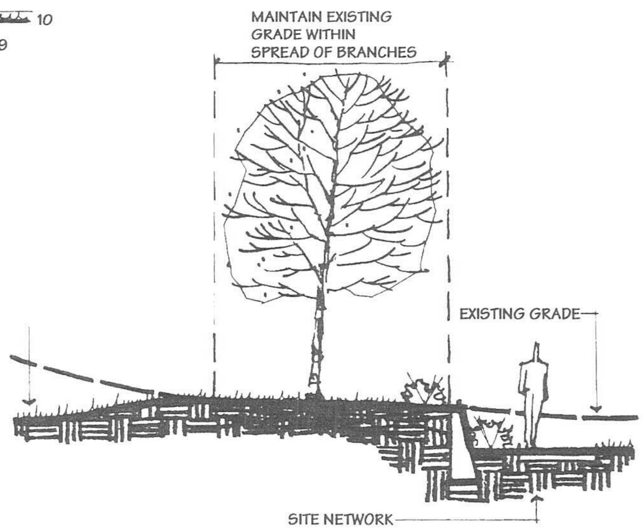


Figure 320-59. Grading near existing trees.

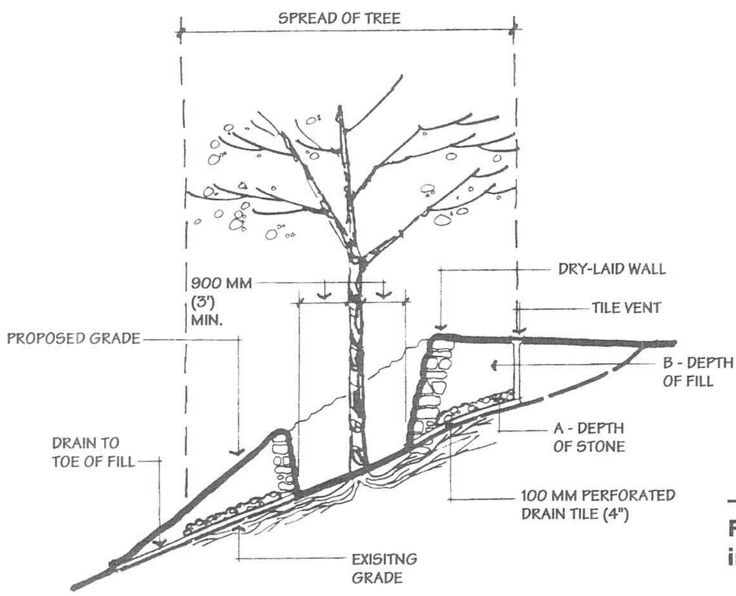


Figure 320-60. Retaining wall and drainage for existing tree in area of fill (section).

protect existing trees. A deck is constructed, with footings that do not disturb the root system around a tree. The deck's layout can be adjusted to the specific site conditions. When buildings or other such structures are involved, as shown in Figure 320-62, it is better to use lightweight footings with crawl spaces rather than on-grade slabs with compacted subgrades.

Figure 320-63 shows how grade beams and piers can be used to support walls and other structures without having to cut the major roots of existing trees.

Erosion Control by Grading:

Most erosion is caused by flowing water. The size and shape of a watershed, the porosity of its soils, and the length and gradient of its slopes and channels are key determinants controlling the volume and velocity of runoff and the risk of erosion. Several site grading techniques can be employed to limit the size, shape, length, and gradient of these slopes and channels, thereby reducing the volume and velocity of runoff.

Gradients can be reduced by extending the length of a slope. This uses more land, but it does reduce the amount of erosion and the potential slumping of hillsides (Figure 320-64).

Used singly or in combination, diversion swales, ditches, and dikes can intercept and divert runoff from the face of a slope (Figure 320-65).

Soil Slippage:

Several factors may cause soil masses altered by either cutting or filling to slide. The most common causes are improper cuts or fills and insufficient attention to surface and subsurface drainage characteristics. (In some regions where there are unstable soils there may be local standards that have to be met, including the use of

Stormwater Management

CREDITS

Contributor:
Robert D. Sykes, ASLA
University of Minnesota, Twin Cities
Minneapolis, Minnesota

Technical Writer:
Kyle D. Brown

Reviewers:
Greg Kopischke, ASLA
Westwood Professional Services, Inc.
Eden Prairie, Minnesota

Nicholas T. Dines, FASLA
University of Massachusetts
Amherst, Massachusetts

N. Dines

CONTENTS

Pedestrian Circulation

CREDITS

Section Editor:
Nicholas T. Dines

Contributor:
Gary M. Fishbeck

Technical Writer:
Jeffrey D. Blankenship

Reviewer:*
Roger B. Martin
Martin-Pitz, Inc.
Minneapolis, Minnesota

*Some data on Steps and Ramps were compiled by Robert LaRocca and Steven Brosnan of Robert LaRocca & Associates, San Francisco, California, and reviewed by David Arbegast of Arbegast, Newton & Griffith, Berkeley, California, and Richard Vignolo, Landscape Architect, San Francisco, California.

Kyle D. Brown

CONTENTS

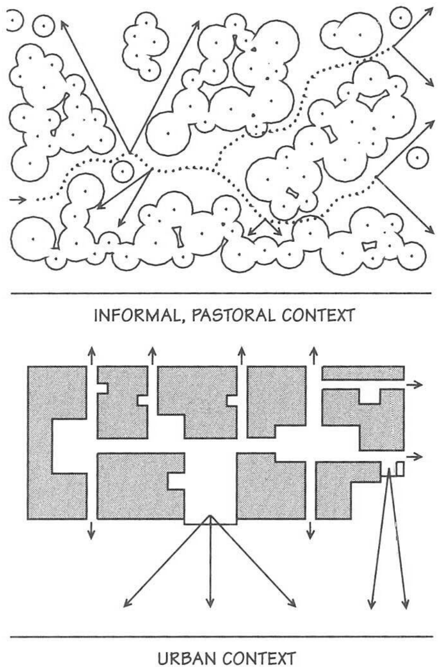


Figure 340-1. Spatial modulation. *Modulation of space can occur both vertically and horizontally in an informal, pastoral context or an urban context.*

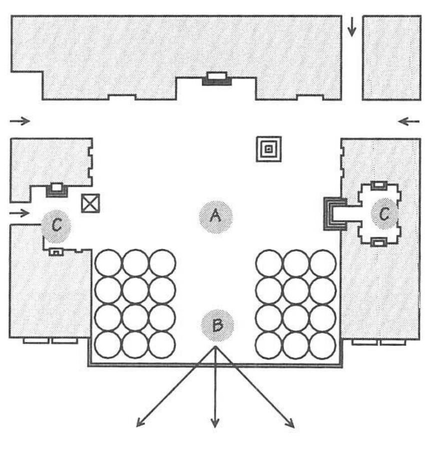


Figure 340-2. Hierarchical ordering of outdoor space. *Note the relationships between (a) primary, (b) secondary, and (c) tertiary spaces.*

1.0 INTRODUCTION

Pedestrian circulation is not easily discussed in specific terms because of the large differences in purpose between various types of systems. Most urban pedestrian circulation systems are typically perceived and utilized as a functional device more than as media for aesthetic experiences, a characteristic representative of park systems and other recreational open spaces. Moreover, because pedestrian circulation is an integral part of any particular design scheme, it is difficult to discuss the subject removed from the context in which it plays a role.

Consequently, this section is limited to a "general" discussion of various aspects of pedestrian circulation. Specific situations may require research beyond the scope of this section and decisions based on professional judgment.

1.1 General

Pedestrian circulation systems fall into two broad categories: (1) those where the basic structure of a system already exists and (2) those where no circulation currently exists.

With existing systems, projects typically involve aesthetic enhancement of the system by provision of various amenities, improved views, conveniences, and imageability. This type of work involves improvement of the "pedestrian experience" as much as it involves improvement of the functional aspects of the system.

In the case of new systems, circulation must first be laid out according to proposed origin and destination points and must have adequate width to accommodate expected loads of pedestrian traffic during peak periods of use. Part of this process includes studying aesthetic aspects which will be carefully integrated with the functional aspects of the proposed system.

Additional information on various aspects of pedestrian circulation can be found in other sections of this handbook, including 210: Spatial Standards; 240: Outdoor Accessibility; 510: Site Furniture and Features; and 540: Outdoor Lighting.

1.2 The Pedestrian Experience

Convenience:

The functional aspect of a pedestrian system is of primary importance, and the quality of this functional aspect is measured in terms of the "convenience" offered by the system. In addition to the obvious requirement of connecting all origin and destination points with walkways of adequate width, the two factors of orientation and negotiation play an important role.

In terms of orientation, landmark features and visual cues can suggest purpose and expected behavior to the pedestrians using the system. These may include walkway width (e.g., wider walkways suggesting greater importance), formality (e.g., curvi-linear walkways suggesting a more relaxing experience), paving material (e.g., expensive or highly articulated materials suggesting greater importance), and the presence and quality of ancillary features (the nature of which may suggest the predominant purpose of the walkway).

Carefully designed visual cues (including signage) can aid the pedestrian in wayfinding and in general orientation within a larger environmental context. This is especially important in complex environments.

Negotiation refers to the relative ease of moving from one destination to another. Pedestrian density, including conflicts at intersections and potential gathering spots, plays an important role in this regard. But other aspects also contribute to difficulty of negotiation. These include physical obstructions (e.g., trash receptacles, light fixtures, flag poles, parking meters, water hydrants, telephones, benches, etc.); the presence of water or ice on the walkway; the nuisance of excessive litter; seed and fruit droppings from overhanging vegetation; and excessive wind problems.

Pathways should be accessible to all types of pedestrians, and sometimes on a selective basis, to emergency vehicles such as police cars, ambulances, and firefighting equipment.

Amenities:

The purpose of any pedestrian circulation system is the connection it offers between various natural or cultural amenities, including the attraction of human activity. Social interaction, both passive and active, is extremely important and in many cases is the primary determinant regarding enjoyment of a place.

Because the activity of watching other people is appealing to many, spaces to gather with ample opportunities to sit are crucial to the success of most places, especially those in urban contexts.

It has been observed that the availability of food and the activity of eating is a strong stimulus which attracts significant numbers of people to a place. For this reason, ven-

SECTION 341

Bicycle Circulation

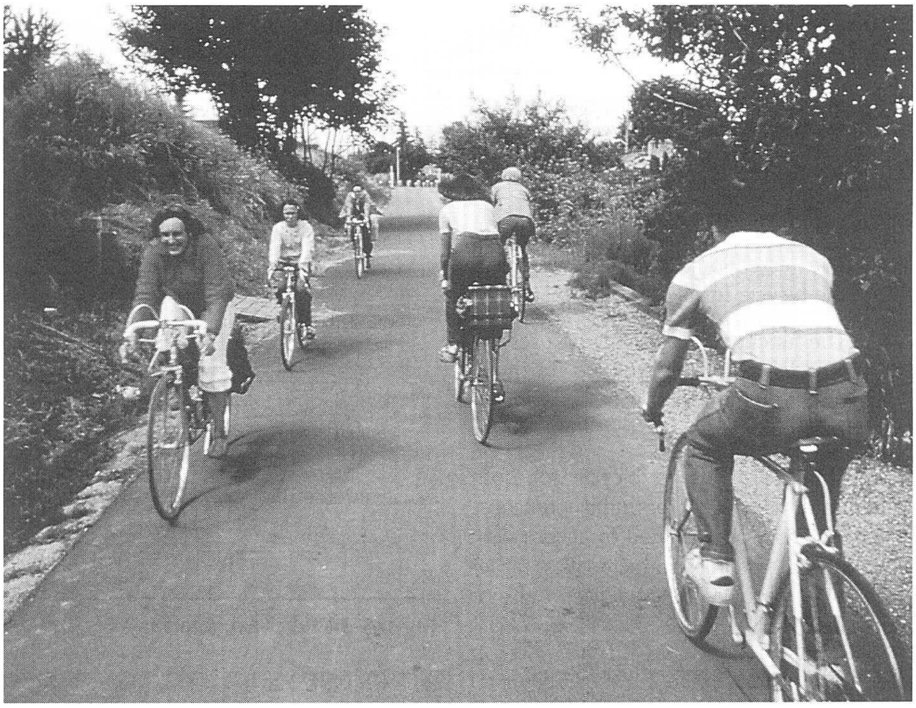
CREDITS

Section Editor:
Nicholas T. Dines

Contributor:
Edward Macleod and Terrance Reckord
MacLeod Reckord Landscape Architects
Seattle, Washington

Reviewers:
Michael Dornfeld
Bicycle Program Coordinator
Washington State Department of Transportation

Alex Sortun
Director, Northwestern University Traffic Institute
Evanston, Illinois


MacLeod Reckord Landscape Architects

CONTENTS

1.0 INTRODUCTION

The increasing use of bicycles in the United States makes it imperative to design bicycle facilities with fewer conflicts between such systems and other modes of travel.

Such improved systems are normally found in the form of a bikeway, defined as "any road, path, or way, which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other modes of transportation" (American Association of State Highway and Transportation Officials).

To design quality bicycle facilities, an understanding of bicyclists and their objectives is important.

2.0 TYPES OF USERS

2.1 Bicyclists

Bicyclists fall into two major categories:

1. The recreational bicyclist, who uses the bicycle for pleasure or exercise
2. The functional bicyclist, who uses the bicycle as an alternative form of transportation to school, to work, or to shop

Most bicyclists use a bicycle for both functional and recreational reasons. Bikeways must be designed to accord with a corridor's existing characteristics rather than with narrowly defined user traits or purposes.

Minimum standards must be emphasized to accommodate a full range of user types while optimizing safety for all.

2.2 Mountain Bikes

Although the primary focus of this section is the design of facilities for touring bicycles, the use of mountain bikes is increasingly popular. Mountain biking typically occurs on all trail systems, and the integration of biking into existing trail systems is a challenge for providers around the country.

3.0 PRIMARY TYPES OF BIKEWAYS

The American Association of State Highway and Transportation Officials (AASHTO) classifies four primary types of bikeways. These are described below.

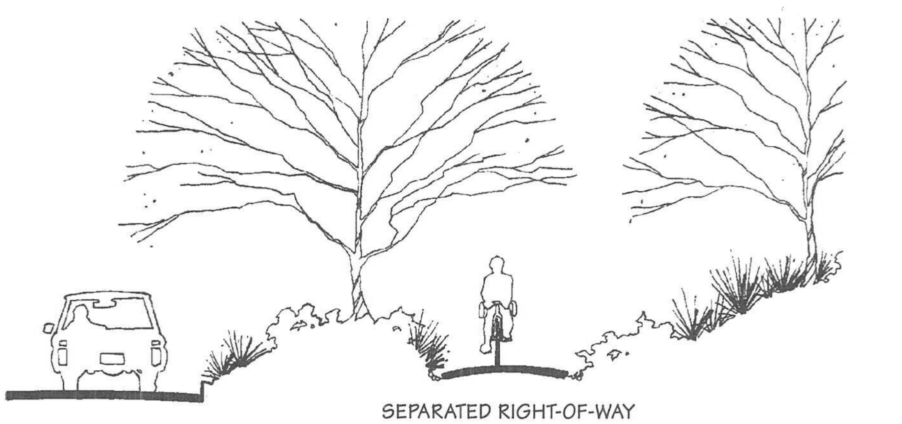


Figure 341-1. Bicycle path.

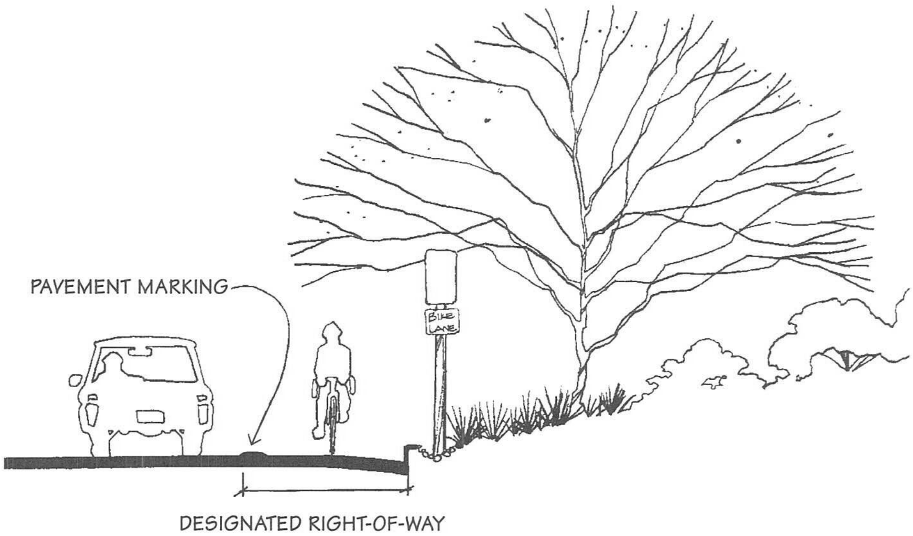


Figure 341-2. Bicycle lane.

3.1 Bicycle Path

Bicycle path refers to a facility separated from motor traffic by an open space or barrier either within the road right-of-way or an independent right-of-way, and for the primary use of bicycles (Figure 341-1).

KEY POINTS: Types of Bikeways

There are four primary types of bikeways which are designed to accommodate the recreational and functional needs of bicyclists.

1. **Bicycle path:** Ideal with dedicated right-of-way and separate furnishings, 2 400-3 600 mm (8-12 ft) min.
2. **Bicycle lane:** Part of road but separated by markings or textured strip, 1 500-1 800 mm (5-6 ft) min.
3. **Wide outside lane:** Less desirable, but common, 4 200 mm (14 ft) min.
4. **Shared roadway:** Common, but has highest potential for conflict with autos, 1 500-1 800 mm (5-6 ft) min.

Vehicular Circulation

CREDITS

Contributor:
Robert Zolomij
Land Design Collaborative
Evanston, Illinois

Technical Writer:
Jeffrey D. Blankenship

Reviewers:
Nicholas T. Dines
University of Massachusetts/Amherst
Amherst, Massachusetts

Glen Erickson
Barton-Ashman Associates, Inc.
Evanston, Illinois

Charles W. Harris
Harvard University
Graduate School of Design
Department of Landscape Architecture
Cambridge, Massachusetts


N. Dines

CONTENTS

SECTION **410**

Retaining Walls

CREDITS

Contributor:
Nicholas T. Dines, FASLA
University of Massachusetts
Amherst, Massachusetts

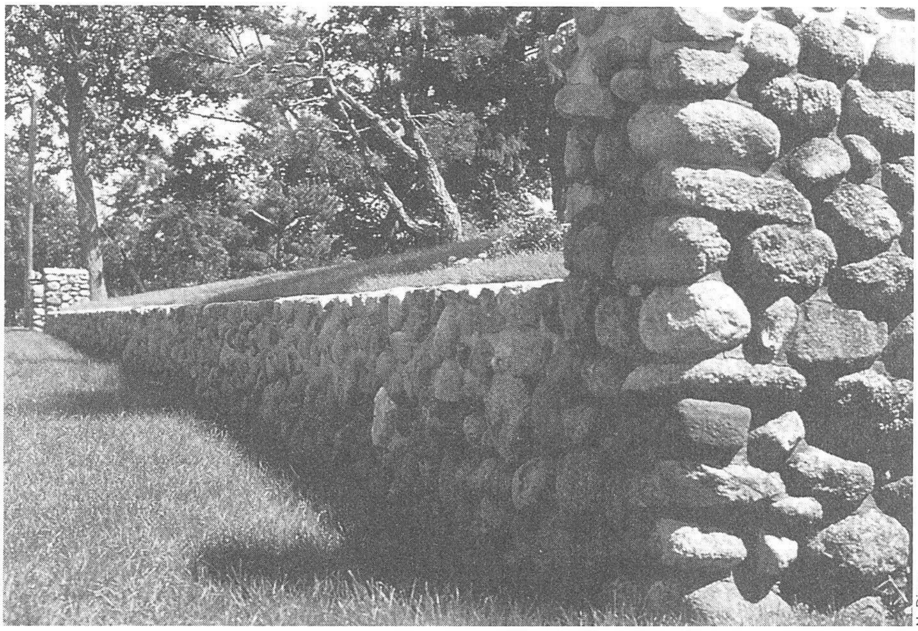
Domenico Annese, RLA, and Peter F. Martecchini, PE
New York, New York

Information on metric calculations was provided by David Grahlman, P.E., Gamsby and Mannerow, Ltd., Guelph, Ontario

Technical Writer:
Kyle D. Brown

Reviewers:
Bradford G. Sears, RLA
Fayetteville, New York

Stephen Hamway
Sasaki Associates, Inc.
Dallas, Texas



N. Dines

CONTENTS

1.0 INTRODUCTION

An earth retaining structure is a landscape device used to accommodate abrupt grade changes which exceed the natural angle of repose of the existing soil (usually 33 to 37 degrees, or about 1 to 1.5). These devices include not only wall structures, but also embankment reinforcing structures such as rip-rap stone, fiber matting, and highly fibrous rooted plants. All such devices, regardless of their material, or shape, must be able to withstand earth pressures, and other related factors which typically cause structural failure, such as vehicle loading, highway vibration (i.e., live loading), and effects of extreme moisture conditions (e.g., heaving due to swelling and frost/thaw cycles).

1.1 Use of Retaining Structures

Typical structures are designed to accommodate one or more of the following purposes:

1. Protect steep slopes from erosion, either as an existing condition or as a mitigating strategy due to construction alterations (Figure 410-1).
2. Protect specimen tree stands from fill or cut conditions (Figure 410-2).
3. Facilitate vertical circulation at steps or ramp structures (Figure 410-3).
4. Facilitate vehicular access in steeply sloping wooded sites, such as parks, camping areas, or private residences (Figure 410-4).
5. Maximize potential for development and/or building area to accommodate an extensive design program for schools, play fields, outdoor theaters, art galleries, etc. (Figure 410-5).
6. Extend the architecture of a building into the site and to express its functioning levels (Figure 410-6).
7. Accommodate grade changes when limited space prohibits non-structural grading solutions (e.g., at property lines, or existing buildings and specimen trees).
8. Achieve an integrated visual appearance of the proposed development in relation to the existing site and surrounding development or context.

Compared to other forms of earth retaining devices, walls can be five to six times more expensive than engineered earth embankments, rip-rap embankments, or bio-engineered embankments, and

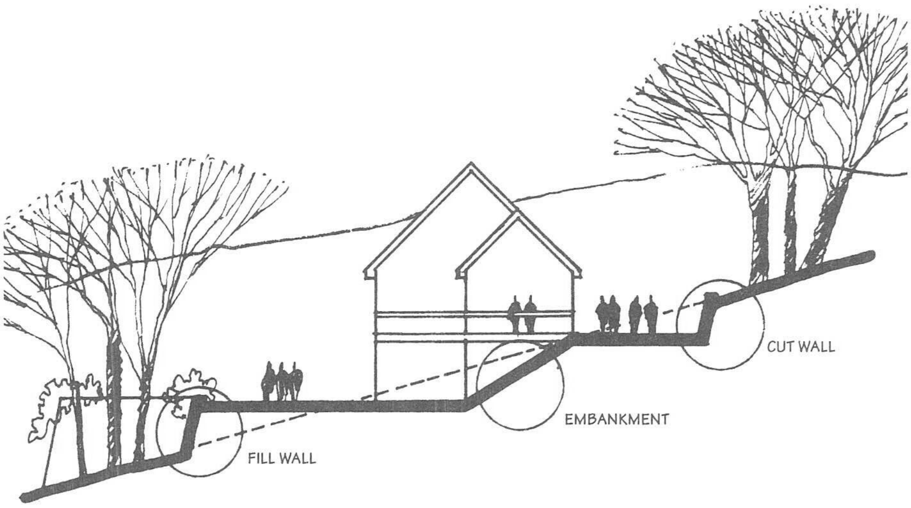


Figure 410-1. Retaining structures for steep slope protection.

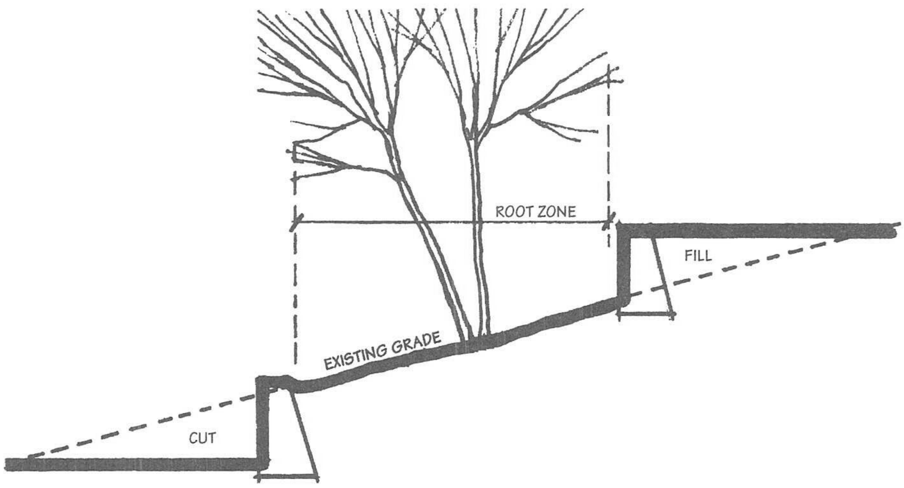


Figure 410-2. Retaining walls for existing tree protection.

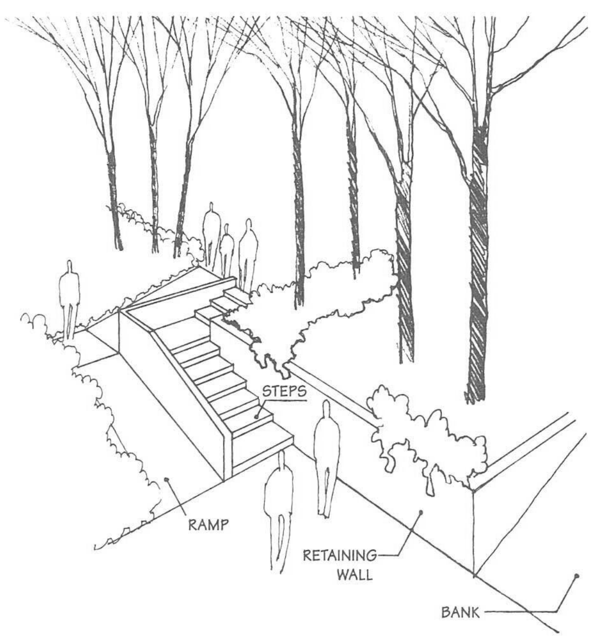


Figure 410-3. Retaining walls to facilitate ramp and step access.

Small Dams

CREDITS

Section Editor:
Charles W. Harris

Technical Writers:
Kyle D. Brown
Krisan Osterby-Benson

Reviewers:
Alton P. Davis, Jr.
GEI Consultants, Inc.
Winchester, Massachusetts

Varoujian Hagopian
Sasaki Associates, Inc.
Watertown, Massachusetts

Steve J. Poulos
GEI Consultants, Inc.
Winchester, Massachusetts

Illustrations:
Ginny Leonard
Ying Wang
Samuel Coplon


Jeffrey D. Blankenship

CONTENTS

Table 420-2. SELECTION CRITERIA FOR SMALL DAMS

	Earthfill	Rockfill	Masonry (Stone or Concrete)	Concrete or Timber Crib
SITE CONSIDERATIONS				
Suitable topography	Low rolling plains	Low rolling plains	Narrow stream; high, rocky walls	Narrow stream; high, rocky walls
Stream diversion	Required during construction	Usually required	Minimal requirements	Minimal requirements
Foundation requirements	Least stringent; solid rock; gravel, sand	Minimal settlement required; same as earth fill	Reasonably sound rock	Suitable for unstable soils
Earthquake resistance	Very good	Excellent	Good	Good
Suitable materials on site	Fill materials may have to be borrowed; variety of materials suitable for zoned embankment	Local stone suitable; rock of all sizes used	Local stone may be suitable; carefully graded aggregate required	Local timber may be suitable; also pre-cast concrete cribbing
Visibility	Slopes are plantable (except with trees)	Highly visible (no planting)	Free, natural forms possible	Beaver type is least visible
COST CONSIDERATIONS*				
Maintenance	Damaged by animals and woody plants; upstream slope inspection and repair required periodically	Upstream slope inspection and repair required periodically	Concrete spalls and other types of masonry damage may occur; periodic inspection and repair required	Considerable maintenance; periodic replacement is required
DESIGN CONSIDERATIONS				
Crest width	Table 420-3	Table 420-3	4-ft (1.2-m) minimum	3-ft (1 -m) minimum
Crest height (freeboard)	Table 420-5	Table 420-5	4 ft (1.2 m) above pond at design discharge	Normal maximum pond level
Maximum gradient of side slopes:				
Upstream	1:2.5	1:1.3 hard rock; fill w/concrete slab	Vertical	1:2
Downstream	1:2 Table 420-6	1:1.7 for hard rock fill w/ asphalt; increase for lower quality rock	1:0.7 (min.)	1:1
Seepage control	Clay core required	Face slab required	None required	Timber planking required
Wave protection	Table 420-14	Face slab required	None required	Timber planking required
Spillway	Spillway generally located away from dam as a separate structure	Spillway generally located away from dam as a separate structure	Overflow crest may be incorporated inexpensively in design	All are overflow dams suitable for large drainage areas
Strength and stability	Easily eroded or destroyed if overtopped	Damaged or destroyed if overtopped	Relatively stable if overtopped	Never fails by overturning
Durability	Considered practically permanent	Considered practically permanent	Considered practically permanent	Short-lived unless continuously maintained (permanent if concrete cribbing is used)

*Optimal type of dam depends on relative cost of securing local borrow and/or construction materials.

SECTION 440

Surfacing and Paving

CREDITS

Section Editor:
Nicholas T. Dines

Consultant:
Royston, Hanamoto, Alley, and Abey
Mill Valley, California

Reviewers:
Robert Fager
Sasaki Associates, Inc.
Watertown, Massachusetts

Charles W. Harris, Emeritus Professor
Harvard Graduate School of Design
Cambridge, Massachusetts


N. Dines

CONTENTS

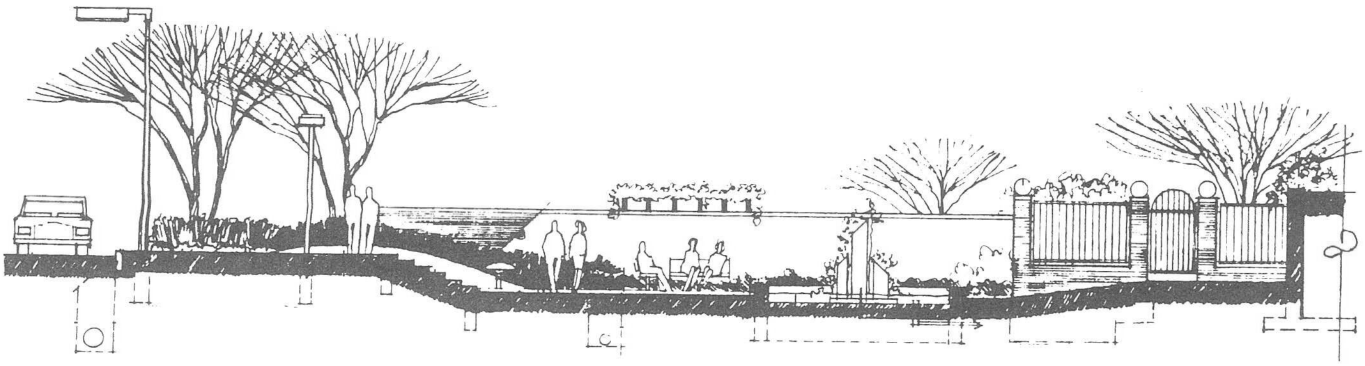


Figure 440-1. Public plaza pavements. *Pavements are typically subjected to medium to heavy duty loads due to dense pedestrian traffic, service and emergency vehicle access, and large-scale mechanical maintenance practices. Cost per square or linear unit is often high due to the need for more durable finishes and stronger materials requiring frequent repair from sustained use and periodic access to buried utilities.*

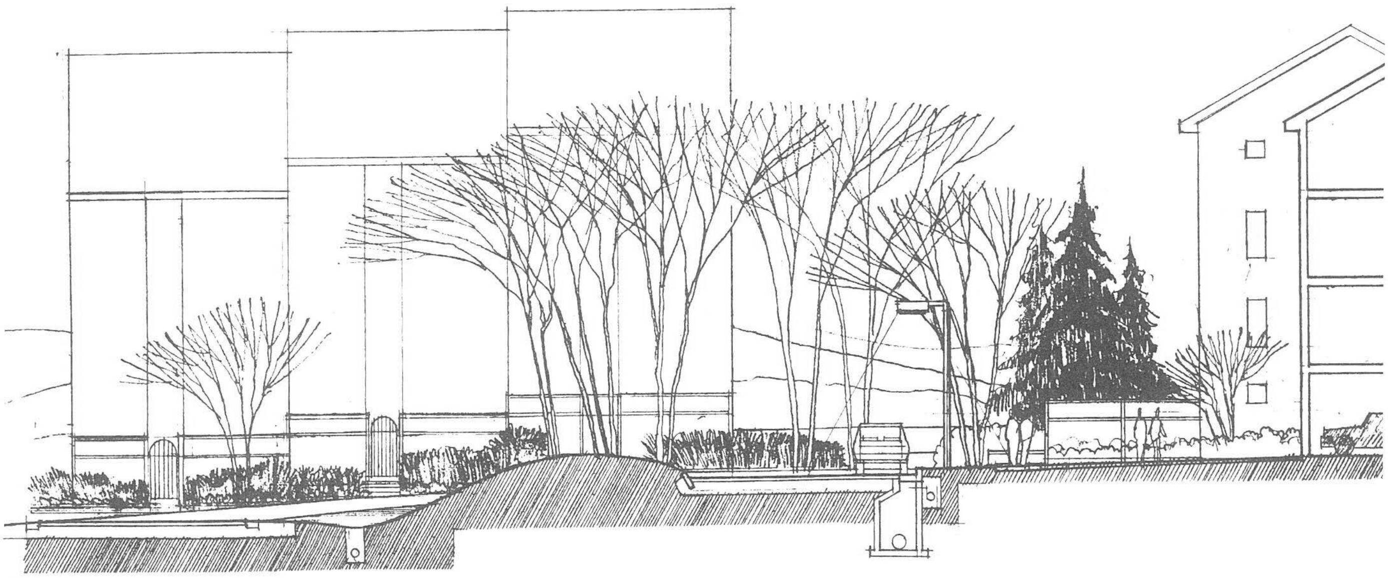


Figure 440-2. Townscape pavements. *Pavements may range from light to heavy duty based upon particular vehicular loading, but are generally rated as light to medium duty. Pedestrian traffic is less dense and materials tend to be moderate in strength, typical of suburban and exurban environments. Costs associated with installation and maintenance tend to be moderate.*

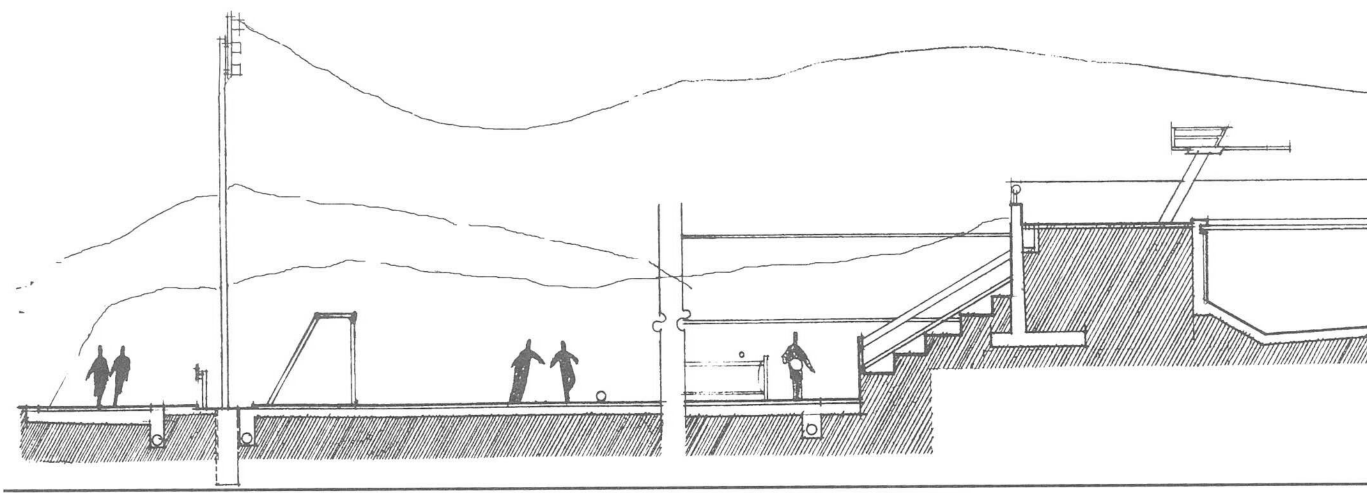


Figure 440-3. Athletic facility pavements. *Pavements typically range from light to medium duty, but occasionally must accommodate heavy duty exposition vehicular loads. This group of pavements are commonly associated with track, field, court, and arena settings. Installation costs are high due to special subgrade preparation and drainage requirements, and long term maintenance is high due to uniformity requirements, specialized equipment, and proprietary surface specifications.*

SECTION 450

Fences, Screens, and Walls

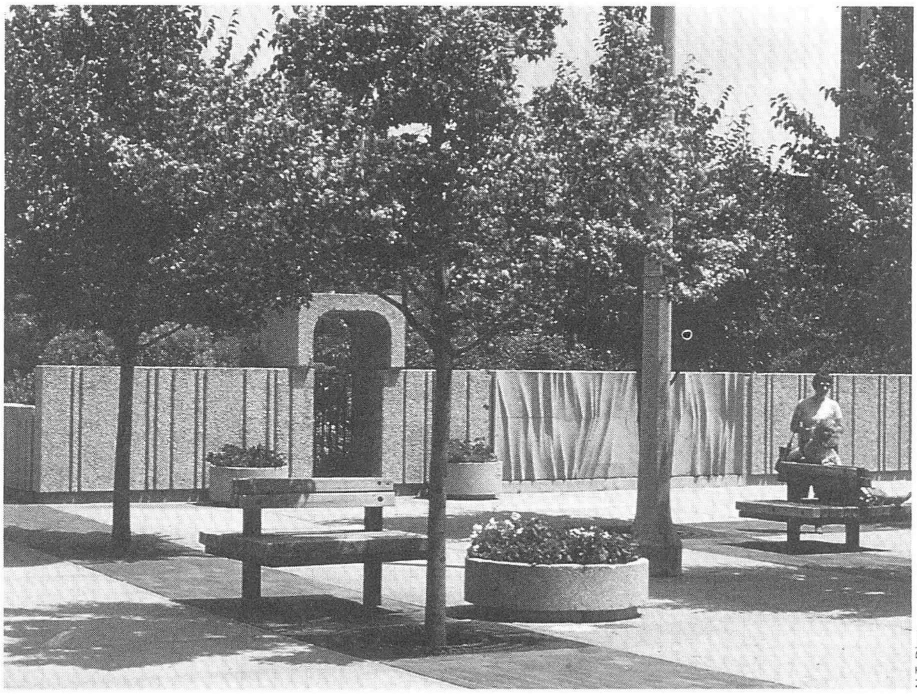
CREDITS

Section Editor:
Nicholas T. Dines

Contributors:
Don Hilderbrandt,
Patrick Mullaly and Kathleen Bogaski
LDR International, Inc.
Columbia, Maryland

Assistants:
David R. Holden
Cynthia L. Riemer
Charles H. Shaw, Jr.
Nancy Takahashi
Charles E. Bailey

Reviewers:
Kenneth DeMay
Sasaki Associates, Inc.
Watertown, Massachusetts



N.T. Dines

CONTENTS

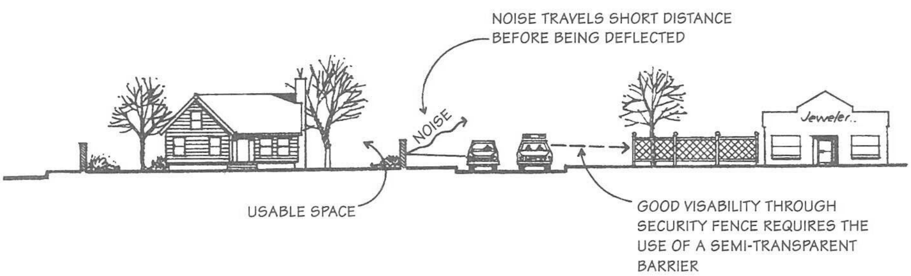


Figure 450-1. Placement of privacy barriers.

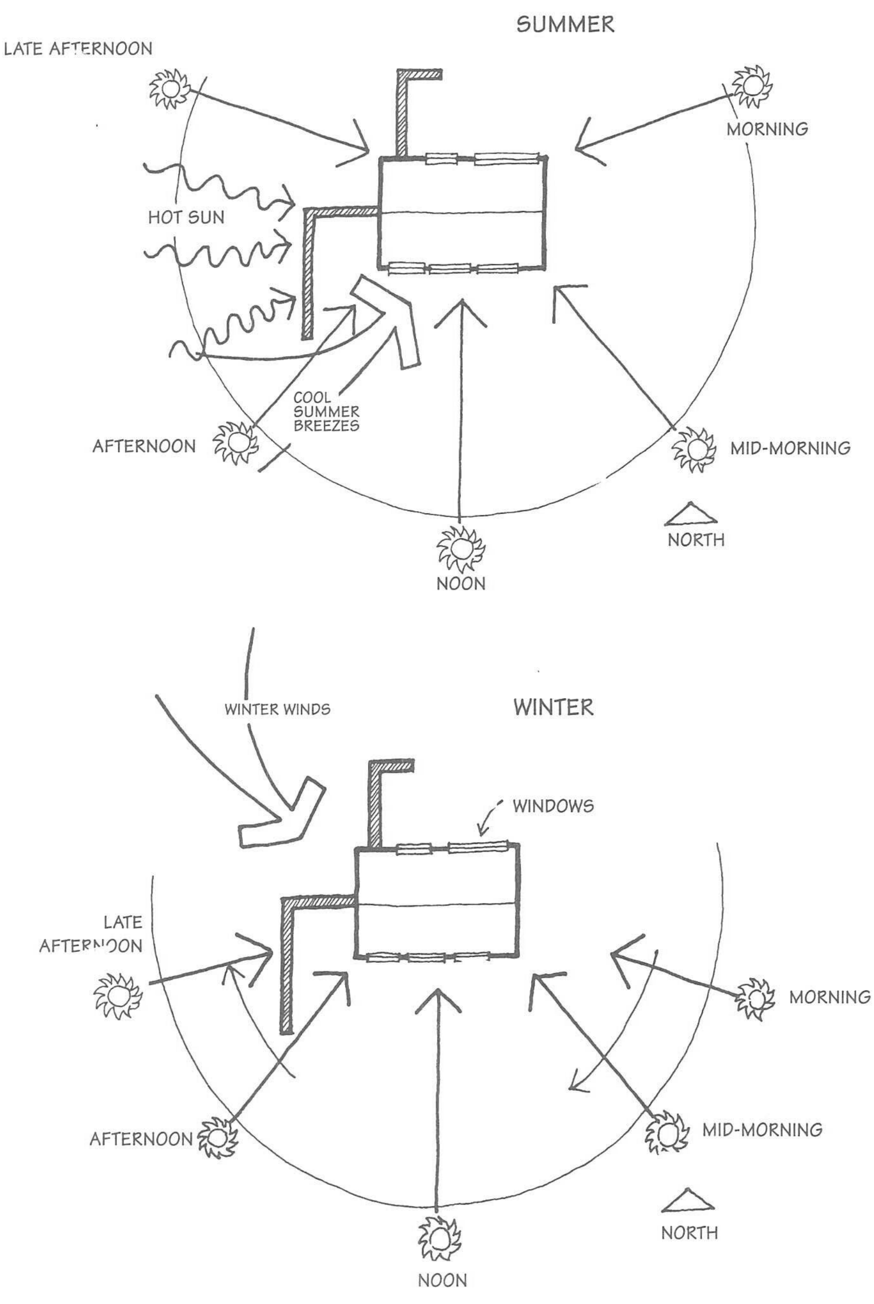


Figure 450-2. Barriers for environmental modification. *Fences, screens, and walls can be used to alter microclimatic qualities of a space in several ways. Example here refers to the northern hemisphere.*

1.0 INTRODUCTION

1.1 General

This section focuses on the basic principles and techniques of selecting, designing and constructing fences, screens, and walls typically found in a variety of site development settings. Major design considerations, structural components, and methods of construction for fences, screens, and walls are provided.

1.2 Design Process

Program requirements: Determine the purpose and use of the proposed barrier, and the degree of exclusion and transparency required, as described in 1.3 Design Considerations.

Schematic Design: a). Determine barrier location, type, size, and style; b). Identify climate modifications and general construction methods; and c). Formulate data to support the design recommendations. Planting and grading should also be considered as an alternative means of providing visual screens and physical barriers where space permits.

Sizing, selection of materials: Walls are often designed from the top down, (i.e., determine wall widths, veneers and cap sizes first, and size footing last based on soil conditions, design loads, and local codes.) Wall and fencing materials may be selected based on availability, and capacity to match the local site and architectural character.

The span between posts or piers determines the size of both wood and metal fencing rails and supports. Plant material should be selected based on existing soil conditions, exposure, hardiness zone, mature height and spread, maintenance requirements, and seasonal interests.

Layout: The layout should be coordinated with utilities, grading and planting plans. Planting and/or grading can accomplish the same purpose as a fence or wall, may be more economical to construct, and require less long-term maintenance. Barriers should disturb drainage patterns only after careful consideration of run-off consequences. Ideally, drainage should be directed away from barrier footings and posts to reduce potential damage to the structural elements.

Details and Refinement of Design: Non-structural features such as fence or wall caps, post tops, wall veneer patterns, and

Wood Decks and Boardwalks

CREDITS

Contributor:
Gary M. Fishbeck

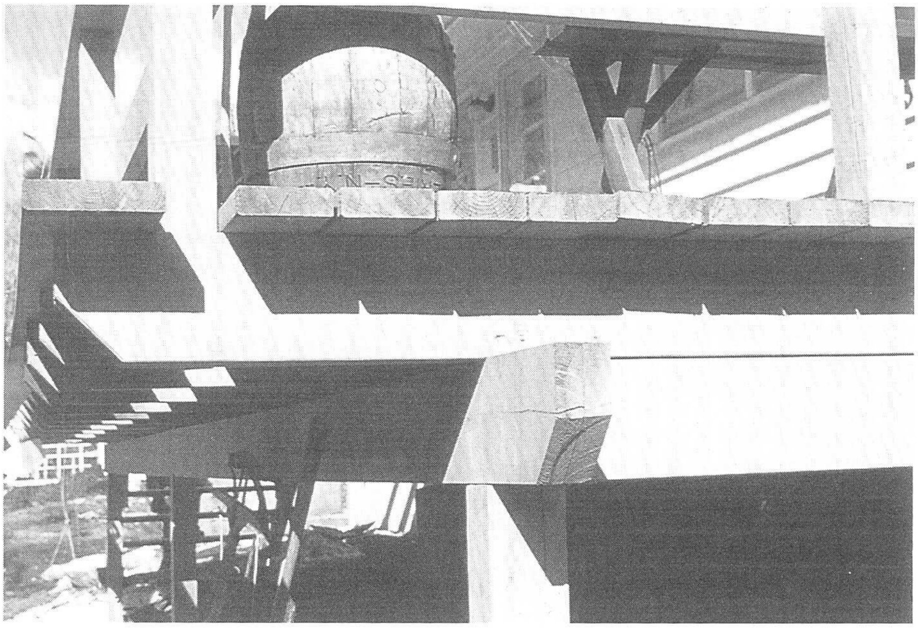
Technical Writer:
Jeffrey D. Blankenship

Graphics:
John Copley
John Copley and Associates, Inc.
Boston, Massachusetts

Reviewers:
J. Brooks Breeden
Department of Landscape Architecture
School of Architecture
Ohio State University
Columbus, Ohio

Olin Fralick
Marvin & Associates, Inc.
Walterboro, South Carolina

Thomas and Heather Ryan
Sasaki Associates, Inc.
Watertown, Massachusetts



Michael Davidsohn

CONTENTS

1.0 INTRODUCTION

1.1 General

This section focuses on fundamental principles and techniques of wood deck and boardwalk design and construction. Each of the major structural components of a deck and its sizing is described. Construction details for various types of connections, including steps and handrailings, are given at the end of the section.

1.2 Design Process

The design of a deck or boardwalk involves an orderly decision-making process. Basic steps in the process include:

1. **Program requirements:** Create a design program with regard to proposed deck uses and resulting size requirements.
2. **Schematic design:** Develop deck or boardwalk form, spatial organization, and expected circulation patterns.
3. **Rough layout and framing plan:** Develop a rough layout and preliminary framing plan which locates all structural elements required, such as footings, beams, joists, decking pattern, stairs, and rails. Calculations cannot begin until a rough framing plan is prepared.
4. **Sizing wood members and refinement of layout:** Calculate weights and sizes proceeding from wearing surface to pier footings to include decking joists, beams, and finally post calculations. (Refer to 4.0 Sizing Wood Members in this section for an explanation of sizing calculations.)
5. **Details and auxiliary features:** Prepare details for all associated features such as steps, railings, benches, hot tubs, and planters. Such features which bear on the deck structure must be included in weight calculations. Methods of attachment for these details sometimes become part of the structural framing plan (e.g. structural posts as posts for handrailings).
6. **Evaluation:** All structural systems should be reviewed by local permitting agencies and structural consultants.

1.3 Preliminary Design Considerations

The factors that will fundamentally determine the appearance, strength, and relative costs of a deck or boardwalk design are:

1. Framing method and layout
2. Construction materials selection
3. Maintenance considerations

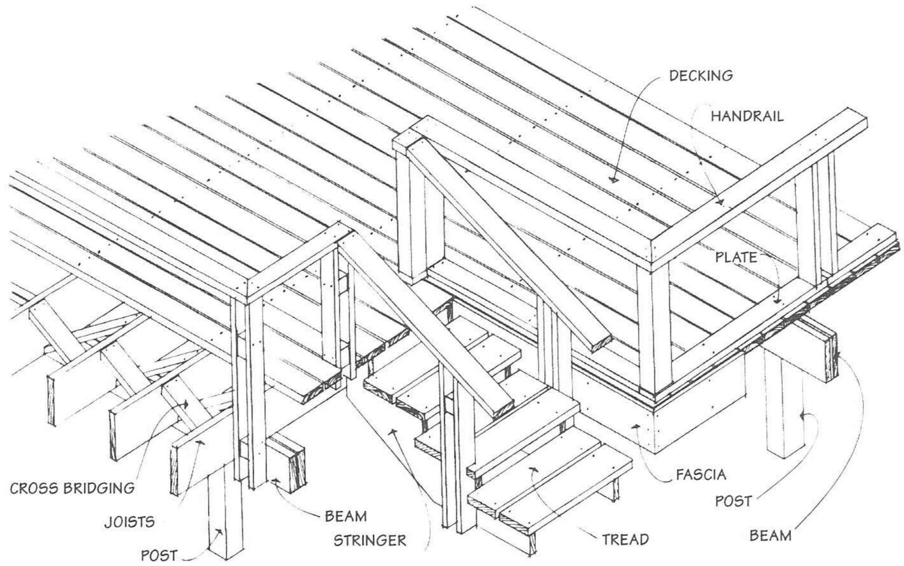


Figure 460-1. Typical platform framing.

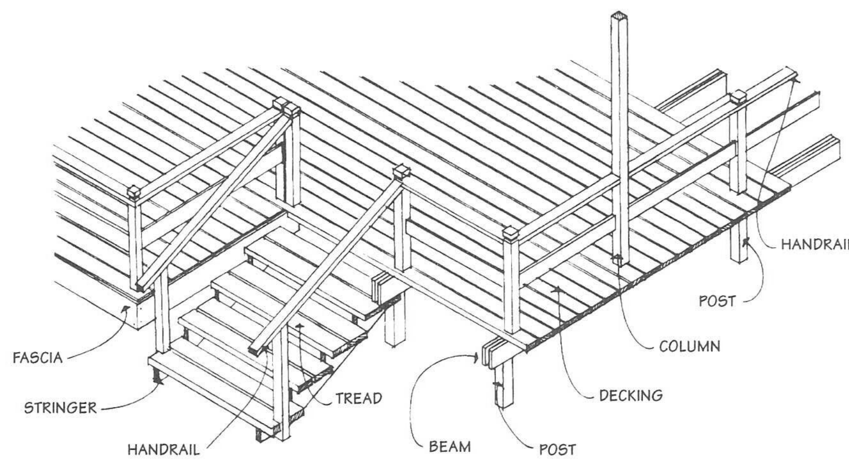


Figure 460-2. Typical plank-and-beam framing.

2.0 PRINCIPLES OF CONSTRUCTION

2.1 Framing Methods

Platform framing and plank-and-beam framing are the two methods commonly employed in deck or boardwalk construction. Both of these methods have advantages and disadvantages, depending on the objectives of the designer. The choice of one method over another is usually based on a combination of cost comparisons, aesthetic preference, and regional practice. The comparative costs between these two framing methods need to be considered on a project-by-project basis due to the many variables involved.

Platform Framing:

Platform framing is a beam-and-joist method of construction (Figure 460-1). Few beams are necessary because joists carry the load over a wide area. Joists typically are of a nominal thickness of 50 mm (2 in) and essentially function as closely spaced beams. The spacing of joists is determined by (1) the load-carrying ability of the joists themselves (a function of their cross-sectional dimension and length of span) and (2) the maximum allowable decking spans, which depend on the cross-sectional dimensions of the decking material and on the species of lumber used. Different species of wood have different inherent strengths.

SECTION **470**

Pedestrian Bridges

CREDITS

Section Editor:
Charles W. Harris

Technical Writers:
Jeffrey D. Blankenship
Tess Canfield

Research Assistant:
Gary Schiff

Selected Graphics:
Jeffrey Lakey

Reviewers:
Hans Willian Hagen, P.E.
LeMessurier Associates, Inc.
Cambridge, Massachusetts

Stephen E. Hamwey, P.E.
Sasaki Associates, Inc.
Watertown, Massachusetts

Anthony Hunt
Anthony Hunt Associates
London, England

Henry H. Liede
Kane, Liede & Ratyna, P.C.
Pleasantville, New York


N. Dines

CONTENTS

1.0 INTRODUCTION

Pedestrian bridges are structures built in the landscape to allow movement across areas that would otherwise be difficult or dangerous to traverse. Bridges become a necessary means for connecting two points in the presence of such obstacles as water, steep topography, or major roadways. Though bridges can enhance the scenic character of a site, they must be seriously considered in the context of cost and liability.

In almost all cases, the design of bridges requires the assistance of structural and/or civil engineers. All dimensions included in this section are for guidance only and for indicating the scale of parts.

2.0 DESIGN CONSIDERATIONS

2.1 Defining the User

Design determinants for bridges are based on both user and site characteristics. Types of users may include:

1. People as individuals or in small or large groups (the latter related to spectators or tourists, etc.).
2. People using wheelchairs, bicycles, or other nonmotorized vehicles.
3. People on horseback and using a range of motorized vehicles (motor bikes, motorcycles, power mowers, and in some instances single cars or lightweight trucks, cattle, etc.).

Any of the above types of users may use a bridge in accordance to or contrary to the designer's intention. In general, pedestrian bridges must conform to the standards of universal accessibility and in the United States must meet the Americans with Disabilities Act Accessibility Guidelines (ADAAG). Refer to Section 240: Outdoor Accessibility for more information.

2.2 Spatial Standards

Spatial standards for bridges to serve bicyclists, pedestrians, and those who are handicapped are given in Table 470-1. Bridges to serve riders on horseback should be at least 1 200 mm (4 ft) wide for single passage crossing.

If a bridge is to be built, then consideration must be given to what may pass underneath. Statutory considerations involving clearances and safety measures apply to roads, rails, and water courses used by canoeists, people fishing or sailing boats, or commercial traffic. Where streams are involved in cold climatic zones, ice floes can create serious problems if not accounted for in the design.

2.3 User Safety

General:

The principal hazard to users of bridges is falling from the bridge or its approach paths. Depending upon the expected users and types of dangers, provisions could range from no handrails over shallow streams to shoulder-high rails with infills of mesh over deep gorges.

Considerations for handicapped users should include appropriate design of the approaches to the bridge. Landings and platforms, rest areas, handrailings, and walking surfaces are all elements that should be checked for compliance with national and local codes. (Refer to Section 240: Outdoor Accessibility, for more information.)

Landings, Rest Areas, and Handrailings:

Level landings or platforms should be provided at the top and bottom of ramp runs. Where pedestrian ramp grades exceed the maximum 1:12 or 8.33 percent, intermediate landings should occur no more than 9 000 mm (30 ft) apart. The landing should have a clear width at least equal to the width of the largest ramp leading to it. The minimum landing depth should be 1 500 mm (5 ft).

Places to sit or rest are particularly beneficial on very long bridges. They can also function as vantage points for scenic views.

Handrailings that are easily grasped should extend continuously along the entire length of the bridge, on both sides, including approach ramps.

Decking and Surface Treatments:

The choice of decking and surface treatments for bridges is very important. Nonslip surfaces are crucial. Wood decking is acceptable if the joints are less than 12 mm (1/2 in) wide. Slip-resistant metal checkerplates, walkway gratings, or traction strips are often used.

3.0 BRIDGE CONSTRUCTION

3.1 Site Selection and Survey

Selection Criteria:

Site factors to consider when deciding on the precise location for a bridge include the following:

1. Which area requires the shortest span?
2. Which area has the best foundation conditions? (In most cases a geological engineer should be consulted)
3. Which area is closest to the line of the existing footpath?
4. Which area has the fewest obstacles in the way of the bridge and/or its approaches?
5. Which area allows the most clearance from flooding?

KEY POINTS: Design Considerations

Design determinants for bridges are based on both user and site characteristics. The potential users of pedestrian bridges must be understood in determining spatial dimensions and design loading for an appropriate bridge type (Table 470-2). Understanding site conditions will help create a bridge that takes advantage of landscape amenities while avoiding negative environmental impacts or safety hazards.

1. In general, pedestrian bridges must conform to the standards of universal accessibility and in the United States meet the Americans with Disabilities Act Accessibility Guidelines (ADAAG).
2. Considerations for handicapped users, including landings and platforms, rest areas, handrailings, and walking surfaces should be checked for compliance with national and local codes. (Refer to Section 240: Outdoor Accessibility, for more information.)
3. Where pedestrian ramp grades exceed the maximum 1:12 or 8.33 percent, intermediate landings should occur no more than 9 000 mm (30 ft) apart. The minimum landing depth should be 1 500 mm (5 ft).
4. The choice of decking and surface treatments for bridges is very important. Slip-resistant metal checkerplates, walkway gratings, or traction strips are often used for safety.

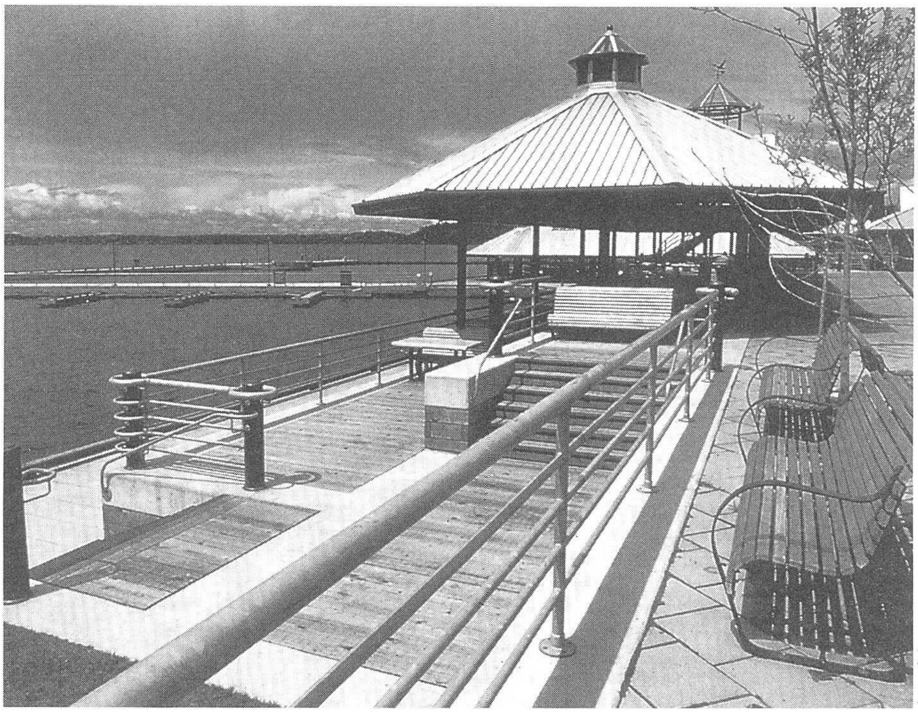
SECTION 510

Site Furniture and Features

CREDITS

Contributor:
Ilse Jones, G. H. Lee,
and Kevin M. Carl
Jones & Jones, Architects
and Landscape Architects
Seattle, Washington
Portland, Oregon

Reviewers:
Nicholas T. Dines
University of Massachusetts
Amherst, Massachusetts


Jones & Jones

CONTENTS

1.0 INTRODUCTION

1.1 General

Elements placed in a landscape or streetscape for comfort, convenience, information, circulation control, protection, and user enjoyment are collectively referred to as site furniture (Figure 510-1). Benches, bollards, signage, lighting, tree grates, and utility boxes are but a few examples. Their design and placement require careful consideration, involving several factors, each of which is described in this section.

Many of the same types of furnishings are also used for similar reasons in special landscapes, such as interiors or roof decks. (Refer to Sections 620: Interior Landscapes, and 610: Roof and Deck Landscapes, for more information.)

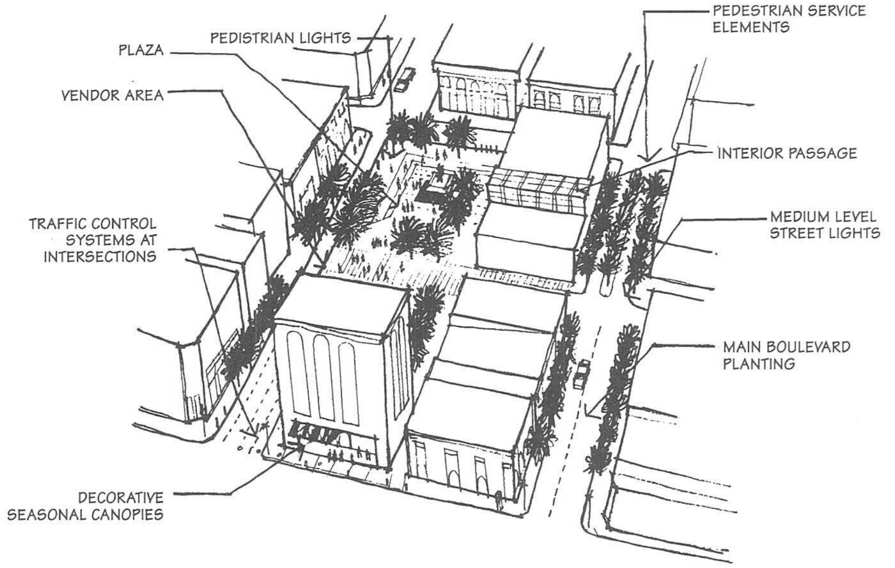


Figure 510-1. The larger setting provides the context of site furniture.

1.2 Design Objectives

Appropriateness:

Appropriateness is a major objective in the design and placement of site furniture elements. It is important to respond to the character of a site as well as its existing and proposed functions (Figures 510-2 and 510-3).

Response to Setting:

Design should respond to the essential identity or inherent character of a place. Successful, lasting design will flow out of its setting, continually responding to the needs of its users, meeting functional requirements, and adapting to the environmental stresses affecting it.

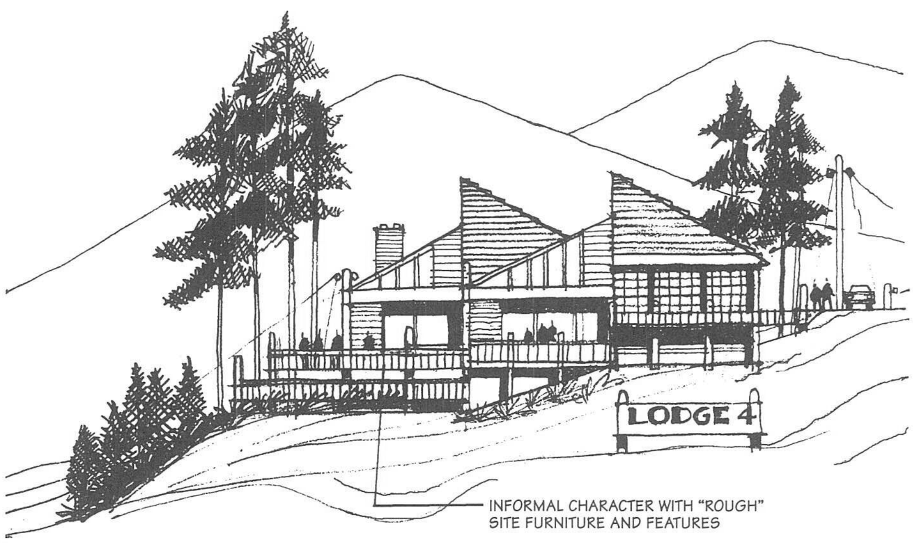


Figure 510-2. Site context: Informal character.

2.0 DESIGN DETERMINANTS

Settings should be analyzed in terms of both cultural and physical factors.

Cultural factors include:

1. Social context
2. Political context

Physical factors include:

1. Climate
2. Natural physiography
3. The existing built environment

Each of these factors is described below.

2.1 Cultural Factors

Social Context:

Attention to both the existing and proposed large-scale social setting will indicate who is currently using the site and who will likely use the site in the future. The manner in which the site is being used requires careful investigation (Figure 510-4).

The traditions and habits of particular user groups provide a basis for unique design departures that can enliven the setting as a whole, while at the same time serving specific needs. This can be reflected both in site organization as a whole and the design of individual elements themselves.

Inattention to the cultural habits and desires of particular groups and the use of improper elements can foster negative reaction in a neighborhood. The use of themes or vernacular forms which have no local cultural root seldom contribute to the evolving identity of a place.

Some ethnic groups, for instance, have need for special types of site furniture appropriate to particular activities. Finding what is needed is not only a basic responsibility of the designer, but often opens up an opportunity to explore new design ideas.

Recreational and Athletic Facilities

CREDITS

Contributors:
James D. Mertes, Ph.D.
Department of Park, Recreation and Tourism Resources
Michigan State University
East Lansing, Michigan

Professor Gaylan Rasmussen, BLA, MLA
Department of Park, Recreation and Tourism Resources
Michigan State University
East Lansing, Michigan

Kay Hutmacher, ASLA
Fresno, California

Gene Schrickel, Terry Cheek, and Victor Baxter
Schrickel, Rollins and Associates
Arlington, Texas

Technical Writer:
Jeffrey D. Blankenship

Research Assistants:
Robert B. Ruth
E. Brian Bristow

Reviewers:
Kevin A. Nelson, Ph. D. Candidate
Department of Parks, Recreation and Tourism
Michigan State University
East Lansing, Michigan

Professor Emeritus Louis F. Twardzik
Department of Parks, Recreation and Tourism
Michigan State University
East Lansing, Michigan

Albert J. Rutledge, Professor & Chairman
Department of Landscape Architecture
Iowa State University
Ames, Iowa


N. Dines

Monty L. Christiansen,
Associate Professor,
Department of Recreation and Parks
Pennsylvania State University
University Park, Pennsylvania

ACKNOWLEDGMENTS

The authors would like to acknowledge the aid and insight provided by Mr. Ernie Ralston, landscape architect, Marshall, Maklin, Monaghan Limited, Edmonton, Alberta; and Mr. Garrett Gill, Department of Park Administration and Landscape Architecture, Texas Tech University, Lubbock, Texas; and David Gill Corporation (golf course architect), St. Charles, Illinois.

Pools and Fountains

CREDITS

Contributor:
Richard Chaix
CMS Collaborative
Carmel, California

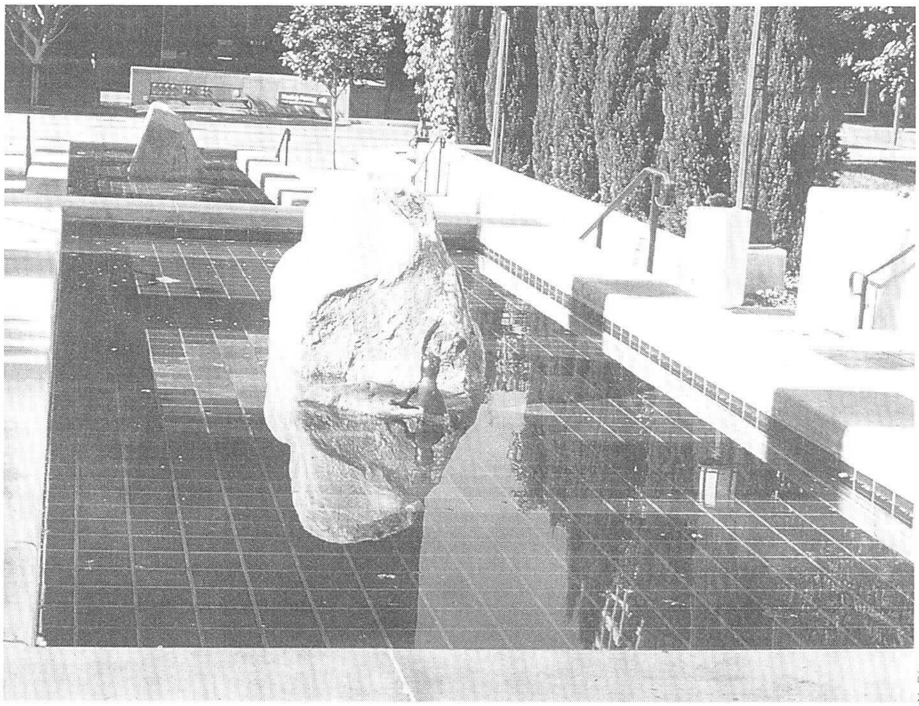
Illustrations:
Rick Briggs
President
SCS Interactive
Springfield, Illinois

Reviewers:
Angela Danadjieva
Danadjieva and Koenig Associates
Tiburon, California

Edward Janelli, Senior Landscape Architect
Department of Public Works
City of San Francisco, California

E. Byron McCulley
Amphion Environmental, Inc.
Oakland, California

Kevin Shanley
The SWA Group



N. Dines

CONTENTS

1.0 HISTORY

Contemporary water displays rely heavily on historic precedent, with elements usually abstracted to satisfy broader design and environmental constraints. Historical models range from ancient irrigation systems to ornate displays within fountains. Often, modern displays are modeled after free flowing streams and falls within natural settings.

2.0 WATER DISPLAY PURPOSE

2.1 Aesthetic Factors

A designer usually incorporates water into a space as a visual element. The aesthetic qualities of water, however, reach far beyond the visual aspect due to the documented psychological effects of water as a metaphor and as a physical factor providing sound, and climatic modification. The sound of water and the coolness associated with being near or touching water are equally a part of our emotional response to water in the environment.

Visual:

Water can function as a focal point within a space or as a means of creating and maintaining a sense of continuity. A water display can strongly temper the character of a space. A sense of calm and serenity is created by a quiet stream or pool, while excitement and drama can be achieved by swiftly moving, densely massed, or strongly vertical displays. The level of formality will be influenced by the forms of the pools and displays, and the mood further defined or reinforced by appropriate lighting.

Psychological:

It is an essential aspect of human behavior to be drawn toward a riverbank, lake edge, or seashore. We either live near water or convey it to where we live, using canals or pipelines. Our food supply likewise depends upon water for growth and sustenance.

Auditory:

The intensity and frequency of the sound generated by a water display can be used to convey a sense of calm or excitement, and can also mask unpleasant or distracting ambient noise.

Sensory Effects:

Airborne spray and evaporation from water displays cause a cooling effect. Droplets and sprays from active, aerated displays are particularly effective.

2.2 Functional Reasons

Pools also may be introduced or used secondarily for the following functional reasons:

Recreation:

Pools may be designed for wading, swimming, fishing, boating, or just water play, as with participatory water displays.

Circulation Control:

Pools may be used to direct or interrupt traffic patterns for reasons of safety or security or simply to promote an orderly progression through a space.

Utilitarian:

Practical applications for water displays include their use as a fire fighting or irrigation reservoir, as a retention pond for site drainage, or as a means for cooling air and/or mechanical equipment.

3.0 WATER

3.1 Quantification

Three units of measure are used to define water used for a display.

Capacity:

The volume of water in a system is usually expressed in liters (L) or gallons (gal). When designing a water display, it is useful to know that 1 m^3 of water is equal to 304.63 L (1 ft^3 is equal to 7.48 gal).

Flowrate:

The amount of water flowing through or circulating within a system is expressed as a volume per unit time, usually cubic meters per second (m^3/s) or gallons per minute (gpm). Flowrate is perhaps best understood by this comparison: a garden hose discharges about 25 Lpm (7 gpm), a fire hose about 560 Lpm (150 gpm), and a sheared-off fire hydrant about 3 750 Lpm (1000 gpm).

Pressure:

In U.S. units, pressure is usually expressed in terms of pounds per square

SECTION 540

Outdoor Lighting

CREDITS

Section Editor:
Nicholas T. Dines

Contributor:

Robert Prouse
HM Brandston and Partners Inc.
New York, New York

Michael Sardina
The SWA Group, Inc.
Boston, Massachusetts

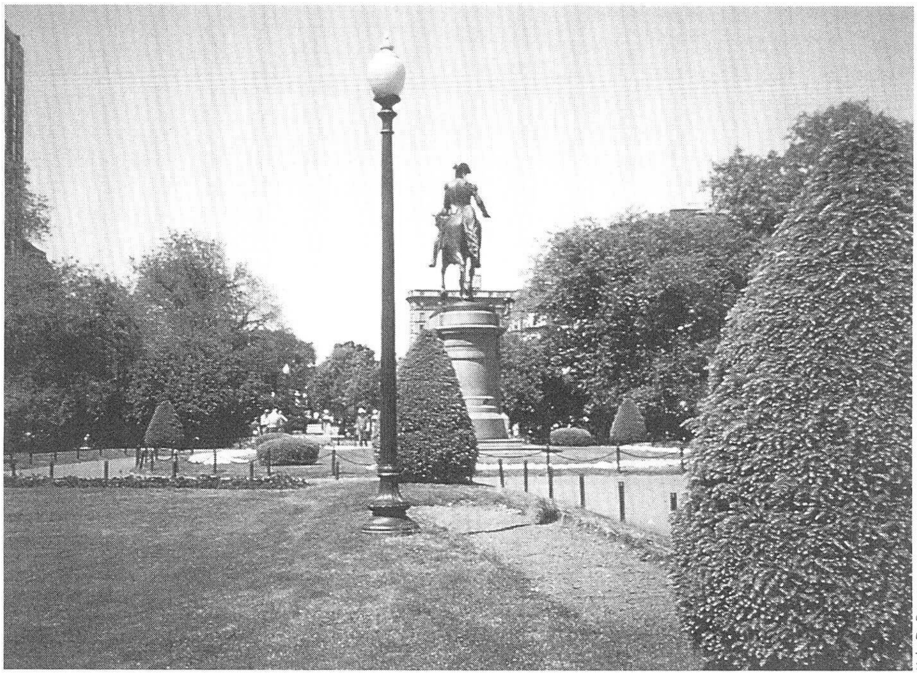
Alan Fujimori
Honolulu, Hawaii

Technical Writer:
Kyle D. Brown

Reviewers:

Peter Coxe
William Lam Associates
Cambridge, Massachusetts

Kenneth E. Bassett
Sasaki Associates, Inc.



Kyle D. Brown

CONTENTS

1.0 INTRODUCTION

1.1 General

This section includes information useful for solving site lighting problems. Included are definitions of terms associated with lighting, general design principles, characteristics of various lamps, and recommended levels of illumination (industry standards) for various landscape uses. The information included here will aid in the process of specifying fixtures for particular lighting projects.

1.2 Objectives of Outdoor Lighting

The purposes of outdoor lighting include: (1) improving the legibility of critical nodes, landmarks, and circulation and activity zones in the landscape; (2) facilitating the safe movement of pedestrians and vehicles, promoting a more secure environment, and minimizing the potential for personal harm and damage to property; and (3) helping to reveal the salient features of a site at a desired intensity of light in order to encourage nighttime use.

2.0 TERMINOLOGY

Lumen: A quantitative unit of measurement referring to the total amount of light energy emitted by a light source, without regard to the direction of its distribution.

Footcandle (fc): A U.S. unit of measurement referring to incident light. Footcandles can be derived from lumens (1 fc = 1 lumen/sq. ft.) or candelas (fc = candelas/distance^2).

Lux (lx): The International Standard (SI) measure of incident light. It is equal to one lumen uniformly distributed over an area of one square meter (10.7 lx = 1 fc) (Figure 540-1).

Candlepower: The unit of intensity of a light source in a specific direction, often referred to as Candela. One candela directed perpendicularly to a surface one foot away generates one footcandle of light.

Illuminance: Incident light, or light striking a surface (Figure 540-2).

Luminance: Light leaving a surface, whether due to the surface's reflectance, or because it is the surface of a light-emitting object (like a light bulb). Luminance is the measurable form of brightness, which is a subjective sensation.

Efficacy: A measure of how efficiently a lamp converts electric power (watts) into light energy (lumens) without regard to the effectiveness of its illumination. It should not be assumed that a lamp which has high efficacy will give better illumination than a less efficient lamp (Figure 540-3).

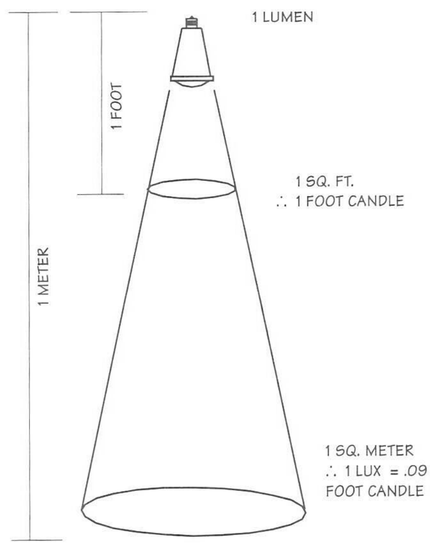


Figure 540-1. Lux and footcandle measurements.

Light depreciation: Lamp output (lumens) will depreciate over its effective life. Illumination will be reduced further due to an accumulation of dirt and grime on the lamp and fixture. Adjustments should be made to compensate for this depreciation when determining the average values of illumination maintained over time. A maintenance factor of 50 to 70 percent is common for outdoor applications. New installations are routinely designed to deliver 1-1/2 to 2 times as much illumination as needed, to sustain this maintained output over the anticipated life of the lamp.

Color: Two measures used to describe the color characteristics of lamps are (1) the apparent color and (2) the color rendering index.

The apparent color of a light source is given by the color temperature. Figure 540-4 shows various index numbers used to rank sources on a scale that range from warm to cool in appearance. Preference for one or another is a matter of taste and usually varies with the context of the application and with the illumination level. Warm tones tend to be favored when illumination is low and cooler tones are preferred under high lighting levels.

The color rendering index (CRI) is a measurement of the degree to which object colors are faithfully rendered. This scale ranges from 0 to 100 and is a reasonable approximation of color rendering accuracy. CRI is completely independent of whether a light source casts the object in a warm or cool tone. The CRI graph shows the ranking of the major outdoor light sources (Figure 540-4). As a general guideline, a minimum CRI of 50 is suggested to attain a reasonably faithful or natural color rendition. Lamps ranked significantly below this are judged to cause visible distortions to appearance.

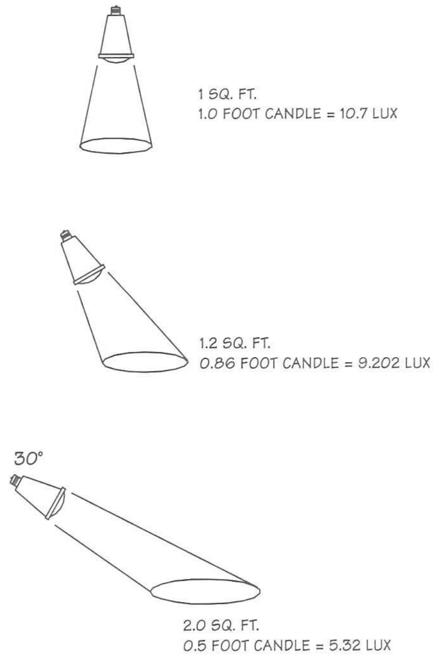


Figure 540-2. Incident illumination.

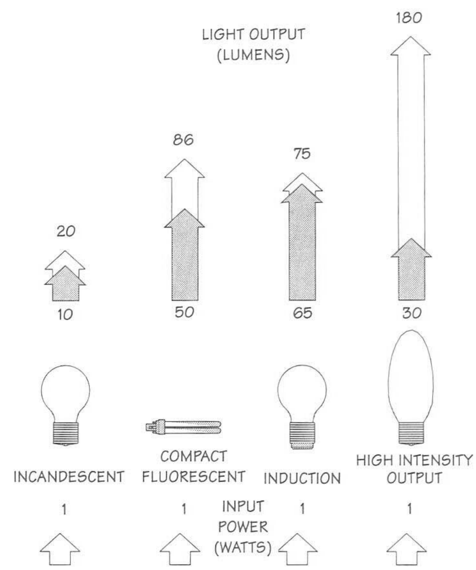


Figure 540-3. Lamp efficacy.

SECTION 550

Plants and Planting

CREDITS

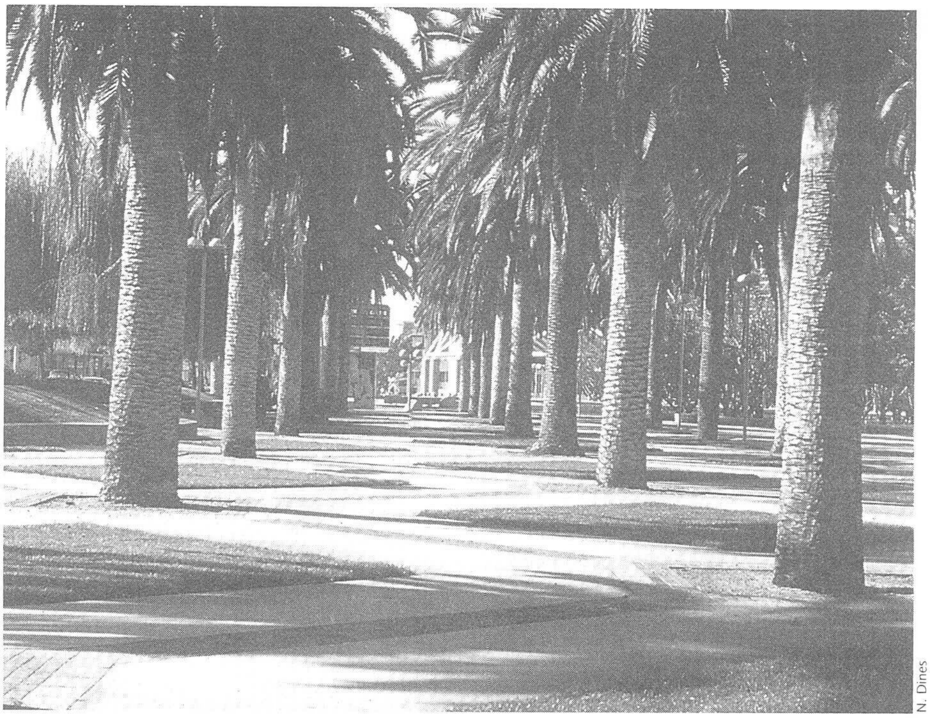
Section Editor:
Nicholas T. Dines

Technical Writers:
David Kvinge
Sarah Gronquist
Jeffrey D. Blankenship

Reviewers:
Dr. David Bloniarz
Urban Forester
Department of Forestry
and Wildlife Management
University of Massachusetts
Amherst, MA

Dr. Dennis Ryan
Department of Forestry
and Wildlife Management
University of Massachusetts
Amherst, MA

The original first edition illustrations for this section were supplied by Michael Van Valkenburgh Associates, Cambridge, Massachusetts.



N. Dines

CONTENTS

1.0 INTRODUCTION AND PURPOSE

The methods by which plants are chosen and the functions that they are intended to serve in designed landscapes have been expanding. While serving as sources of aesthetic pleasure, plants also reinforce the existing native ecosystem and work as bioengineering agents for soil retention and restoration.

This section provides information on planting design and plant-related technology. It is assumed that the reader has a working knowledge of plant materials and their uses or has sought such information elsewhere.

2.0 DESIGN CRITERIA

Certain procedures are common to many planting design processes. A balance must be struck between considerations of plant function, cost, hardiness, safety, and maintenance.

2.1 Major Functions of Plant Materials

Aesthetics:

Visual principles of color, texture, scale, and rhythm can be used to create an aesthetically pleasing human environment. Special plantings of high visual interest or quality, like specimen trees or perennial borders, can be used to dramatize certain views or alter a user's perception of scale.

Table 550-1 is a crown density matrix which illustrates the shade characteristics of a variety of trees.

Fragrant plants also contribute to the quality of human experience in the landscape. Conversely, the unpleasant odor of some plants may make some people nauseous (Refer to Table 240-2 in Section 240, Outdoor Accessibility, for a listing of some plants that bear unpleasant odors).

Efforts should also be made to support the existing visual character and ecological function of the site within its regional context wherever possible. The use of native plants mixed with a small proportion of compatible exotics is generally encouraged in order to add interest and variety while reflecting a regional context.

Environmental Modification:

Outdoor spaces that do not fall within the physical range of human comfort will not be used. The microclimate of an outdoor space can be changed through the careful placement of trees and shrubs to block excessive sun or wind. Plantings can also reduce snow drifting across roads and other passageways. For more information on climate control, refer to Section 220: Energy and Resource Conservation.

Screening:

Living barriers can range from semitransparent visual screens to formidable thorned hedges. Plant screens can provide privacy, mark boundaries, discourage intruders, or block unpleasant views.

Circulation Control:

Plantings can control and direct the movements of people, animals, or vehicles. Where established pedestrian shortcuts are to be discouraged, thorned, dense-growing plants may be necessary to change user habits.

Production:

Plants have long been harvested for food, flowers and raw building materials. They also provide food and shelter for wildlife. Planting can encourage the presence of birds, butterflies or other forms of wildlife for human enjoyment. In some cases, a site can be designed to support regional ecosystems.

Bioengineering and Other Forms of Structural Mitigation:

The natural regenerative tendency of plant material can be used to stabilize eroded banks, revitalize damaged soils, or strengthen wildlife habitats. Some of these mitigation techniques are discussed in 6.0, Specialized Planting Strategies, of this section and in Section 640: Disturbed Landscapes.

2.2 Cost

Initial nursery and planting costs must always be balanced against the cost of long-term maintenance. Some slow-growing trees are expensive as nursery stock but require little care once established and can grace the landscape for hundreds of years. The initial labor expense of careful planting may also be balanced in the long term by the sturdiness of a vigorous, healthy plant that has been handled gently, planted properly, and placed suitably for its requirements.

Plant materials are available at nurseries in different forms, depending on the cultural practices of each nursery and on market demands. Some of the most common forms are discussed in Table 550-2, grouped by plant type.

Specimen Plantings:

A "specimen" plant is chosen for the high visual quality of texture, color, or form it can provide at a crucial focal point in the landscape. A specimen plant is generally installed as a mature plant, when its true form and unique, individual character has begun to emerge; thus, it will be more expensive than plant materials used for massing.

Table 550-1. CROWN DENSITY OF VARIOUS TREES

Least Dense	Less Dense	Moderately Dense	Somewhat Dense	Most Dense
Palo Verde	Larch	Tree of Heaven	Tulip Tree	Japanese Pagoda Tree
Horsetail Casuarina	Kentucky Coffee Tree	Bald Cypress	Sweet Gum	Littleleaf Linden
Thornless Honeylocust	Ginkgo	Camphor Tree	Dawn Redwood	Norway Maple
Jacaranda	Amur Cork	London Plane	Pin Oak	Willow Oak
Desert Willow	Yellowwood	Red Maple	Modesto Ash	Live Oak
California Pepper Tree			Sugar Maple	Chinese Elm
			Red Oak	Sterile Mulberry
				Indian Laurel
				American Holly
				Southern Magnolia

SECTION 610

Roof and Deck Landscapes

CREDITS

Contributor:
Theodore Osmundson & Associates
Theodore Osmundson, writer
Gordon Osmundson, editor
San Francisco, California

Graphics:
Theodore Osmundson, FASLA
April Potter

Technical Writer:
Kyle D. Brown

Research Advisor:
Ralph E. Wilcoxen
Berkeley, California

Reviewers:
Thomas Wirth, ASLA
Sherborn, Massachusetts

William L. Clarke
EDAW
San Francisco, California

Fred H. Peterson
Soil & Plant Lab, Inc.
Santa Clara, California


Theodore Osmundson

CONTENTS

1.0 INTRODUCTION

The high cost of land in urban areas has caused a reappraisal of the usable space on the roofs of buildings. Flat space, whether above underground structures or on levels above the street, is expensive to obtain. Consequently, the development and use of roof areas is rapidly becoming an economic necessity.

Although aesthetic and social needs regarding roof and deck spaces have prevailed for centuries, most structures depend on economic justification to be built and maintained. Aesthetic justification is obvious from a superficial downward glance at the roofscape of our cities. The social justification is almost as obvious when comparison is made between undeveloped roof terraces and the public and commercially developed areas throughout the world. Roof and deck landscapes provide outdoor areas for social interchange that are otherwise almost impossible to obtain in most densely developed cities.

There are important design and structural differences between ground level landscape development and rooftop developments. This section deals with the following special construction requirements:

1. Protection of the integrity of the roof and structure.
2. Positive drainage.
3. A long-term, lightweight planting medium.
4. Adaptation to climate.
5. Optimum irrigation.
6. Selection of paving, structural materials, site furnishings, and water as a design element.
7. Provision of utilities.
8. Public safety and security.
9. Ease of maintenance.

This section covers only new construction. Construction methods needed for existing or historic buildings are too complex and unique to each situation to be included, although the above-listed construction requirements may be involved.

2.0 PROTECTION OF THE ROOF AND STRUCTURE

The single most important consideration concerning rooftop landscape construction is protecting the integrity of the roof and structure beneath the garden. For this reason, there must be waterproofing of exceptional security and longevity to prevent damage. The roof structure and waterproofing is an integral part of the building; consequently, it is the building architect's responsibility to: (1) waterproof the roof, (2) protect the waterproofing from mechanical damage, and (3) insulate the roof for energy conservation. The landscape architect or rooftop designer has no final responsibility for the design and construction of these items, she or he can only specify the roof's physical requirements. However, it is the rooftop designer's responsibility to protect the roof from damage during garden construction. As a general rule, this responsibility begins with the bottom of the drainage layer that is added to the finished roof.

2.1 Load Bearing Capacity

The maximum load bearing capacity of a roof is established by the structural engineer and must never be exceeded. In new construction, the roof structure can usually be strengthened to accommodate heavier loads. Typically, a minimum additional dead load limit of 7.18 kPa (150 psf) between columns is needed to accommodate the construction of a roof garden, although the loads above columns and at the bearing edges of a roof can be considerably greater. A structural engineer should always be consulted before beginning any type of roof or deck landscape design and construction.

2.2 Waterproofing

Waterproofing is another important factor in the design of a roof garden. A typical section through a roof consists of the structural framing or reinforced concrete slab, sometimes sloping to provide drainage to roof drains, a layer of waterproofing material, a layer of insulation, and a layer of lightweight concrete to protect the insulation and the waterproof membrane (Figure 610-1). Alternatively, the insulation may be installed inside the ceiling of the structure. The final layer of lightweight concrete is sloped to drain.

There are an increasing variety of waterproof membranes, employing different materials and methods. Elastomeric materials offer the greatest protection. Bituminous waterproofing should be avoided. Areas where the waterproofing is exposed should be flashed and protected from potentially harmful sun rays.

A complete and long-lasting seal must be achieved before any additional materials can be placed on top of the membrane. Quality control and testing by the building architect is crucial at this stage, to ensure the integrity of the roof, and thereby to prevent costly repairs if leaks occur under the finished roof or deck landscape. A properly installed waterproof membrane can last for the life of a building, however, a single leak may require the removal of the entire garden in order to find the leak.

KEY POINTS: Protection of Structure

The single most important consideration concerning roof and deck landscape construction is protecting the roof and structure from damage due to excessive loading or leaks.

1. The building architect and/or structural engineer should always be consulted prior to roof or deck landscape design and construction.
2. Rooftops must typically be able to support a dead load limit of 7.18 kPa (150 psf) to accommodate the construction of a garden. The loads above support columns and at the edges of a roof can be considerably greater.
3. The roof should be completely covered by a waterproof membrane. Elastomeric materials offer the greatest waterproof protection currently available. Bituminous waterproofing should be avoided.
4. The best drainage system for the roof garden is usually through the same system used by the building. A typical design incorporates a drainage mat placed on the protection board/slab, that directs all filtration water into the roof drains.
5. Anchoring structures to the rooftop slab and penetrating the waterproof membrane should be avoided whenever possible. Figures 610-22 through 610-24 illustrate alternative methods of anchoring.

SECTION **620**

Interior Landscapes

CREDITS

Contributors:
Jay Graham
Graham Landscape Architecture
Annapolis, Maryland

Nelson Hammer, ASLA
Hammer Design
Boston, Massachusetts

Gerard Leider
Rentokil Environmental Services
Riverwoods, Illinois

Technical Writer:
Kyle D. Brown

Reviewers:
Ellen Carlsen
Rentokil Environmental Services
Burtonsville, Maryland


Nelson Hammer

CONTENTS

1.0 INTRODUCTION

The interior landscape designer must be mindful that the primary function of most interior environments is to serve people rather than to grow plants. With the exception of facilities specifically designed for the display or growth of plants (such as greenhouses or conservatories), plant materials must be able to tolerate the environmental conditions created for human comfort. Budgetary considerations will often preclude the adaptation of a building's environmental systems to accommodate plant needs. However, with minor modifications to the physical conditions within a building, it is possible to find many plants from the tropical and subtropical regions of the world that will survive indoors in the temperature and humidity ranges also comfortable for human activity.

The "hardscape" aspects of interior landscape design and construction, (such as paving materials, landscape furniture, pools and fountains) are not significantly different than those same elements in the exterior environment.

This section will focus primarily on the physical needs and requirements of plant materials used within interior, climate controlled spaces.

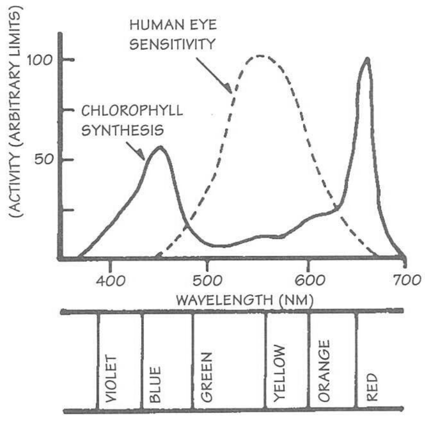


Figure 620-1. Response curves for the manufacture of chlorophyll.

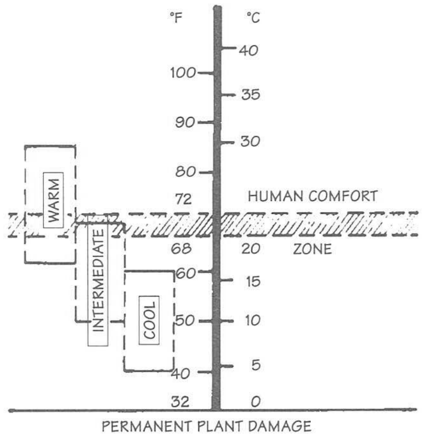


Figure 620-2. Temperature range of plants.

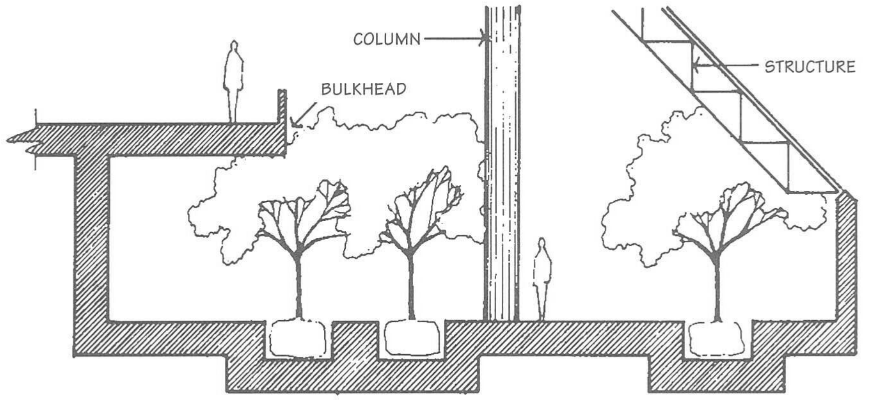


Figure 620-3. Height and spread of large materials.

2.0 PHYSICAL REQUIREMENTS OF PLANTS

2.1 Light

Growing plants convert radiant energy (from daylight or electric light sources) into food. Plants use radiant energy of wavelengths in the 400- to 850-nanometer (nm) range. White light, the visible part of the radiant energy spectrum, consists of wavelengths in the 430- to 700-nm range. Light for plant growth is typically described in terms of intensity, duration, and quality.

Intensity:

Intensity of light is a quantitative figure typically measured in lux (footcandles), or lumens per square meter (square foot). A lumen is the specific quantity of light emitted by a light source without regard to the direction of its distribution. A lux (footcandle) is a quantitative measure referring to how much light is being received on a surface. (Refer to Section 540: Outdoor Lighting, for more information on definitions and principles of lighting.)

Different plants have varying minimum requirements for light intensity (Table 620-4). Bright daylight is typically about 53 500-128 400 lx (5,000-12,000 fc), depending on latitude, season, and time of day. The average working environment in a building interior sometimes only receives 535 lx (50 fc) or less.

Duration:

While research continues to seek the necessary balance between intensity and duration for optimum plant growth, it is apparent that continuous illumination is not a suitable substitute for less than the minimum required intensity. Plants need periods of rest, each species having evolved unique preferences for particular photoperiods, the relative lengths of lightness and darkness affecting the growth of an organism. The average photoperiod for plants is 8 to 12 hours of darkness and 12 to 16 hours of light. If only minimum light intensity is provided, optimum light duration must be provided.

Quality:

Light quality refers to the type of radiant energy available to plants. Figure 620-1 shows that plants use radiant energy primarily from the blue and red ends of the visible spectrum. Most electric light sources are primarily monochromatic and tend to emphasize the yellow-green part of the visible spectrum. Natural light, which contains the entire spectrum of visible light plus ultraviolet and infrared wavelengths, is ideal for plant growth. However, light passing through tinted or reflective glass will have its spectral energy distribution altered in addition to reducing its intensity. Glazing manufacturers can provide the designer with data documenting both the spectral energy distribution and percentage of light transmittance of their products.

2.2 Temperature, Humidity, and Air Quality

Plant requirements for air typically refer to temperature, relative humidity, and air quality.

SECTION 640

Disturbed Landscapes

CREDITS

Contributors:

William Agnew
REVEG Environmental Consulting, Inc.
Fort Collins, Colorado

Herbert R. Schaal
EDAW, Inc.
Fort Collins, Colorado

Marc Theisen
Synthetic Industries
Chattanooga, Tennessee

Reviewers:

Dr. David Johnson
Western Ecological Resources
Boulder, Colorado

Dr. Edward F. Redente
Shepard Miller, Inc.
Fort Collins, Colorado

Herbert R. Shaal, EDAW, Inc.

CONTENTS

1.0 INTRODUCTION

A disturbed landscape is any portion of land surface that has been drastically altered and is not in an attractive, stable, or productive condition. Disturbed lands are extremely vulnerable to erosion, and they may have surfaces unsuitable for plant growth because of compaction, steepness, stoniness, infertility, phytotoxic chemicals, acidity, alkalinity, or instability. Floods, fire, volcanic eruption, agriculture, mining, highway construction, overuse, and land development are examples of natural events and human activities which create disturbed landscapes.

1.1 Problem of Erosion

The impact of a particular land disturbance is rarely limited to the altered site. Soil erosion is inevitable on disturbed landscapes and will significantly affect downstream waters. The U.S. Environmental Protection Agency (EPA) reports that sediment yields from areas undergoing construction are 20 to 40,000 times greater than from undisturbed woodlands. Each year in the United States, 3 600 billion kg (4 billion tons) of soil erode from the land. Sediment accounts for more than 2/3 of all pollutants entering U.S. waterways. Estimates indicate up to $13 billion per year is spent in the U.S. to directly mitigate the off-site impacts of erosion and sediment. Sediment adversely affects recreational areas, aquatic life, and domestic water supplies.

Soils develop slowly through complex organic and inorganic processes. One hundred years are required for the formation of 25 mm (1 in) of topsoil in typical subhumid regions. In arid regions and high-altitude areas, where natural processes are much slower than in humid regions, 1000 years may be required. Topsoil is clearly a most valuable and limited natural resource which has to be managed with great care and responsibility.

In response to this increasing environmental awareness, important legislation has been drafted to help control the problems of erosion and water pollution. The U.S. federal government passed the National Environmental Policy Act in 1969 and later passed Public Law (PL) 92-500, an amendment to the Federal Water Pollution Control Act Amendments of 1972. In 1972, the Federal Clean Water Act established the National Pollutant Discharge Elimination System (NPDES) permit system. This amendment encourages states to establish regulations to control non-point sources of water pollutants. Public Law (PL) 95-87, the Surface Mining Control and Reclamation Act (SMCRA) of 1977, created the Office of Surface Mining. These two acts set out a variety of specific requirements, but their common goal is to limit erosion and return the landscape to a stable and productive condition. Since SMCRA, a variety of other laws have been enacted that ultimately impact large scale disturbance activities and include: Water Quality Act of 1987 which outlined the National Stormwater program; Hazardous and Solid Waste Amendments to RCRA (1984) and RCRA, subtitle D (1991) which called for minimum nationwide standards for protecting human health and the environment and provided technical support to states to develop environmentally sound waste management standards; Amendment to the Clean Water Act of 1992 began requiring disturbances greater than 5 acres to obtain a NPDES permit to help identify and quantify releases of pollutants into our watersheds.

Section 640 describes general principles and methods of reclamation useful in accomplishing that goal.

2.0 RECLAMATION PROCESS

Although the basic reclamation process is the same for both existing and proposed landscape disturbances, there are several significant advantages to planning the reclamation prior to the disturbance. Prior planning can limit both on- and off-site impacts, make the operations and use of equipment more efficient, speed up the reclamation process, provide better reclamation conditions, and significantly reduce the costs.

The following steps are essential:

1. Establishing objectives
2. Determining factors that may influence methods of reclamation
3. Selecting appropriate reclamation methods, materials, and developing a plan

2.1 Establishing Objectives

Meeting Government Standards:

The standards established in the United States (and in many other countries) by federal, state, and local governments provide the basis for many reclamation objectives. The standards typically require such measures as returning the ground surface to approximately its original contour, reestablishing vegetative cover to control erosion at a degree equal to predisturbance levels, and covering all acid-forming and other toxic materials. Additional objectives are derived from the land use goals for the disturbed area.

Economic and Social Objectives:

Determining potential uses for any given site may be made by:

1. Identifying uses for which there may be a demand or a need
2. Analyzing proposed uses to confirm the degree of demand or need through a market analysis
3. Analyzing the site to determine engineering and environmental feasabilities
4. Analyzing costs and benefits to determine the return on investment and the social, environmental, and economic consequences of development
5. Creatively applying principles of landscape architecture to achieve efficiencies, maximize benefits, and minimize adverse environmental impacts
6. Organizing public meetings to solicit input from the community

Environmental Objectives:

In addition to economic and social objectives, consideration should be given to such environmental factors as:

1. Water quality
2. Air quality
3. Erosion
4. Aesthetics
5. Wildlife
6. Adjacent areas
7. Long-range productivity
8. Post-disturbance landuse

Evaluation of Objectives:

Objectives should be specific and quantifiable. They must be realistic and matched to acceptable risks and reasonable costs. For example, it is possible to:

1. Determine the amount of erosion which will occur on a disturbed site during certain high-precipitation events.
2. Determine the frequency of these events and establish the risk for any given year.
3. Determine the loss and damage which would result from the event.

Sound Control

CREDITS

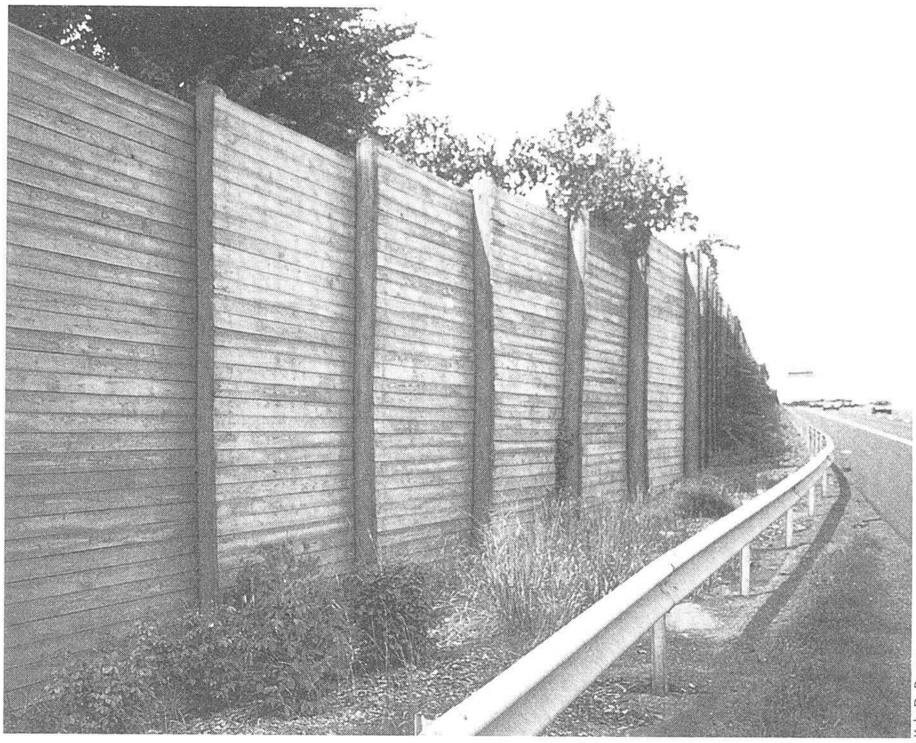
Contributors:
Walter Kehm
E. D. A. Collaborative, Inc.
Toronto, Ontario
Canada

Phillip Ellis
Wimpey Laboratories, Ltd.
Hayes, Middlesex
England

Reviewers:
J. R. Wear
Ministry of Transportation and Communications
Province of Ontario
Downsview, Ontario
Canada

Robert Armstrong
Federal Highway Administration
Washington, D.C.

Robert Newman
Christopher Menge
Bolt Beranek and Newman Inc.
Cambridge, Massachusetts



Kyle D. Brown

CONTENTS

1.0 INTRODUCTION

This section provides design and planning guidelines for the reduction or elimination of unwanted sound in the landscape. Because sound control is a very large subject, the amount of technical information presented here is necessarily limited. However, sources of additional information are listed under References at the end of this section. Regulations and standards for noise abatement and acoustical planning are not common, but an investigation of local ordinances is nevertheless essential when one is involved in any land use planning project.

The science of sound control in the landscape involves much more than the simple quantification of data. The quality of sound may be as important as the quantity of sound. Some sounds can have profound psychological effects on people. For example, the constant drone of cars on a highway is rarely as offensive as the squealing of brakes at an intersection. Masking unwanted sound (by falling water, for instance) is a technique which can mitigate noise disturbance by modifying the quality of the sound received by the ear.

1.1 Basic Approaches to Sound Control

Two approaches to sound control in the landscape include acoustical planning, where potential noise problems are minimized during design stages, prior to any construction, and retrofitting, where noise problems are mitigated by alteration to existing developments.

Acoustical Planning (Preplanning):

Where acoustical planning is possible, setbacks and other methods can be employed to minimize sound transmissions. Acoustical planning should be part of any land use planning project, especially with such major projects as airports, highways, and railroads. Acoustical models should be developed and tested to assess the planning implications both on and off the property.

Acoustical planning is more desirable than retrofitting, because as potential noise problems are identified, cost-saving mitigative measures can be taken to reduce noise levels to acceptable standards while at the same time designing a physical landscape with improved visual qualities. This can be achieved, for instance, through grading concepts that retain significant natural landforms and existing vegetation, as well as incorporate noise buffer mounds where necessary. Preplanning can accommodate public and private interests by reducing noise to acceptable levels, while retaining landscapes of high quality.

Retrofitting:

Acoustical planning principles can also be effectively applied to existing development, but the aesthetic results are often unattractive. Establishing adequate rights-of-way or buffer zones is difficult, typically including architectural barriers or walls. Capital construction and eventual maintenance costs can become limiting factors.

1.2 Acoustic Variables

Three acoustic variables to address when attempting to minimize noise problems in the landscape are: (1) the source of the sound, (2) the path and distance of the sound transmission, and (3) the receiver of the sound.

Source of the Sound:

Most noise can be modified by acoustical treatment at its source; however, this is often not as economically feasible as control of noise by various landscape planning techniques.

Path and Distance of Sound Transmission:

The path and the distance of sound transmission constitute an important variable in any strategy of noise reduction. A valley or a downwind site, for instance, can make any development located in these areas more susceptible to noise. Valleys and ravines can exacerbate conditions by channelizing sound waves. Such topographic conditions can present problems when intensively used highways or railways cross a valley, for instance. Analyses of topographic and climatic factors are required to assess the directions of sound transmission.

Receiver of the Sound:

People who are accustomed to quiet landscapes are significantly less tolerant of noise than people accustomed to suburban or urban environments. Masking of noise can sometimes be accomplished by introducing pleasant sounds, such as the sound of flowing water or rustling leaves.

Table 660-1. TYPICAL SOUND LEVELS OF EVERYDAY OCCURANCES

Occurrence	Sound level, dB(A)
Weakest sound that can be heard (threshold of hearing)	0
Inside broadcast studio	20
Rural area at night	25
Whispered conversation at 2 m (6 ft)	30
Library	35
Residential area during daytime	
Rural	40
Suburban	50
Suburban, adjacent to airport	60
Conversation at 1 m (3 ft)	60
City center	65
Major roads (adjacent property ±20 m (65 ft) inside)	
Township road	50
Highway	60
Freeway (12-lane)	75
Diesel truck at 15 m (50 ft)	90
Noisy metal-working shop	100
Impulsive pile driving at 10 m (32 ft)	110
Jet taking off at 50 m (165 ft)	120
Pain begins	>120

2.0 PHYSICS OF SOUND

2.1 Nature of Sound Waves

Sound waves are generated by any pulsation or vibration of a source. The surrounding air is disturbed, thereby causing pressure changes which can be heard. The greater the change in pressure, the louder the sound.

The rate of repetition of these sound waves is referred to as frequency. It is measured in cycles per second or units of hertz (Hz). The normal audible range for humans is 20 to 20,000 Hz.

2.2 Sound Pressures and Decibels

Although the human ear acts like a sound filter by discriminating against some frequencies and giving preference to others, the range of sound pressure which the human ear can detect is relatively broad.

Water Supply

CREDITS

Contributor:
Daniel Bubly, P.E., L.A., A.I.C.P.
Bubly Associates, Inc.
Sharon, Massachusetts

Graphics:
Joseph C. Cloud

Mark B. Darnold, P.E.,
The Berkshire Design Group, Inc.
Northampton, Massachusetts

Reviewer:
Robert T. Ferrari, P.E.
Ferrari-Atwood Engineering, Inc.
Providence, Rhode Island

Jeffrey D. Blankenship

CONTENTS

1.0 INTRODUCTION

Piped water supplies are ordinarily used for:

1. Potable water for homes, schools, industries, etc.
2. Fire fighting
3. Nonagricultural irrigation (lawns and gardens)

In many cases, all three uses are supplied by a single system of piping, although there are cases where all three are supplied by separate systems.

2.0 STANDARDS AND CRITERIA

2.1 Water Quality

Water intended for human consumption must meet extensive physical, chemical, and biological standards for quality and reliability. These standards include color, taste, and transparency as well as freedom from bacteria and chemicals related to human or industrial wastes.

Specific water quality standards are published in the United States by individual state and federal agencies, but there are variations between states and counties and these standards do change with time. Some existing public water supplies do not meet all the standards to which they are subject because (1) most of these standards are very conservative and (2) some are not related to public health or safety but rather to aesthetic qualities of water (e.g., the ease of use in washing machines).

2.2 Water Quantity

The amount of water used in various parts of the world varies with regional legal, and political traditions. For instance, in the northeastern United States the average water use is about 75 gal (285 L) per capita per day in rural areas, and 150 gal (570 L) per capita per day in metropolitan areas. This is a region (1) where the English common-law tradition limits the right to water to nonconsumptive uses (use and return to stream), (2) where little water is used for irrigation, and (3) where water supply systems are funded entirely with local fees and taxes. In metropolitan areas of the southwest, where the Spanish law tradition grants preemptive rights to water on a first-come-first-established basis, average (publicly supplied) water use is about 350 gal (1325 L) per capita per day.

Table 710-1. PLANNING GUIDE FOR WATER

Types of establishments	Gallons per person per day (unless otherwise noted)
Airports (per passenger)	5
Apartments, multiple family (per resident)	60
Bathhouses and swimming pools	10
Camps:	
Construction, semipermanent	50
Day (with no meals served)	15
Luxury	100
Resorts, day and night, with limited plumbing	50
Campground with central comfort facilities	35
Cottages and small dwellingswith seasonal occupancy	50
Country clubs (per resident member)	100
Country clubs (per nonresident member present)	25
Dwellings:	
Boardinghouses	50
Additional for nonresident boarders	10
Luxury residences and estates	150
Multiple-family apartments	60
Rooming houses	40
Single-family houses	75
Factories (gallons per person per shift, exclusive of industrial waste)	35
Highway rest area (per person)	5
Hotels with private baths (two persons per room)	60
Hotels without private baths	50
Institutions other than hospitals (per person)	125
Hospitals (per bed)	250+
Laundries, self-serviced (gallons per washing, i.e., per customer)	50
Mobile home parks (per space)	250
Motels with bath, toilet, and kitchen facilities (per bed space)	50
Motels (per bed space)	40
Picnic parks (toilet wastes only, per picnicker)	5
Picnic with bathhouses, showers, and flush toilets (per picnicker)	10
Restaurants with toilet facilities (per patron)	10
Without toilet facilities (per patron)	3
With bars and cocktail lounge (additional quantity per patron)	2
Schools:	
Boarding (per pupil)	100
Day, with cafeteria, gymnasiums, and showers (per pupil)	25
Day, with cafeteria but no gymnasiums or showers (per pupil)	20
Day, without cafeteria, gymnasiums, or showers (per pupil)	15
Service stations (per vehicle)	10
Stores (per toilet room)	400
Theaters:	
Drive-in (per car space)	5
Movie (per auditorium seat)	5
Trailers without individual baths and sewer (per person)	50

Tables 710-1 and 710-2 illustrate the specific water requirements for various land uses and the rates of flow for various plumbing fixtures.

2.3 Fire Fighting Requirements

For fire fighting, the amount of water that should be immediately availableóparticularly the rate at which it should be capable of being delivered to any building or group of buildingsóis a function of the size, density,

710 Water Supply

Sewage Disposal

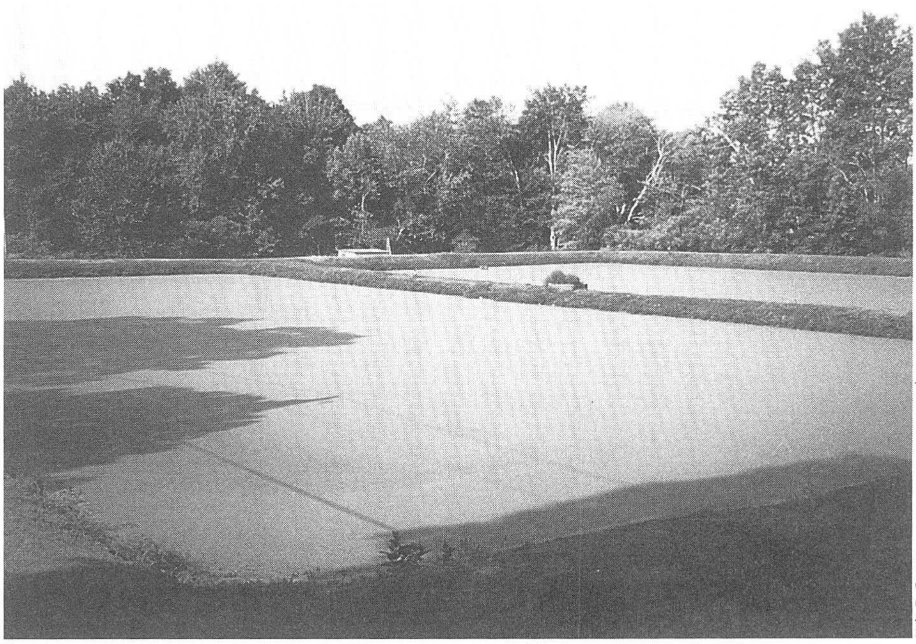
CREDITS

Contributor:
Mark B. Darnold, P.E.,
The Berkshire Design Group, Inc.
Northampton, Massachusetts

Daniel Bubly, P.E., L.A., A.I.C.P.
Bubly Associates, Inc.
Sharon, Massachusetts

Graphics:
Gary M. Fishbeck

Reviewer:
Robert F. Ferrari, P.E.
Ferrari-Atwood Engineering, Inc.
Providence, Rhode Island


Kyle D. Brown

CONTENTS

1.0 INTRODUCTION

Some form of sewage disposal is necessary in most building or land development projects for the disposal of domestic waterborne wastes. Such wastes are either piped off-site to a municipal sewer system or are treated and disposed of on-site. Proper design for the treatment and disposal of domestic waterborne wastes is essential for the protection of public health, safety, and welfare.

1.1 Types of Sewage Systems

The type of sewage disposal system chosen for the development of any tract of land will influence the pattern and density of that development. The sewerage for any project can include:

1. Simple, economical systems for the safe, environmentally sound disposal of wastewater
2. More complex and costly systems for overcoming the limits of poorly drained or impermeable soils on sites that have good locations or other valuable aspects
3. More complex and costly systems for increasing the density of development on a site (Figure 720-1)

1.2 On-Site Disposal

It is expected that the use of on-site disposal will increase as urban development spreads outward beyond the extent of existing sewage collection systems and as existing public treatment plants run out of reserve capacity.

Some developments, particularly industrial use, will require special on-site systems for wastes that cannot be discharged to municipal sewer systems or that cannot be disposed of through on-site systems designed for domestic or human wastes. Site designers should be aware: (1) that many industrial wastes require special treatment (designed by specialists in the specific industry) and (2) that for such industrial wastes, after removal of hazardous compounds, the treated effluent may be disposed of by ordinary on-site leaching or by discharge to a municipal sewer.

2.0 DESCRIPTION OF SEWAGE SYSTEM PROCESSES

Effective sewage disposal includes physical disposal of the sewage into the environment without adverse health, odor, aesthetic, or nutrient (fertilization) effects.

All currently permissible sewage disposal systems include some method for separation of solids from wastewater, for disposal of the solids, for oxidation of putrescible substances dissolved in the wastewater, for destruction of pathogens, and ultimately for discharge of the resulting effluent to the ground, to a waterbody, or to the atmosphere.

At a typical modern large-scale municipal treatment plant, the solids are settled out and then physically skimmed off the top and bottom of the wastewater stream and either incinerated or landfilled, the wastewater is actively aerated to biologically remove most of the dissolved putrescibles and suspended organic solids, and the resulting effluent is dosed with chlorine and discharged to a river or large body of water.

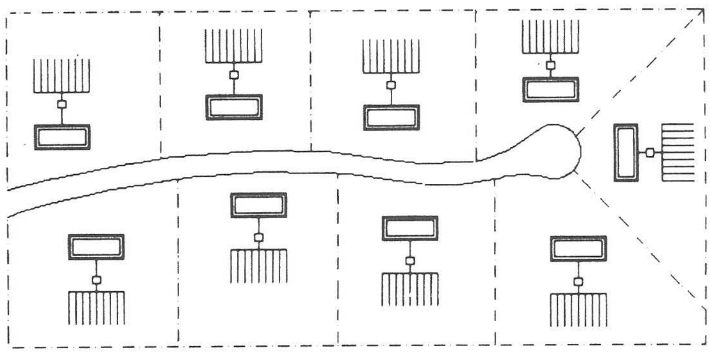
For a small on-site system, the processes would include the digestion of solids into liquids and gases, the oxidation of dissolved putrescibles, the destruction of pathogens by biologically active filtration, and the discharge of effluent, preferably to the ground or, alternatively, to a waterbody or to the atmosphere.

The average amount of domestic sewage disposed in the United States is about 245 L (65 gal) per capita per day. About one-third of domestic sewage is toilet waste; one-third, laundry waste; and one-third, drainage from sinks and tubs.

3.0 SYSTEM ALTERNATIVES

Alternative methods of sewage disposal on a tract of land include: (1) discharge to a municipal sewer system and (2) various kinds of on-site disposal systems. Selection of the method depends on location, geohydrologic conditions local codes, and density of development.

In general, connection to an existing municipal system will be the least complex method. In addition, where such connec-



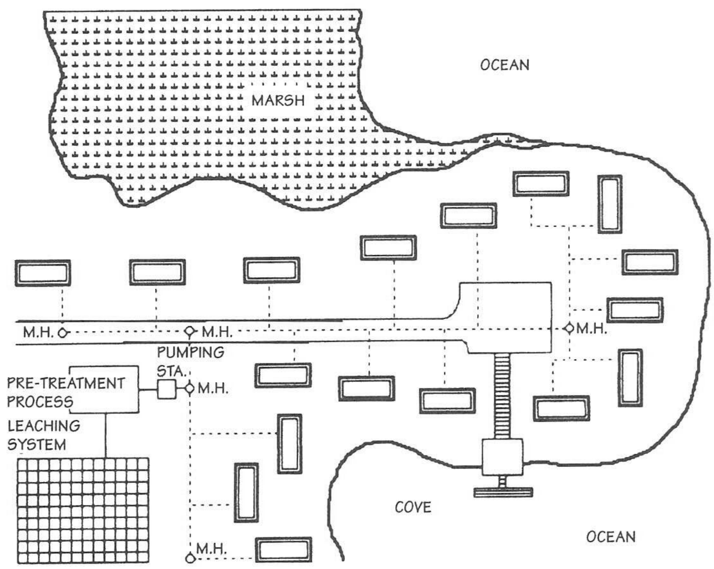


Figure 720-1. Alternative land use and alternative on-site disposal.

720 Sewage Disposal

Recreational Water Bodies

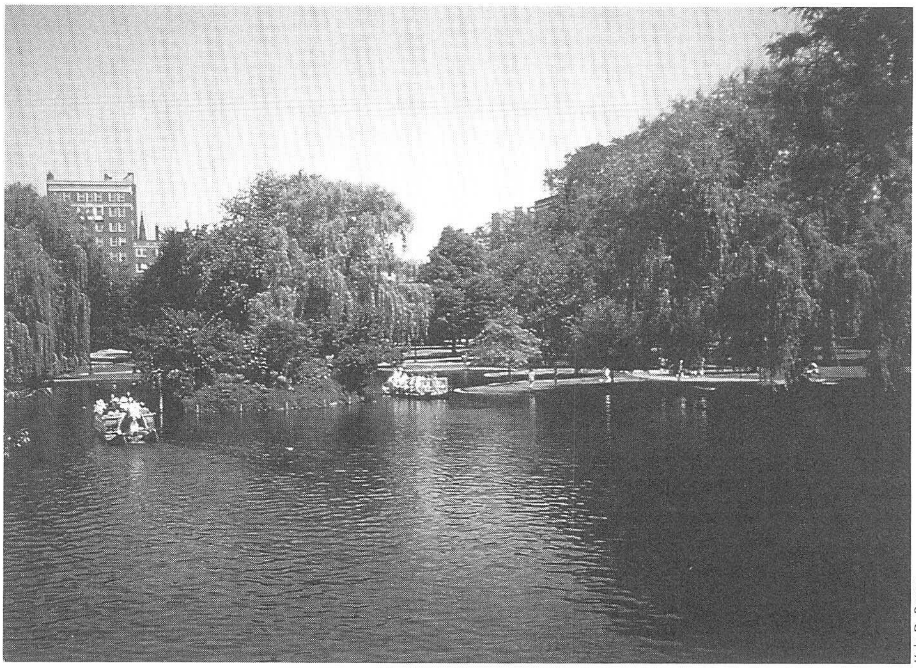
CREDITS

Contributor:
Daniel Bubly, P.E., L.A., A.I.C.P.
Bubly Associates, Inc.
Sharon, Massachusetts

Graphics:
Gary M. Fishbeck

Reviewers:
Mark B. Darnold, P.E.,
The Berkshire Design Group, Inc.
Northampton, Massachusetts

Robert F. Ferrari, P.E.
Ferrari-Atwood Engineering, Inc.
Providence, Rhode Island



Kyle D. Brown

CONTENTS

1.0 INTRODUCTION

Impounded surface waters are often valued for:

1. Swimming and related recreation
2. Wildlife habitat
3. Aesthetic (i.e., visual) reasons

Principal concerns in the design of recreational water bodies are control of (a) water quality, (b) water level fluctuation, and (c) edge treatment. Each of these concerns should be addressed and specifically incorporated into the plans and designs for recreational water bodies. Unless the water body is large enough to establish zones, it is often not feasible to incorporate several recreational functions into one area. For instance, swimming and boating do not mix.

Impoundments designed primarily for power and flood control tend to have short periods of water detention, i.e., their annual flowthrough is larger than their storage capacity, hence their retained water tends to be turbid and tactilely unattractive. On the other hand, impoundments designed for water storage (i.e., water supply and large-scale irrigation) tend to have long periods of retention, and therefore their water is more transparent and tactilely more attractive.

Similarly, reservoirs that are small with respect to the amount of water drawn from them may have wider variations of water levels. This makes the shorelines more difficult to use for recreational purposes and may affect the aesthetic values during certain seasons. Large reservoirs tend to have more stable water levels with respect to their slower rates of withdrawal and, therefore, are more suitable for recreational uses.

Note that daily flowthrough, a key parameter in the design of mechanically filtered swimming pools, is not appropriate to determine for ponds and lakes. They typically have far more water per swimmer than the typical large public swimming pool.

2.0 EVALUATIVE CRITERIA FOR RECREATIONAL WATER BODIES

Waters for recreational use must meet various standards of quality, appearance, and ease of maintenance.

2.1 Water Quality

1. In a public health sense, fresh water used for swimming should approach the quality standards used for drinking waters.
2. In an aesthetic sense, swimming waters should be as transparent as possible, including being free from algae, weeds, organic detritus, and suspended silts and clays.
3. In a public safety sense, intensively used swimming waters should have sufficient transparency to facilitate rescue of drowning victims.
4. For wildlife habitat and scenic values, any water quality except the most seriously polluted will be appropriate. A diversity of water body characteristics (i.e., quality, depth, temperature, and form) will support the greatest number of species.

2.2 Water Levels

1. For swimming uses, water control systems should be designed so that levels can be maintained during dry summer seasons, or so that access to the water can be maintained when water levels fall.
2. For aesthetic (i.e., nonswimming) reasons, water bodies that are expected to lose a major portion of their water during the summer should be shaped as a shallow basin to support a vegetative cover (i.e., marsh, shrub swamp, etc.) to avoid revealing a muddy edge or bottom.

2.3 Side Slopes

The action of waves will eventually erode any pond embankment to a wavecut beach (except those heavily armored with stone, concrete, or metal). The eventual slope of the beach will depend on the texture of the soil involved. For instance, coarse sand will form an approximate 10 percent slope, and finer sands a 5 percent slope. The vertical extent of the erosion will approximate the height of waves generated on the pond. Wave height is a function of pond size, its wind exposure, and other factors, including the size of boats and the relative exposure of the particular reach of shoreline.

Figure 740-1 shows the form of a wave-cut beach, with 300 mm (1 ft) waves and a stable water level, on a 1:5 slope in coarse sand. Note the steep drop that can form just below the beach. On a steeper average slope, say 1:3, or in fine sand, the drop would be over 1 m (3 ft) deep and could constitute a safety hazard for swimmers, especially children.

Alternative shoreline treatments include riprap, stone armor, and various types of walls. In each, consideration should be given to the human usage of the surrounding area, including ways to escape if anyone happens to fall into the water.

3.0 SWIMMING WATERS

3.1 General

Two common alternatives for swimming include:

1. Swimming pools with:
   a. Filtration to remove suspended materials
   b. Algicides to control algae
   c. Chlorination to control bacteria
2. Ponds and lakes with:
   a. Long storage times to settle suspended materials
   b. Control of algae by controlling watershed land use and drainage

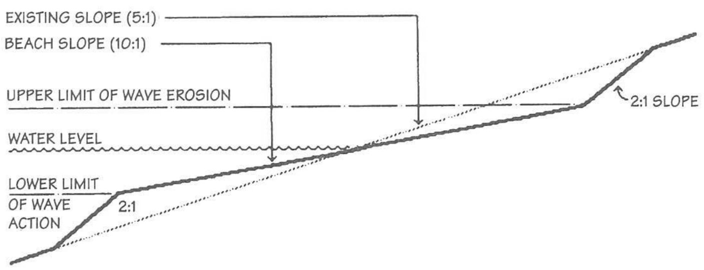


Figure 740-1. Wave-cut beach form on erodible shore.

SECTION 750

Irrigation

CREDITS

Contributors:

Jim Wright,
Category Manager, Rotors
The Toro Company
Riverside, California

Erich O. Wittig
The Toro Company
Riverside, California

Advisors/Reviewers:

Ken Killian
Killian Design Group, Inc.
Howard, Illinois

Jeffrey D. Brauer
Golfscapes, Inc.
Dallas, Texas

Richard Lakutis
The Architects Collaborative, Inc.
Cambridge, Massachusetts

Stephen W. Smith
EDAW, Inc.
Fort Collins, Colorado

John Hooper
Hooper Engineering, Ltd.
Palintine, Illinois

Michael Holland
Sasaki Associates, Inc.
Watertown, Massachusetts

Toro Corp.

CONTENTS

1.0 INTRODUCTION

1.1 General

Irrigation is sometimes necessary to keep landscapes at an optimum functional or aesthetical peak. Although all geographic areas receive rainfall sufficient to sustain indigenous plant materials growing under natural conditions, situations involving introduced species, or species growing under less-than-ideal conditions, often require some form of irrigation to maintain healthy plant growth.

This section focuses on various types of irrigation systems and on means for selecting the most economical system for any given situation.

1.2 Important Considerations

Plant Growth Requirements:

The quantity of water necessary for healthy plant growth must be determined in order to design an irrigation system of highest efficiency. If growth conditions are less than ideal, supplemental water may be necessary to overcome incidences of plant stress.

Some plantings may require irrigation during construction processes, or during and after transplantation until established. A controlled application of water will greatly improve the germination rate in seeded areas and will enable seedlings to develop to maturity. Turfgrass is used most often in nonnative environments, and even though some varieties are drought-tolerant, a regular schedule of water is necessary to maintain a green, healthy turf.

Conservation of Water:

Conservation of water is an important ecological issue. Along with water depletion, common problems include saltwater intrusion and land subsidence. The rising cost of water requires efficient use and management of all water resources.

Automatic sprinkler systems are designed to increase the efficiency of landscape water usage. Efficiency is accomplished by first determining which plant materials require irrigation and how much water is required, and then designing irrigation systems which apply that water with minimum waste.

Effluent water is being used in many areas as a conservation measure, with considerable success. (Refer to 2.4 Effluent Water in this section for more information.)

2.0 WATER SOURCES

2.1 Municipal Water

Most landscape projects use potable water provided by the local water district.

Research necessary at the outset of an irrigation project includes:

1. The possibility of an alternative source of water that would be more cost-effective on a long-term basis.
2. A determination of existing static pressure in municipal lines (including high and low times), of the size of the main line in closest proximity to the project site, and of any local codes that may be pertinent to the installation of an irrigation system.

Table 750-1. RAINFALL AND EVAPOTRANSPIRATION DATA (EXAMPLE)

Massachusetts	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Western (Pittsfield)													
RF	3.39	2.69	3.56	3.90	4.00	3.96	4.41	3.73	4.43	3.25	4.06	3.41	44.79
EVT	0.00	0.00	0.46	1.51	3.33	4.78	5.77	4.93	3.05	1.61	0.58	0.00	26.02
DIFF	3.39	2.69	3.10	2.39	0.67	−0.82	−1.36	−1.20	1.38	1.64	3.48	3.41	18.77
Central (Springfield)													
RF	3.86	3.10	4.09	3.84	3.58	3.71	3.60	3.79	3.95	3.23	4.14	3.60	44.49
EVT	0.00	0.00	0.67	1.79	3.66	5.30	6.38	5.50	3.55	1.89	0.76	0.00	29.50
DIFF	3.86	3.10	3.42	2.05	−0.08	−1.59	−2.78	−1.71	0.40	1.34	3.38	3.60	14.99
Coastal (Boston)													
RF	4.04	3.37	4.19	3.86	3.23	3.17	2.85	3.85	3.64	3.33	4.11	3.73	43.37
EVT	0.00	0.00	0.73	1.71	3.37	4.95	6.18	5.48	3.58	2.05	0.87	0.30	29.22
DIFF	4.04	3.37	3.46	2.15	−0.14	−1.78	−3.33	−1.63	0.06	1.28	3.24	3.43	14.15

Note: RF—rainfall, EVT—evapotranspiration rate, DIFF—the average amount of water needed to be added per month to sustain healthy turf.

SECTION 810

Soils and Aggregates

CREDITS

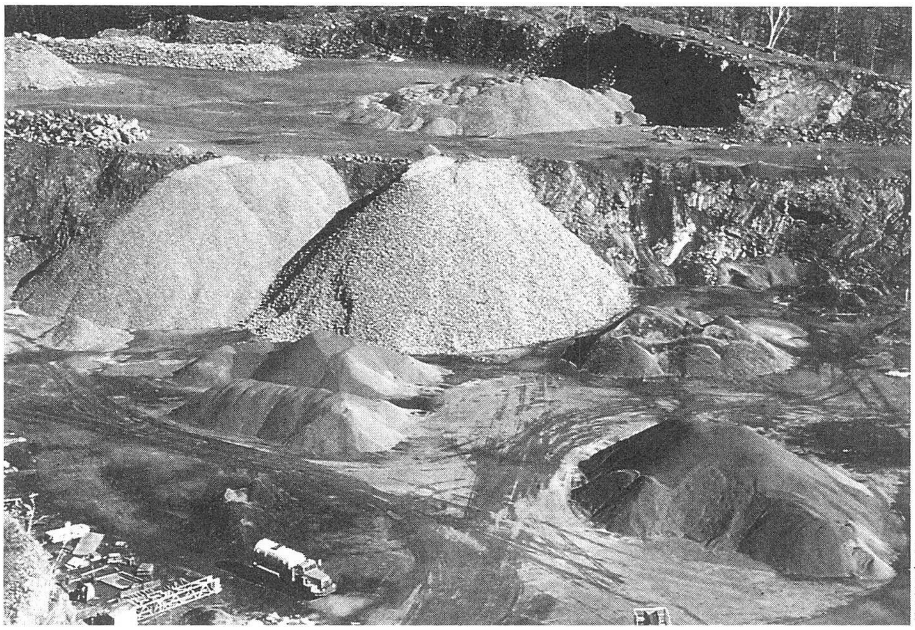
Section Editor:
Charles W. Harris

Technical Writers:
Tobias Dayman
Kyle D. Brown

Reference:
Dr. Philip J. Craul
Author, *Urban Soil in Landscape Design*
Senior Lecturer in Landscape Architecture
Graduate School of Design,
Harvard University
Prior: Professor of Soil Science, SUNY, Syracuse, NY

Douglas S. Way, Professor of LA
Ohio State University, Columbus, OH

Neil Cavanaugh, P.E., Braintree, MA
Robert N. Pine, P.E., West Acton, MA


Kat Hardesty

CONTENTS

1.0 INTRODUCTION

1.1 Soils

Physical and chemical properties of soils are important site determinants influencing the spatial allocation of land uses, the design and construction of structures, and the selection and installation of plant materials.

Certain properties of soils can be readily deduced from knowledge of soil type, while others can only be determined by careful field and laboratory testing, especially urban soils which are not presently mapped except in rare cases. The properties of a soil that are relevant to consider depend on the type of land use and development proposed.

1.2 Aggregates

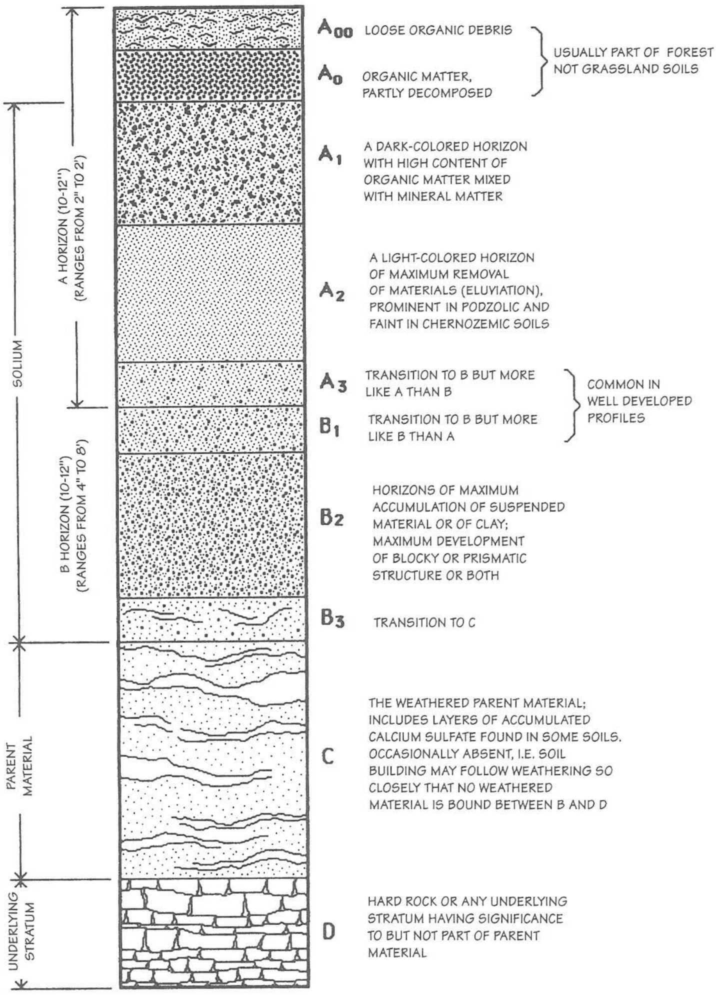
In landscape construction, the term aggregate typically refers to crushed rock or gravel rather than to the aggregation of soil particles. Information on the choice of an aggregate for specific purposes (foundations, road construction, etc.) is presented in 4.0 Aggregates of this section. Information on aggregates for making of asphalt or concrete is covered in Sections 820: Asphalt and 830: Concrete.

2.0 SOIL CLASSIFICATION SYSTEMS

This section describes the most common soil classification systems and the basic properties of soils that are critical for site development and horticultural applications. Typically, urban soils are drastically disturbed by human activities. As a result they are seldom classified because they do not fit in with the present USDA classification system. Presently they are being studied by the USDA-NRCS and they may soon come up with a classification system for them.

2.1 Soil Profile

In the process of natural formation, soil layers (i.e., horizons) develop with different textures, mineral contents, and chemical makeup. A soil profile is a vertical section through these horizons. A taxonomy has been developed to designate each horizon and zones within each horizon. The extent to which a profile becomes well-developed is largely a function of climate. Humid climates produce more fully developed profiles than arid climates. A typical profile in a humid climate has a well-developed A-, B-, C-, and sometimes D-horizon. Figure 810-



Master horizons and subordinate symbols for horizons of soil profiles

Master horizons

01	Organic undecomposed horizon
02	Organic decomposed horizon
A1	Organic accumulation in mineral soil horizon
A2	Leached bleached horizon (eluviated)
A3	Transition horizon to B
AB	Transition horizon between A and B—more like A in upper part
A&B	A2 with less than 50% of horizon occupied by spots of A2
AC	Transition horizon
B&A	B with less than 50% of horizon occupied by spots of A2
B	Horizon with accumulation of clay, iron, cations, humus; residual concentration of clay; coatings; or alterations of original material forming clay and structure
B1	Transition horizon more like B than A
B2	Maximum expression of B horizon
B3	Transitional horizon to C or R
C	Altered material from which A and B horizons are presumed to be formed
R	Consolidated bedrock

Subordinate Symbols

b	Buried horizon
ca	Calcium in horizon
cs	Gypsum in horizon
cn	Concretions in horizon
f	Frozen horizon
g	Gleyed horizon
h	Humus in horizon
ir	Iron accumulation in horizon
m	Cemented horizon
p	Plowed horizon
sa	Salt accumulation in horizon
si	Silica cemented horizon
t	Clay accumulation in horizon
x	Fragipan horizon
II,III,IV	Lithologic discontinuities
A'2, B'2	Second sequence in bisequal soil

Figure 810-1. Hypothetical soil profile showing all major soil horizons. *Note that no one soil has all of these profiles.*

SECTION **820**

Asphalt

CREDITS

Section Editor:
Charles W. Harris

Technical writer:
Tobias Dayman with professional advice and inputs from Robert H. Joubert of the Asphalt Institute

Reviewer:
Robert H. Joubert, Regional Representative Asphalt Institute Methuen, Massachusetts

Kyle D. Brown

CONTENTS

1.0 INTRODUCTION

1.1 General

Technically, the term asphalt refers only to asphalt cement or "binder," the basic cementitious material that is eventually mixed with aggregate to form pavements. In common usage, however, the terms asphalt, asphalt pavement, asphalt concrete, and bituminous concrete refer to the many available mixtures of asphalt and aggregate that are used for various purposes in landscape construction.

This section focuses exclusively on asphalt when used for paving, etc. although asphalt cement or binder is also commonly used as a sealant and as an adhesive (mastic).

1.2 Manufacturing Standards

The American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) have established specifications on the manufacture and use of asphalt cement or binder products, and asphalt concrete mixtures commonly used in the United States. These specifications were used as a guide for data shown in this section.

It should be noted that in 1994 the industry formally accepted and began to implement the results of a ten year research effort conducted under the US Federal Strategic Highway Research Program (SHRP). This resulted in developing a new system for the design of asphalt paving to be known as Superpave. They are in the process of introducing a new designation for asphalt cement which hence-forth is to be called an "asphaltic binder." This binder will be known as PG (Performance Graded) binder and the new specifications for this asphaltic binder will be shown as a higher positive number followed by a negative number as for example PG 64-22. The first number represents a hot pavement design criteria in degrees centigrade and the second number represents the low or cold pavement design criteria in degrees centigrade. The grades will vary by 6 degree increments on both the high and low ends.

Since these new specifications are not officially available at the time of publication of this handbook (1997), the U.S. readers of this Section are urged to seek the latest detailed data from either national or local sources. Every major governmental unit throughout the world has established a set of standard specifications for asphaltic cement or binders that should be used as a guide to the production of quality asphalt pavements within its jurisdiction. Local standards and practices should always be consulted for the appropriate designs and specifications for any specific region or area.

Table 820-1. ASPHALT CEMENT GRADING SYSTEMS

Grading System*	Grades † (Hard or thicker ⟷ Soft, or thinner)	Remarks
Penetration graded	40–50 60–70 85–100 120–150 200–300	Older system that measures needle penetration. Asphalt is sampled at 77°F (25°C). Still in use in Canada and in some states.
Viscosity graded	AC-40 AC-30 AC-20 AC-10 AC-5 AC-2.5	Newer system introduced in 1972. Scientifically measures viscosity of the asphalt at 140°F (60°C). Most states use this system.
Viscosity graded on aged residue (AR)	AR-160 AR-20 AR-40 AR-80 AR-10	A variation of the more standard viscosity graded system. Measures asphalt after simulated aging. Used in several western states.

* Consult local highway departments for criteria of local grading systems. Local criteria are often slight modifications of the above specifications, altered to suit local conditions.

† The hard-soft scale is used to indicate relative hardness within each grading system and not as a comparison of hardness from one grading system to another. The grades toward the harder, or thicker, end of the spectrum tend to be used in heavier traffic conditions or warmer climates. Cooler climates or lighter loads utilize grades toward the softer end of the spectrum.

2.0 ASPHALT CEMENT OR BINDER

2.1 Properties of Asphalt Cement or Binder

Asphalt cement or binder has several important properties that effect how this material can be used for various purposes and conditions.

Thermoplasticity: Asphalt cement or binder is an adhesive which deforms under loads or liquefies with heat. These properties cause it to be classified a flexible type of pavement.

Viscosity and Grades: The viscosity of asphalt is directly influenced by temperature. A temperature/viscosity slope can be plotted to define the temperature for mixing and compaction. An increase in temperature means a decrease in viscosity.

Asphalt cement or binder can have grades of hardness or viscosity (Table 820-1). Each grade is intended for specific purposes. There are three different methods for grading asphalt cement or binders used in the United States and Canada. All three grade asphalt according to degree of hardness. Table 820-2 lists various grades of asphalt's from each method that are appropriate for roads, depending on climatic conditions.

Weathering: The oxidation of the surface and the evaporation of lighter hydrocarbons (volatilization) causes asphalt to lose its plasticity and to become brittle with age. Properly sloped subbases and subgrades, proper compaction of layers, and timely sealing and surfacing treatments keep weathering to a minimum.

Insolvency: Asphalt is resistant to the chemical effects of water and of most salts, acids, and alkali's except petroleum-based materials, such as gasoline and oil-based paints if applied in concentrated amounts. Tar sealers are used on asphalt surfaces where concentrated spillage is expected.

Color: Asphalt is naturally black, but certain proprietary products or paving processes can alter that color. (Refer to 7.3 Colored Asphalt Pavements in this section for more information.)

Concrete

CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
Kyle D. Brown

Reviewers:
Steven H. Kosmatka, P.E., Director
Construction Information Services
Portland Cement Association
Skokie, Illinois

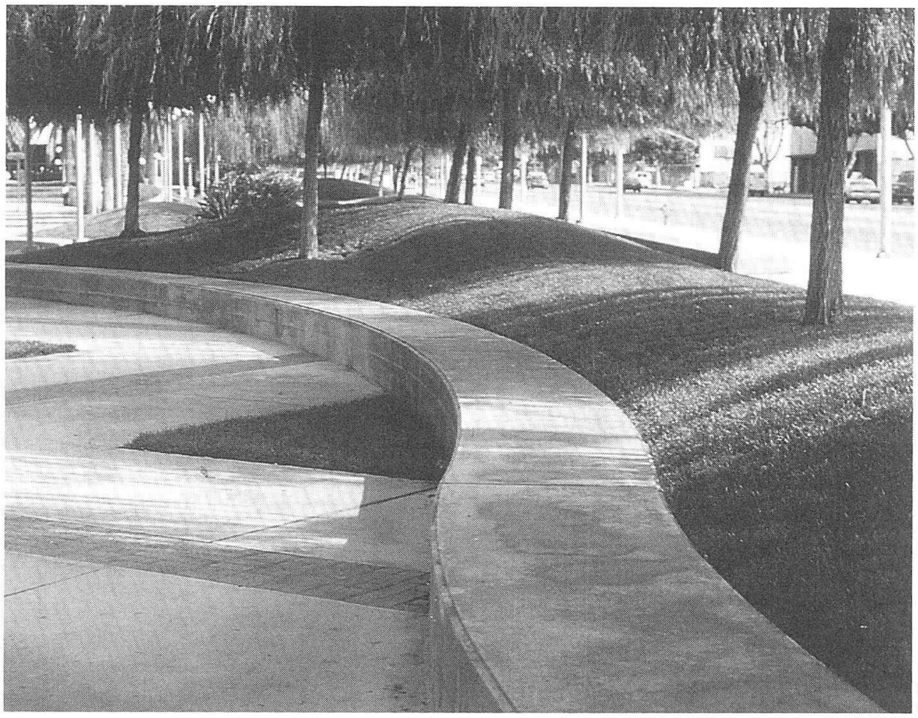
Dave DeAngelis, Technical Director
Bomanite Corporation,
Madera, CA

Ronald Chiaramonte,
Cambridge, MA

Paul DiBona,
Watertown. MA

Robert Fager,
Watertown, MS

Herman G. Protoze,
Newton, MA


N. Dines

CONTENTS

1.0 INTRODUCTION

1.1 General

Concrete is a mixture of aggregate, portland cement, water, and sometimes special admixtures. Its most outstanding qualities are strength, durability, stability, availability, adaptability, and, in most cases, its relatively low cost in terms of construction and lifetime maintenance.

1.2 Properties of Concrete

The properties of concrete are determined by any one of the following several factors: (1) the quality of all constituents, including the type of cement used, the soundness of the aggregates used, the relative proportion of coarse and fine aggregate, the ratio of water to cement, and the type and amount of any chemicals, admixtures, and other compounds added to the mix; and (2) the skills used in placing, consolidating, finishing, and curing the concrete.

Five major properties to consider when producing finished concrete are described below.

Strength:

Strength is usually the first consideration for all concrete's except for lightweight or insulating concretes. The relative strength of concrete is a function of the type of cement and aggregate selected. Full strength is reached after about 28 days, however the strength may continue to increase past this date if sufficient moisture is available.

Resistance to Freeze/Thaw and Deicing Chemicals:

Resistance to freeze/thaw and deicing chemicals can be increased by the use of an air-entraining agent (i.e., an air-entraining admixture). Admixtures may reduce, or enhance somewhat, the potential strength of the concrete mix. (Refer to 5.0 Admixtures for Concrete in this section for more information.)

Resistance to Abrasion and Wear:

Resistance to abrasion and wear can be increased if the concrete mix contains well-graded strong aggregate and is well-consolidated when placed. For some purposes, special aggregate and finishes may be required. Finishing procedures are extremely critical for achieving abrasion resistance.

Reduction of Water Penetration:

Reduction of water penetration can be achieved by four means: (1) by keeping the water/cement ratio to less than 0.50 by weight, (2) by carefully treating all joints and cracks to prevent leaks, (3) by adding chemicals and admixtures to the concrete mix to reduce water penetration, and (4) by applying a waterproof surface seal or compound. Adding certain chemicals and admixtures to reduce water penetration often requires adding more mixing water, which may increase the permeability of the concrete.

Control of Setting Time for Concrete:

Control of the setting time for concrete is often needed in order to (1) reduce the setting time when temperatures are low enough to cause the water in the mix to freeze, (2) to increase the time for working concrete during very hot weather, and (3) to control bleeding, or the movement of water to the surface of freshly placed concrete. Also, normal bleeding will be a problem if finishing (floating, troweling, etc.) is performed while bleed water is on the surface

1.3 Methods of Placement

Three basic methods for placing concrete include:

1. Formed and molded (cast in place or precast)
2. Sprayed or air-blown (shotcrete)
3. Mixed in place (such as soil cement or dry-casting)

The most common technique for placement is the formed and molded method. The other methods offer distinct advantages only in certain situations.

Sprayed concrete can be applied to very complex horizontal and vertical surfaces, including hyperbolic forms. It can also be applied in relatively thin cross sections and will attain a very high density and strength. Sprayed concrete is widely used for constructing swimming pools and other sculptured elements within the landscape and for repairing deteriorating structures.

Mixed-in-place or soil concrete has been used for a long time to create low-cost stabilized surfaces. This typically involves mixing dry cement into the existing soil or surface materials, adding water, and then remixing and compacting.

This section covers only formed and molded concrete in detail.

1.4 Types of Concrete

There are many types of concrete that can be mixed for various applications. The most

KEY POINTS: Concrete Mixtures

1. Full strength of concrete is reached after about 28 days, however the strength may continue to increase past this age if sufficient moisture is available.

2. Resistance to abrasion and wear can be increased if the concrete mix contains well-graded strong aggregate and is well-consolidated when placed.

3. Reduction of water penetration can be achieved by four means:
   (a) by keeping the water/cement ratio to less than 0.50 by weight.
   (b) by carefully treating all joints and cracks to prevent leaks.
   (c) by adding chemicals and admixtures to the concrete mix to reduce water penetration.
   (d) by applying a waterproof surface seal or compound.

4. Control of the setting time for concrete is often needed to
   (a) reduce the setting time when temperatures are below freezing.
   (b) to increase the time for working concrete during very hot weather.
   (c) to control bleeding, or the movement of water to the surface of freshly placed concrete.

5. Air-entrained concrete should be used under all conditions involving severe exposure to frost/thaw temperatures.

6. Potable water is typically satisfactory for use in concrete. Water containing sulfates, salts or deleterious substances should be avoided.

7. Water to cement ratios should be selected on the basis of strength and workability requirements. Minimum cement content should not be less than 470 lb/yd^3.

SECTION **840**

Masonry

CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
David Clough

Reviewers:
Richard Lakutis, L.A.
Landtech Associates

Lexington, Massachusetts
Steven H. Kosmatka, P.E., Director
Construction Information Services
Portland Cement Association
Skokie, Illinois

Vincent P. Rico, L.A.
Sasaki Associates
Watertown, Massachusetts and
Rico Associates, Shrewsbury, MA

Brian Trimble, Sr. Engineer
Technical Services
Brick Institute of America
Reston, Virginia

International Masonry Institute
Washington, DC


N.Dines

CONTENTS

1.0 INTRODUCTION

Clay, concrete, and stone masonry products are used extensively in landscape construction for a variety of purposes. Their modular characteristics, texture, and color, as well as their properties of durability, compressive strength, and resistance to moisture, allow them to be used in a wide range of applications.

Several other sections of this handbook contain more technical data and standards showing how one or more of these masonry materials can be used for variety of specific purposes. For instance, see Sections: 410: Retaining Walls and Devices, 440: Surfacing and Paving, 450: Fences, Screens and Walls, and 530: Pools and Fountains. Also, manufactures for each type of masonry material or product should be consulted to seek their suggestions on how to use one or more of their materials or standard, new or custom products. Typlically, they offer data on the range of shapes, sizes, finishes, product and installation specifications, etc.

2.0 CLAY MASONRY

2.1 General Classification and Properties:

Clay masonry is typically classified into three groups: solid masonry units, hollow masonry units, and architectural terracotta. Individual products within these groups are further classified by size, grade, type, color, and texture. When in doubt or when the material is is be obtained and used outside of the USA, then the manufacturers for the types of clay materials or products being considered should be consulted to seek their suggestions on how to use one or more of their standard, new or custom made products. Typically, they offer data on the range of shapes, sizes, finishes, product and installation specifications, etc.

Solid Masonry Units (Brick):

A masonry unit is classified as solid if the void area does not exceed 25 percent of the total cross-sectional area of the unit. Solid masonry units typically include building brick (ASTM C62), facing brick (ASTM C216), ceramic glazed facing brick (ASTM C126), hollow brick (ASTM C652), and paving brick (ASTM C902).

Properties of Clay Masonry Units:

The characteristics of the raw clay material as well as the manufacturing process itself determine the properties of finished clay masonry units. Table 840-1 lists these basic properties.

Compressive Strength: Measured by the amount of stress placed perpendicularly to the loading plane. Bricks can be classified by compressive strength when such values are above those used in the graded classification. (Table 840-1)

Table 840-1. BASIC PROPERTIES OF CLAY MASONRY

	Properties and Test Methods*				
	Compressive Strength, psi	Modulus of Rupture, psi†	Water Absorption, %	Density, pcf	Material Specifications
Clay - Solid Masonry Units (Brick)‡					
Building and facing					ASTM C62-84 (building brick)
Grade SW	3000		17		ASTM C216-84 (facing brick)
Grade MW	2500		22		
Grade NW	1500				
Glazed facing	3000				ASTM C126-82
Paving					ASTM (902-79a)
Grade SX	8000		8		
Grade MX	3000		14		
Grade NX	3000		no limit		
Hollow					ASTM C652-81
Grade SW	3000		17		
Grade MW	2500		22		
Hollow Masonry Units (Tile)					
Load-bearing wall tile					ASTM C34-62 (reapproved 1975)
Type LBX	1400		18	52	
Type LB	1000		25	52	
Facing tile					ASTM C212-60 (reapproved 1981)
Standard	1400		7	48	
Special duty	2500		13	48	
Sand lime brick					
Grade SW	4500	650	7-10		ASTM C73-75
Grade MW	2500	450	7-10		

* For methods of testing clay brick, see ASTM C67-83.

† Modulus of rupture is a measure of flexural strength.

‡ Density, pcf = 103-145.

Source: Sweet's Selection Data: Stone and Masonry, McGraw-Hill, New York.

SECTION 850

Wood

CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
Tobias Dayman

Reviewers:
Robert Fager, LA
Walker Kluesing Design Group
Boston, Massachusetts

Laurence Zuelke, FASLA
Lincoln, Massachusettes


N. Dines

CONTENTS

1.0 INTRODUCTION

1.1 General

This section provides basic information on lumber and the proper use of wood in outdoor environments. In a world where there is a growing concern to promote use of renewal and sustainable resources, wood products typically fall within this area of concern. Rare woods which are harvested in ways that destroy ancient forests and their larger eco-systems and upset other natural systems (increase water runoff and water pollution, etc.) are to be discouraged and avoided if at all possible. There is a growing international effort (such as the "Smart Woods Program") which is promoting the creation of plantations where once rare timber trees (such as teak, etc.) can be grown and harvested for their wood.

Also, there is emerging a wider use of wood substitutes, such as "post-consumer" plastics which are being made into "lumber-like" products. See Section 870: Plastics and Glass for more information. This Section focuses primarily on softwoods as a construction material, their properties and characteristics that effect their use in design and construction. It does not include information on techniques of wood construction. These aspects and the hardware used in wood construction are covered in separate sections throughout the handbook, including: Section 470: Pedestrian Bridges, Section 460: Wood Decks and Boardwalks, Section 870: Plastics and Glass, and Section 860: Metals.

1.2 Important Properties of Wood

Moisture Content:

Moisture Content: (MC) refers to the amount of water contained in wood which is usually expressed as a percentage relative to the weight of oven-dried wood ("x" percent MC). Unseasoned (i.e., green or fresh-cut wood) has a very high moisture content. The level of moisture in newly cut wood can be lowered by different processes and are described as follows:

Unseasoned lumber: is the wood immediately after it has been cut.

Common Lumber: typically has a moisture content of 15 to 19 percentage. This improves the strength of the wood, reduces shrinkage and warping, etc.

Air-dried lumber: typically contains 12-15 percent moisture. It has been dried simply by exposure to the atmosphere. Most lumber is air-dried, although complete air drying of large timbers is usually impractical.

Kiln-dried lumber: typically has a moisture content as low as 6% to as high as 19%. This wood has been dried in a kiln under controlled heat and temperature to achieve a desired moisture content. It is primarily done for "appearance grades" or "finished lumber where dimensional stability and appearances are important. Kiln-dried stamped on individual wood members is always accompanied by a moisture content percentage.

Equilibrium moisture content: refers to the moisture content that a wood member will attain in service as affected by local temperatures and humidity. Specification of moisture content in lumber stock should be as near as possible to the moisture content the lumber will attain in service. (see Table 850-1).

Weight:

The unit weight of various woods depends both on the species and moisture content of the individual piece. The unit weight of wood is a rough indicator of its relative strength, with higher values implying greater strengths. Refer to Table 850-2 for the specific values of various species.

Strength:

The ability of a wood member to resist loading depends on the strength of the wood species, its orientation in the structure, and the cross-sectional dimension of the member. The inherent strength of a wood is expressed in a number of ways as described below. Design values for various softwood species are given in Tables 850-3.

Tensile strength (F_t): refers to the ability of a wood member to resist stretching or stresses imposed parallel to the grain. Tensile strength is reduced by the presence of knots, splits, and checks in the member. The tensile strength of wood perpendicular to the grain is very low.

Compressive strength: refers to the ability of a wood member to resist loads that are crushing the wood member. Compressive strengths parallel to the grain

Table 850-1. EQUILIBRIUM MOISTURE CONTENTS FOR WOOD IN VARIOUS ENVIRONMENTS

Temperature (Dry Bulb) °F	Relative Humidity, %																			
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	98
30	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3	26.9
40	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3	26.9
50	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3	26.9
60	1.3	2.5	3.6	4.6	5.4	6.2	7.0	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1	26.8
70	1.3	2.5	3.5	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9	26.6
80	1.3	2.4	3.5	4.4	5.3	6.1	6.8	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6	26.3
90	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3	26.0
100	1.2	2.3	3.3	4.2	5.0	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.3	13.6	15.1	17.0	19.5	22.9	25.6
110	1.1	2.2	3.2	4.0	4.9	5.6	6.3	7.0	7.7	8.4	9.2	10.0	11.0	12.0	13.2	14.7	16.6	19.1	22.4	25.2
120	1.1	2.1	3.0	3.9	4.7	5.4	6.1	6.8	7.5	8.2	8.9	9.7	10.6	11.7	12.9	14.4	16.2	18.6	22.0	24.7
130	1.0	2.0	2.9	3.7	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	10.3	11.3	12.5	14.0	15.8	18.2	21.5	24.2
140	.9	1.9	2.8	3.6	4.3	5.0	5.7	6.3	7.0	7.7	8.4	9.1	10.0	11.0	12.1	13.6	15.3	17.7	21.0	23.7
150	.9	1.8	2.6	3.4	4.1	4.8	5.5	6.1	6.7	7.4	8.1	8.8	9.7	10.6	11.8	13.1	14.9	17.2	20.4	23.1
160	.8	1.6	2.4	3.2	3.9	4.6	5.2	5.8	6.4	7.1	7.8	8.5	9.3	10.3	11.4	12.7	14.4	16.7	19.9	22.5
170	.7	1.5	2.3	3.0	3.7	4.3	4.9	5.6	6.2	6.8	7.4	8.2	9.0	9.9	11.0	12.3	14.0	16.2	19.3	21.9
180	.7	1.4	2.1	2.8	3.5	4.1	4.7	5.3	5.9	6.5	7.1	7.8	8.6	9.5	10.5	11.8	13.5	15.7	18.7	21.3
190	.6	1.3	1.9	2.6	3.2	3.8	4.4	5.0	5.5	6.1	6.8	7.5	8.2	9.1	10.1	11.4	13.0	15.1	18.1	20.7
200	.5	1.1	1.7	2.4	3.0	3.5	4.1	4.6	5.2	5.8	6.4	7.1	7.8	8.7	9.7	10.9	12.5	14.6	17.5	20.0
210	.5	1.0	1.6	2.1	2.7	3.2	3.8	4.3	4.9	5.4	6.0	6.7	7.4	8.3	9.2	10.4	12.0	14.0	16.9	19.3

Source: U.S. Forest Products Laboratory, *Wood Engineering Handbook,* Prentice-Hall, Englewood Cliffs, New Jersey,

Metals

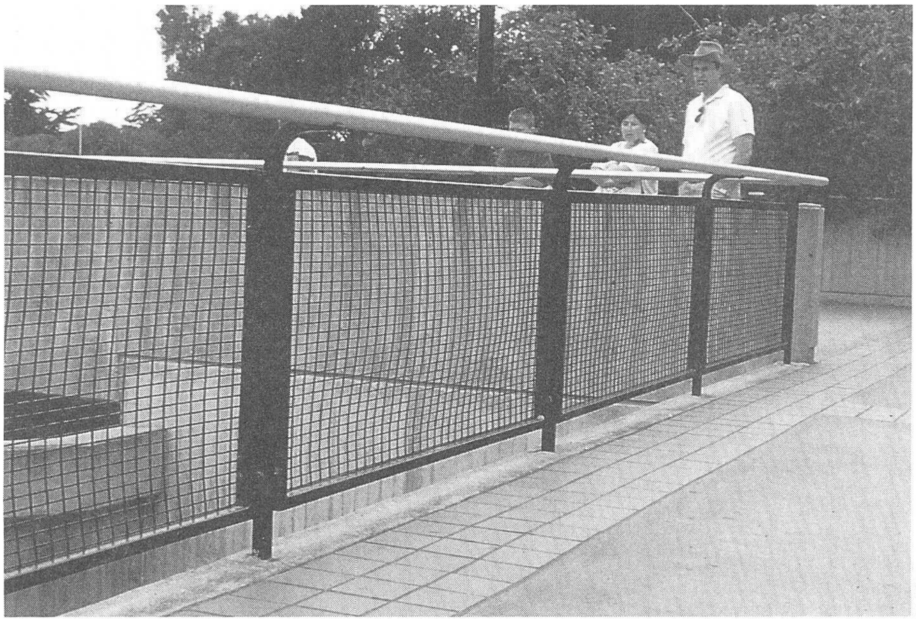
CREDITS

Section Editor:
Charles W. Harris

Technical Writer:
Tobias Dayman
with extensive professional advice
and assistance from David Mittelstadt

Reviewers:
David Mittelstadt, LA
Sasaki, Assoc., Inc.
Watertown, Massachusetts

Laurence Zuelke, FASLA
Lincoln, Massachusetts


N. Dines

CONTENTS

1.0 INTRODUCTION

1.1 General

Metal technology is complex, and consultation with a structural engineer is important whenever issues of bearing strength, durability, codes, or issues of safety are involved.

1.2 Basic Properties of Metal

When using any metals related to outdoor construction there are five generic criteria that should be evaluated and, if appropriate, factored into your recommendations for use of a particular metal. These are discussed here in brief, to remind users of this handbook of their importance and the possible need to consult more technical sources of data and/or a structural engineer.

Galvanic corrosion is a process that occurs when two different metals are in physical contact with one another. The more anodic of the two metals corrodes, and its material is deposited on the more cathodic (more "noble") metal when a solution (such as water) is present. The solution conducts electricity between the two metals.

Typically, the solution is water in the form of moisture condensation, and contaminants within the water act as the electrolyte. The corrosion potential increases in industrial, non-arid and seacoast areas because of increased contaminants and/or moisture. The galvanic predisposition of several metals and metal alloys is shown in Table 860-1.

Galvanic corrosion is controlled by:

1. Using similar metals in the galvanic series
2. Using sacrificial anode coatings which corrode and form a protective layer.
3. Providing a barrier to inhibit exposure to moisture such as paint or a bituminous coating.
4. Installing a surface metal cladding (with galvanic potential similar to the expected conditions) onto a base metal that, if exposed, would otherwise be anodic or cathodic.
5. Applying a paint or primer that either chemically changes the surface of the metal or includes an alkaline chemical that greatly reduces the rate of galvanic action to an acceptable level.

Chemical corrosion refers to the dissolving of a metal by some type of chemical reaction caused by a gas or acid. Because each type of metal reacts differently to various chemicals found in the environment it is very important to make the proper selection according to specific site conditions.

Finishes:

Metal products can be finished to provide a variety of colors, textures, patterns, and degrees of reflectivity as well as to provide greater protection against abrasion and corrosion. Metal finishes are categorized according to the basic process by which they are applied. Certain finishing processes are suitable only for certain kinds of metals. Basic finishes for metals include:

TABLE 860-1. GALVANIC SERIES OF METALS*

1. Aluminum
2. Zinc
3. Steel
4. Iron
5. Nickel
6. Tin
7. Lead
8. Copper
9. Stainless steel

* When any two metals on the list are in contact with one another in the presence of moisture, the lower one will be corroded. The further apart on the list, the more rapid and extensive will be the galvanic corrosion. This series is meant only as a guide to illustrate relative susceptibilities to galvanic corrosion.

1. Mechanical finishes, include grinding, polishing, buffing, rubbing, or sandblasting.
2. Chemical finishes, refer to the reaction of a chemical to a metal surface to produce colors, textures, and/or corrosion resistance.
3. Anodized finishes, which are produced by placing a metal into an acid solution and passing an electric current through it. This alters the outer surface of the metal to create an integral corrosion-resistant layer. Clear, translucent, or opaque finishes in a variety of colors are available. Anodized finishes are used almost exclusively on aluminum.
4. Applied coatings, which refer to the process of adding materials to the surface of a metal to provide color, corrosion resistance, and/or protection against abrasion. Such coatings include paints, enamels, plastic films, galvanizing, and cladding. Some plastic coatings are proprietary products not covered by established standards of performance.

Manufacturing and Fastening:

Metals are formulated in a mill and then undergo fabrication to produce objects in desired shapes. Fabrication processes include rolling, extruding, casting, drawing, and forging. Thermal treatments are applied to metals to alter their strength, hardness, machinability, ductility, and cold-forming characteristics. Many types of thermal treatments are available, the most common of which are tempering, quenching, and annealing.

KEY POINTS: Basic Metal Properties

1. Metal technology is complex, and consultation with a structural engineer is important whenever issues of bearing strength, durability, codes, or issues of safety are involved.
2. The galvanic corrosion potential of metal increases in industrial, non-arid, and seacoast areas because of increased contaminants and/or moisture in the atmosphere.
3. Galvanic corrosion is controlled by:
   a) Using similar metals in the galvanic series (Table 860-1).
   b) Using coatings that purposely corrode, thereby leaving the desired surface untouched and protected.
   c) Applying paint or a bituminous coating, to inhibit exposure to moisture.
   d) Installing a surface metal cladding.
   e) Applying paint or primer that either chemically changes the surface of the metal.
4. Metal can be finished by mechanical, chemical, or anodized methods, or by applying coatings such as paints or enamels.
5. Finishes on certain metals may be limited to particular fastening techniques if marring of the surface is a concern. Specialists should be consulted when fastening metals in order to determine the suitability of a fastening technique.

SECTION **870**

Plastics and Glass

CREDITS

Section Editor:
Charles W. Harris

Technical Writers:
Tobia Dayman
Krisan Osterby-Benson

Reviewers:
Neil Dean
Sasaki Associates, Inc.
Watertown, Massachusetts

Vincent P. Rico, L.A.
Sasaki Associates, Inc.
Watertown, Massachusetts and
Rico Associates, Shrewsbury, MA

Albert Dietz
Department of Architecture
Massachusetts Institute of Technology
Cambridge, Massachusetts

Society of the Plastics Industry
New York, New York

National Glass Association
Bellflower, California

Kyle D. Brown

CONTENTS

1.0 INTRODUCTION

This section describes two groups of materials: plastics and glass. In the past use of these two materials in terms of landscape design and construction has been very limited. More recently, there has been a surge of interest and use of these materials. This is particularly true of products and devices made out of a variety of types of plastics or combinations (reinforced plastics with fiber glass) and laminates, etc. These uses overlap several topical sections such as Sections: 330, 450, 460, 510, 540, etc.) and a few sections of Divisions 800: Materials and 900: Details and Devices. Refer to Table 870-7 for more information on these overlaps.

Manufacturers of these materials and products made from them should be consulted for suggestions on how to use one or more of their materials and products. Typically, they offer data on the range of shapes, sizes, finishes, products, product and installation specifications.

2.0 PLASTICS

Plastic have become important material for both construction and manufacturing of special products used in the landscape primarily because of their moisture and corrosion resistance, toughness, malleability, and light weight.

Basically, plastic is a synthetic or man-made material made up of giant molecules built around a carbon or a silicon atom. There are many terms used to identify different types of plactic. Some of the better known terms are vinyls (such as polyvinyl choloride or PVC), acrylics , and polyesters (often reinforced by fiber glass). More simply they can be categorized into two basic groups as a function of how they are made and their response to heat:

Thermoplastics soften with exposure to heat and harden when cooled (like candle wax). This process can be repeated any number of times.

Thermosets are plastic materials which are heated, shaped and then they cool and harden into a permanent set. Repeated exposure to temperatures above the normal air temperatures will cause gradual chemical decomposition, brittleness, etc.

2.1 Properties of Plastics:

Tensile Strength: Most plastics are similar to wood in terms of tensile strength. Laminates and reinforced plastics offer greater strength, a few of which exceed the strength of steel, especially on a strength-to-weight basis (Table 870-1). Fiberglass-reinforced plastics (FRPs) have the highest tensile strengths.

Stiffness: In construction, stiffness is often more important than strength. Thermosets are slightly stiffer than thermoplastics, and reinforced plastics are the stiffest of all. Most are roughly comparable to wood, although the stiffness of some high-performance composites approaches that of aluminum or steel.

Toughness: Toughness is generally expressed in terms of the ability to resist impact. Plastics (and different formulations of the same plastic) can vary widely in impact resistance.

Hardness: Plastics scratch more easily than glass or steel, but some types of plastic may be more resistent to wear (e.g., as bearings) and may be superior to steel. Their resistance to indentation is usually better than that of commonly used wood species across the grain, but some soft plastics are easily indented.

Expansion and Contraction: Thermal expansion is characteristically high in plastics. Thermosets expand less than thermoplastics. Reinforced plastics and laminates expand the least and are nearly comparable to aluminum. Expansion joints are necessary when materials of widely different expansion rates are abutt or are joined.

Corrosion Resistance: Plastics vary in their resistance to attack by chemical reagents. Generally speaking, a plastic can be found to resist any common chemical. Fluorocarbons are the most inert and are susceptible to attack by only the most powerful reagents. Other plastics are susceptible to only selective action by particular chemicals.

2.2 Basic Types of Plastics

Many kinds of plastic materials are commercially available. Table 870-2 describes those commonly available and their typical uses.

2.3 Plastic Formats

Plastic is available in a variety of formats. Tables 870-3 through 870-6 give commonly available sizes and important characteristics.

Sheet Plastic: The availability of sheet plastics varies between manufacturers. Special orders are sometimes possible (Table 870-3).

Corrugated Plastic Sheets: These are made of fiberglass or non-reinforced plastic and are typically used for roofing applications although they can be used for other non-structural purposes such as panels for fences, screens or free-standing walls as in Sec. 450. These products are often rated for strength, fire resistance, and other characteristics (Table 870-4).

Rigid Plastic Pipe: These are made of polyvinyls and chloride (PVC) and when a stablizer is added it prevents or retards degradation of the plastic due to exposure to sunlight and other environmental conditions. Is commonly used in drainage, irrigation, pools and fountain applications (Table 870-5).

Flexible Tubing: This is commonly used to protect underground wires and in irrigation applications (Table 870-6).

2.4 Plastic Products.

870-7 shows the range of types of plastic products that are becoming available for a variety of purposes which overlap several other sections of this handbook. It is expected that many more will be developed and become widely used as the possibilities and benefits of using plastic become better understood.

Manufacturers of plastic materials and products should be consulted for suggestions on how to use one or more of their materials and products. Typically, they offer data on the range of shapes, sizes, finishes, products, product and installation specifications.

KEY POINTS: Plastics

1. Most plastics are similar to wood in terms of tensile strength and stiffness. Laminates and reinforced plastics offer greater strength, a few of which exceed the strength and stiffness of aluminum and steel, especially on a strength-to-weight basis

2. When two types of plastic, or plastic and another material are joined together, expansion joints are necessary if materials have widely different expansion rates.

3. Plastics scratch more easily than glass or steel, but some resist wear (e.g., plastic bearings) and may be superior to steel.

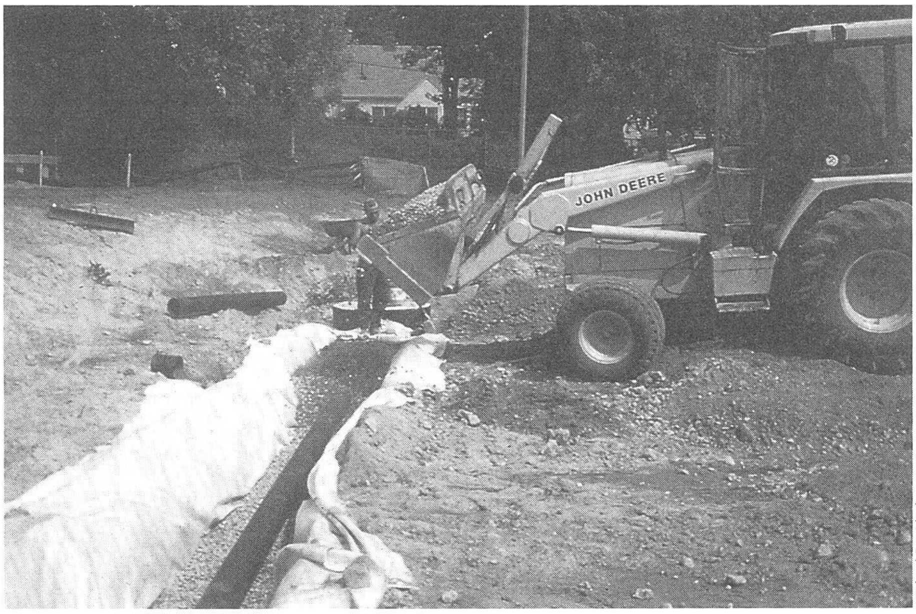
Geotextiles

CREDITS

Section Editor:
Charles Harris

Contributor:
Tom Ryan
Hargreaves Associates
Cambridge, Massachusetts/San Francisco, California

Reviewer:
Christopher J. Stohr, Associate Geologist
Engineering Geology Division
State Geological Survey
Champaign, Illinois



Michael Davidsohn

CONTENTS

1.0 INTRODUCTION

Geotextiles and their associated products (geogrids, composite drains, geo-cells, and grid or fiber soil reinforcement) allow landscape architects to improve the basic properties of soils. With geotextiles one can increase bearing capacity, facilitate drainage, decrease erosion, and prevent the intermixing of different soil types. When selecting geotextiles, the key is to match the fabric, grid, etc., to the specific conditions that need to be modified.

2.0 BASIC FUNCTIONS OF GEOTEXTILES

The physical characteristics of a geotextile determine its value for an intended application. For example, some fabrics (or portions thereof) deteriorate over time, a trait desirable for short-term erosion control, while others resist deterioration, a trait desirable for soil separation and drainage applications. Common functions are described below.

2.1 Separation

A major use of geotextiles is to separate materials. Subsoil can be prevented from migrating into roadway base aggregate or railroad ballast, and different zones of material (i.e., clay, drain rock, etc.) can be kept separate in earth dams. Drain rock can be kept unclogged in planters, and retaining wall backfill can be kept separate from adjacent soil. The function of separation often coincides with other functions, such as filtration and reinforcement. Fabrics can be used as flexible concrete formwork. The fabric can be placed in difficult-to-get-at places and inflated with concrete or grout. The permeability of the fabric allows air or water to escape from the form as the concrete fills the cavity between the layers of fabric.

2.2 Reinforcement

Geotextiles can be used to reinforce soils to improve bearing capacity, extending the range of moisture that can be accommodated under a load. Fabrics can be used to bind soil areas together to act as a unit to support foundations or to secure structures horizontally as deadmen. Grids can reinforce soil, similar to steel or mesh in concrete, and fabrics or grids can be mixed into soil, similar to fiber reinforcement of concrete. They can also be used between layers of pavement to control reflected cracking and other failures. Geotextiles can be laid over soft, compressible subsoils and under an aggregate base for both drainage and added strength in roadways and other structures. Fabrics can also be used in turf to increase the durability of playing fields.

2.3 Filtration (Drainage)

Geotextiles can be used as a filter material in many drainage applications. Fabric is used to filter fine soil particles out of coarser stone drainage media in underdrains, at the base of planters, behind retaining walls, etc. They can also be used to wrap perforated pipe or other drainage media to prevent intrusion of fine soil particles into the drainage medium.

2.4 Surface Protection (Erosion Control)

Geotextiles can be used effectively to reduce soil erosion by reducing the velocity of surface runoff waters and securing surface soil particles in place. Fabrics for this purpose can be made of durable artificial fibers offering a long life, or natural or artificial fibers that deteriorate over time, or a combination of the two.

Erosion along coastlines or along waterways can be minimized by using a permeable fabric grid or containment web, covered by heavy aggregate (the fabric traps

Table 880-1. PROPERTIES OF VARIOUS GEOTEXTILE FIBERS

	Fibers					
Property	**Nylon 66**	**Nylon 6**	**Polyethylene**	**Polypropylene**	**Polyvinyl chloride**	**Jute**
Fiber properties:						
Tenacity, g/denier (approx.)	8	8	4.5	8	1.8	-
Extension at break, % (approx.)	15	17	25	18	25	-
Specific gravity	1.14	1.14	.94	.91	1.69	1.5
Melting point, °C	250	215	120	165	-	-
Maximum operating temperature, °C (approx.)	90	Below 65	55	90	-	Below 65
Resistance to:*						
Fungus	3	3	4	3	3	1
Insects	2	2	4	2	3	1
Vermin	2	2	4	2	3	1
Mineral acids	2	2	4	4	3	1
Alkalis	3	3	4	4	3	1
Dry heat	2	2	2	2	2	2
Moist heat	3	3	2	2	2	2
Oxidizing Agents	2	2	1	3	-	-
Abrasion	4	4	3	3	4	3
Ultraviolet light	3	3	1	3	4	1

* Poor 1; fair 2; good 3; excellent 4.
Source: Extracted from a paper by E.W. Cannon, *Civil Engineering,* March 1976.

DIVISION 900

Details and Devices

CREDITS

Contributor:
Nicholas T. Dines, FASLA

CAD Drawings:
Xiaoxin Zhang
Jeffrey D. Blankenship
Kyle D. Brown
Hongbing Tang
Vesna Maneva

Reviewers:
Shavaun Towers, ASLA
Rolland/Towers, L.L.C.
New Haven, CT

Mark Zarrillo, FASLA
Symmes, Maini and McKee Associates
Cambridge, MA

N. Dines

CONTENTS

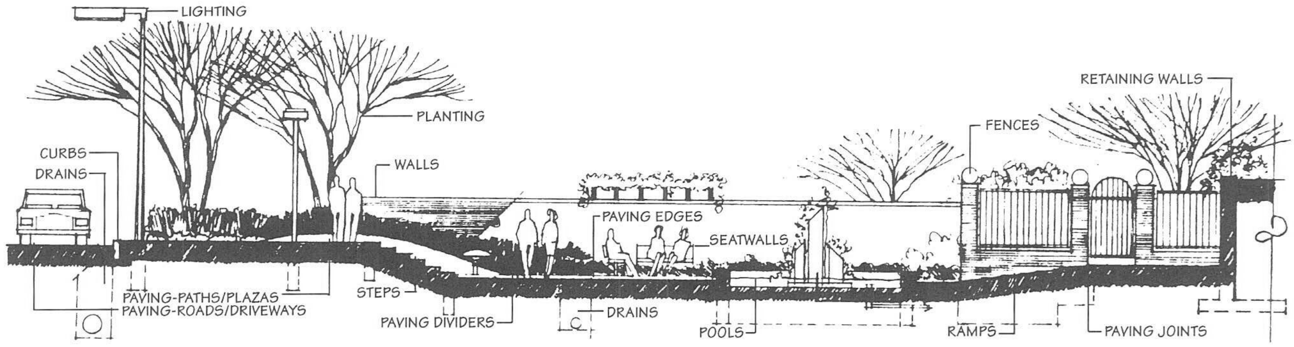


Figure 900-1. Public plaza design cross section. *A typical design section depicting various detail types which commonly occur in such a landscape setting. Each setting carries its own set of descriptive details related to the activities or structures associated with each setting.*

1.0 INTRODUCTION

Design details together with written specifications illustrate and describe how proposed site design elements are to be furnished, assembled, installed or placed on the site by the contractor. Details describe surface finishes and the structures required to support them. Generally, a construction detail is required to describe ground plane changes in elevation and material, or at architectural structure foundations or thresholds. Additionally, details are required to describe site system components such as, utilities, stormwater devices, and other site improvements, which may include proprietary or custom built elements. Figure 900-1 illustrates a typical design cross section depicting the range of detail types found in a public plaza. Each landscape type may require details common to all site construction as well as details unique to that particular type.

The details illustrated in this Division represent medium duty details designed for well drained soils, unless specifically noted. They are grouped by detail type, and represent a limited anthology to serve as a basis for further design development. Some common details are annotated to indicate how they may be modified to accommodate more intense loading or poorly drained soils. Each detail is dimensioned using dual metric and US units, and is subject to local variations, physical conditions, and cultural customs. These details are not to be used as construction documents, since any detail must be derived from the specific site requirements. All structural specifications must be approved by appropriate local authorities and licensed consultants.

2.0 DESIGN CRITERIA

Site construction details are typically designed to accommodate:

1. **Application requirements with regard to design loads or use intensity:** Loading or use are described as light, medium, or heavy duty. Each detail type possesses its own rating criteria for determining its duty of service. Pavements vary by design load which is expressed as finish material strength, and aggregate base thickness. Tree planting may vary by size and degree of environmental stress, while swale design may vary by volume and velocity of discharge.
2. **Soils and hydrology:** Common details require adaptation to colloidal or expansive clay soils subject to capillary moisture migration. This typically involves additional aggregate subbases, fabric separators, and strategically placed subdrain pipes. Eccentrically loaded structures may require wider footings at greater depth to resist lateral sheer.
3. **Climate:** Hot arid, hot humid, temperate, and cold climates affect footing and pipe trenching depths, expansion joint design, material porosity and absorption tolerances, color, slope, etc. In addition, long-term maintenance requirements may limit the palette of materials in particular climate zones.
4. **Regulatory specifications:** Local codes and Federal agency regulations may severely restrict the use of certain materials and design forms.

3.0 UNIT COST

The unit cost of a particular detail is determined by the cost of materials, labor, equipment, and contractor overhead and profit. The long-term cost of a particular installation is determined by its embodied energy value, its rated length of service, and its annual maintenance budget requirements. Prudent detail design requires that all of these factors be considered in the development of final details and construction specifications.

4.0 ENERGY AND RESOURCE CONSERVATION

It is highly recommended that long term embodied energy and maintenance costs be given a high priority in the final design development process. Recycled materials should be specified first from the local region, second from surrounding regions, and third from more distant sources. Newly processed short-lived materials made from non-renewable extracted resources should be avoided, along with processed materials requiring intercontinental importation. Materials with high embodied energy ratings should also have a long life expectancy, such as quarried igneous stone, stainless steel, etc., or should be made from recycled materials, such as aluminum extrusions made from recycled cans and scrap.

5.0 MAINTENANCE

Without proper maintenance, most pavements and structural site improvements will begin to show wear and deterioration within 10 to 15 years. Plantings typically mature during this same period. Proper maintenance involves periodic surface coatings, pointing, cleaning and sealing of joints, flushing and oxidizing of drains and infiltration devices, and pruning, transplanting, and dividing of plantings. Ideally, the designer should arrange to make periodic inspections as part of a site management contract agreement to insure that performance specifications be maintained during the design life-cycle.

SECTION 911

Edges

1.0 INTRODUCTION

Edge structures used in flexible pavement design serve to contain the pavement and prevent lateral creep. They also may provide additional support to prevent crushing due to loading at the edge. Rigid pavement edges are used primarily as reinforcement against edge loading. In both cases, edging may also serve to define a pavement and to separate two different materials. Selection of proper edging must consider site climate and maintenance practices. Details illustrate flexible and rigid pavement edges.

1.1 General Notes

Wood edges are temporary and require aggregate bases to prolong the life of the wood. Wood stakes securing wood edges will heave in clay soils and frost /thaw zones. Metal stakes may prevent excessive heaving. Edging between materials must be handicapped accessible in most cases. Concrete edging may act as a grade beam for flexible pavements and as a reinforcement for rigid pavements. Many precast units are available for edging applications. Care should be taken to assess material compatibility with regard to maintenance requirements and durability when joining two materials.

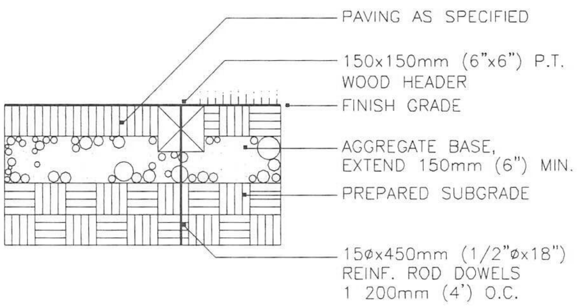


Figure 911-1. Wood edge with steel pins. *Extend aggregate beyond edge. Smaller edging may use steel stakes on outer edge.*

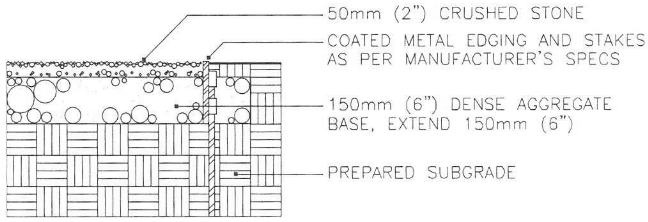


Figure 911-2. Aggregate paving with metal edge. *Superior method for edging loose material when inconspicuous edge is required.*

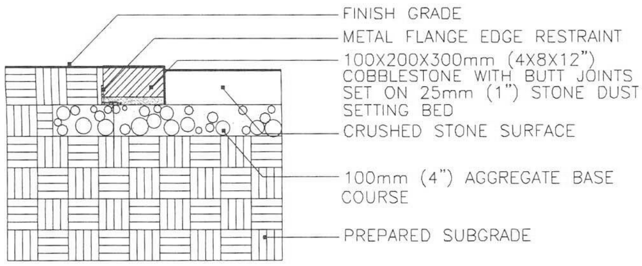


Figure 911-3. Cobblestone path with metal pins. *Stone edge rides on top of edging for secure retention. Metal is not visible.*

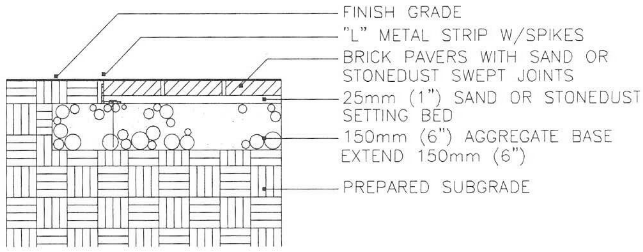


Figure 911-4. Brick pavers with metal "L" edge. *Brick setting bed rests on metal flange for even appearance. Good for planting edge.*

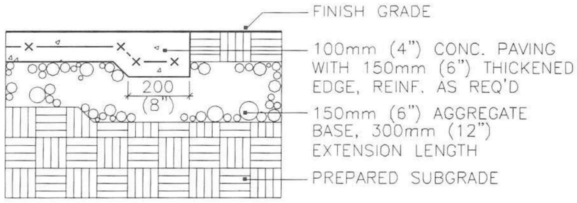


Figure 911-5. Concrete paving with thickened edge. *Used to protect slab edge from light service vehicle loading in parks and plazas.*

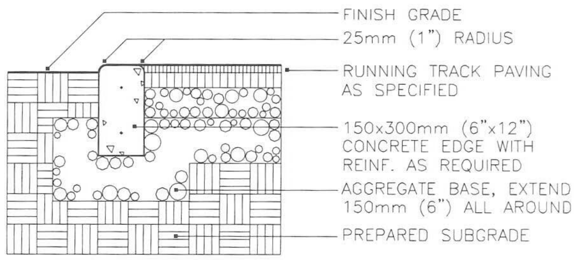


Figure 911-6. Concrete grade beam for running track. *Reinforced concrete track edge restraint. Aggregate needed due to track runoff.*

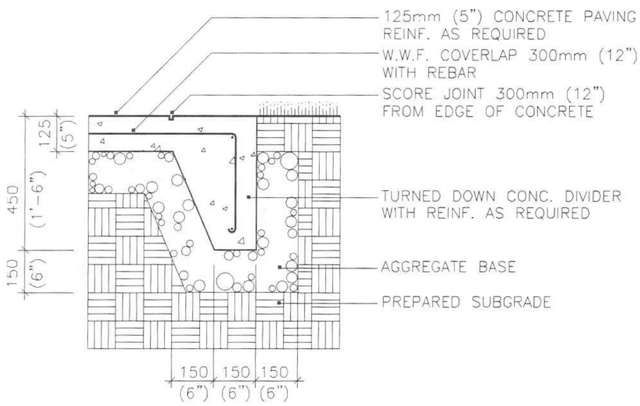


Figure 911-7. Turn-down concrete edge. *May also be used for small light duty curb detail for 100-150 mm (4-6 in) curbs.*

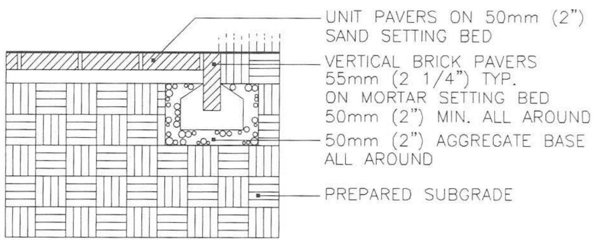


Figure 911-8. Brick paving edge on mortar setting bed. *Bricks mortared at edge joint. Mortar struck below pavement base. Not used in cold zones.*

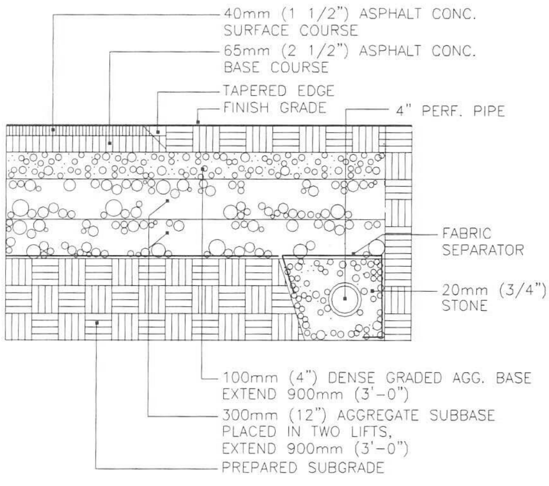


Figure 911-9. Asphalt paving with tapered edge on clay soil. *The same tapered edge may be used in well drained soils with single course base.*

SECTION 912

Joints

1.0 INTRODUCTION

Pavement joints allow for expansion and contraction in rigid pavements or join two different materials, or abutting slabs. The selected details illustrate a range of conditions and materials.

1.1 General Notes

Control joints in concrete are required to provide controlled break points in the event of swelling stresses. Expansion joints are typically required every 7 500 mm (25 ft) to allow for contraction and expansion due to temperature fluctuations. Expansion joints should be sealed in cold climates to prevent saturation and freezing within the joint. All joints should be periodically cleaned and resealed. Unit pavers mortared onto slabs require sealed expansion joints to be aligned with slab joints. Metal pins and sleeves may be used in heavy duty concrete joints with care being taken to thicken the slab around the sleeve and pins for strength. Slab ends may also be keyed using pre-formed expansion joint fillers in standard slab thicknesses.

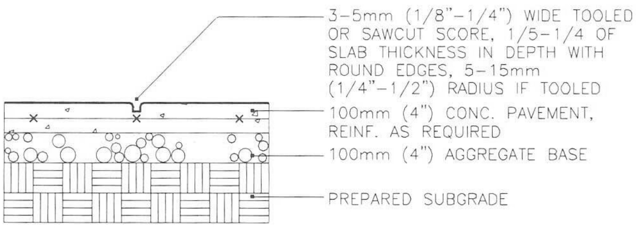


Figure 912-1. Concrete paving control joint. *Control joints may be scored in wet concrete, or sawn in cured concrete.*

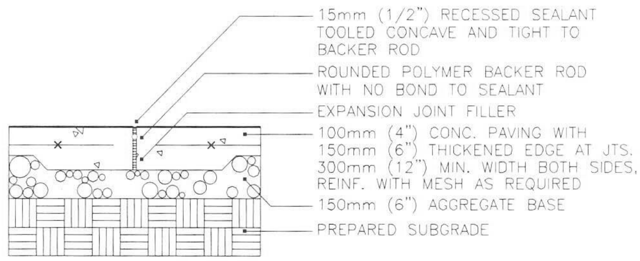


Figure 912-2. Concrete paving expansion joint with thickened edge. *Used when vehicular loading may require extra support.*

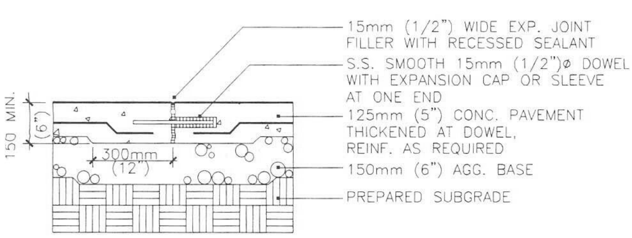


Figure 912-3. Concrete paving expansion joint with dowel. *Used to tie one slab to the next and still allow movement. May corrode in cold zones.*

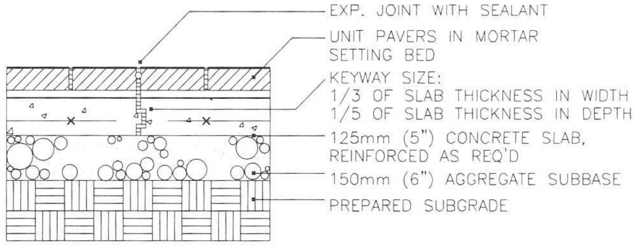


Figure 912-4. Keyed expansion joint in brick paving on concrete base. *Formed with pre-molded expansion joint filler. Seal joint from water infiltration.*

SECTION 913

Dividers

1.0 INTRODUCTION

Dividers to create visual or textural transitions from one paving material to another, or to emphasize a visual band in a large pavement system. Maintenance required for the divider should not adversely affect surrounding materials. Care should be taken to avoid differential settlement at junctions. The selected details illustrates various material combinations in a number of design circumstances.

1.1 General Notes

Decorative bands in pavements should create smooth joints with surrounding materials and in most instances should be subject to the same accessibility standards as the main pavement. Avoid large differences between divider thickness and adjacent pavement thickness to allow for even subgrade conditions. Rigid bands are typically set before flexible infill pavements.

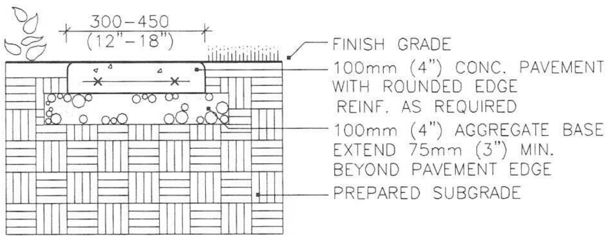


Figure 913-1. Concrete mowing strip. *Concrete strips may be tinted or textured to create neat trim for turf and garden areas.*

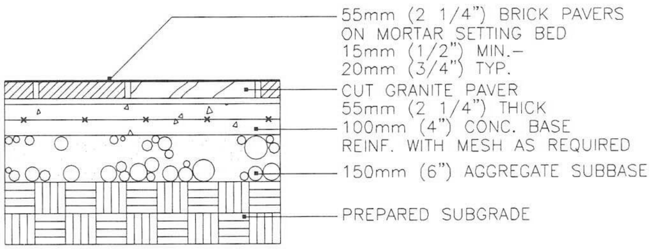


Figure 913-2. Granite band in brick paving. *Granite band should be no thicker than the brick paver. If less, shim with mortar.*

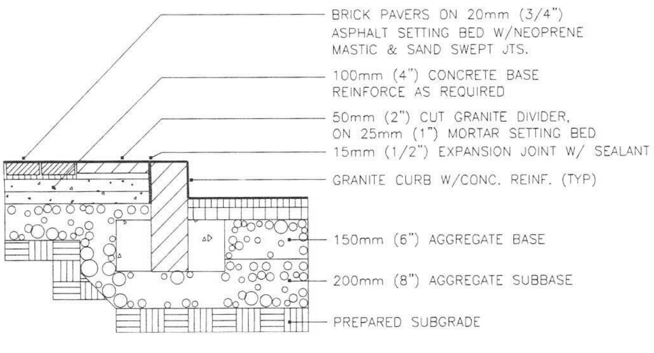


Figure 913-3. Granite band at granite curb. *Extend expansion joint to granite band and seal. If thin veneer, shim with mortar.*

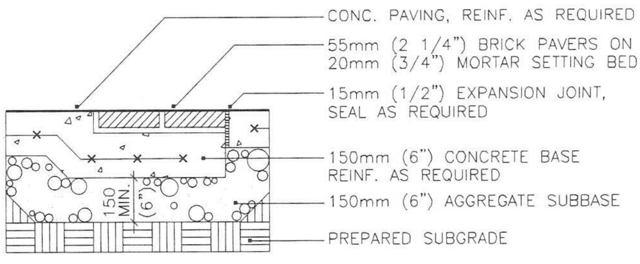


Figure 913-4. Brick band in concrete paving. *Slab requires inset to allow for modular brick on mortar bed. Light vehicular loading.*

SECTION 914

Athletic and Game Surfaces

1.0 INTRODUCTION

Athletic and game surfaces typically include general field play, sanctioned games such as football, baseball, softball, and soccer, as well as specialized games such as lawn bowling, tennis, and croquet. The following details illustrate a sampling of reinforced natural turf and synthetic turf surfaces. All such surfaces require regular maintenance and grooming.

1.1 General Notes

All natural turf requires irrigation, and may be heated in cold climates for professional or collegiate play. Irrigation systems are often set within the growth horizon for direct root feeding. Heating tubes are commonly set below the soil horizon, and within the top layer of the aggregate base. Synthetic turf surfaces require minimal slope for outdoor installations. Modern practice uses a monolithic resilient porous pad under the synthetic surface to absorb impacts for greater player protection and better internal drainage. The goal of these details is to provide a smooth uniform playing surface capable of supporting light service vehicle loading. It is common practice to carefully screen and amend soil to secure the best combination of structural bearing, infiltration, and capillarity.

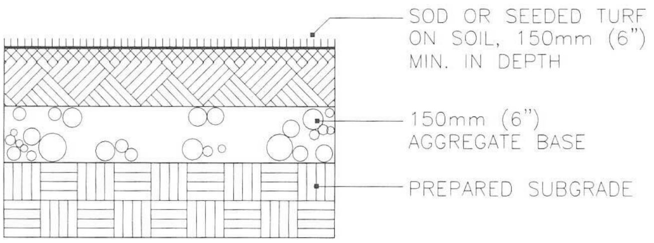


Figure 914-1. Game lawn on aggregate base. *Fine aggregate base allows light vehicular loading. A 200 mm (8") soil depth is preferred*

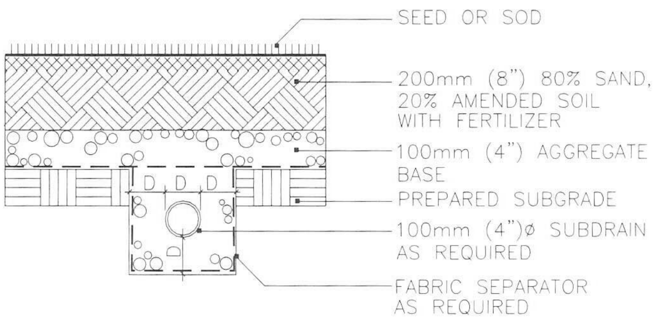


Figure 914-2. Natural turf athletic field. *Dense grade aggregate base placed on a fabric separator. Sand amendment for to drainage.*

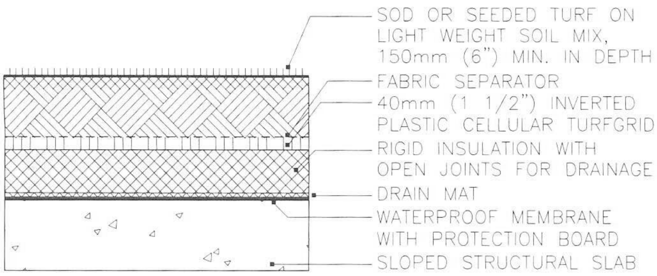


Figure 914-3. Game lawn with inverted cellular turfgrid on structure. *A 300 mm (12") lightweight soil depth is preferred. Requires a soil separator as shown.*

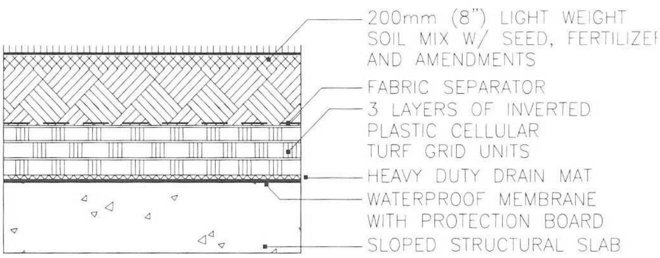


Figure 914-4. Natural turf athletic field- on structure. *Fabric separator is required. A 300 mm (12") lightweight soil depth is preferred.*

SECTION 915

Curbs

1.0 INTRODUCTION

Pavement curbs allow road and path grades to be depressed and to act both as wheel barriers and stormwater runoff containment edges. Curbs are classified as vertical, sloped, mountable, or curb and gutter combination types. They range in height from 100-200 mm (4-8 in). Selected details illustrate a range of materials and curb configurations.

1.1 General Notes

Wood curbs should be used for informal or temporary conditions only. They require extended aggregate bases and periodic pins to secure them to the pavement base. Steel pins resist seasonal heaving and can be re-set easily. Brick and masonry curbs may serve as light duty curbs in pedestrian systems or light residential drives in warm climates. Stone curbs are more resistant to plowing and general maintenance. Concrete curbs come in standard profiles and may be custom formed to provide ramp access. Slip form curbs in cold climates are often placed using high strength concrete without reinforcing. Curb and gutter configurations allow for free aggregate base drainage.

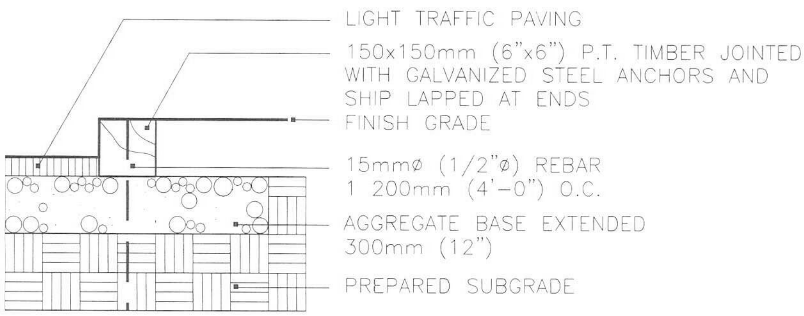


Figure 915-1. Wood curb with rebar pins at notched joint. *Informal edge or parking area curb stop. May also be placed on asphalt base course.*

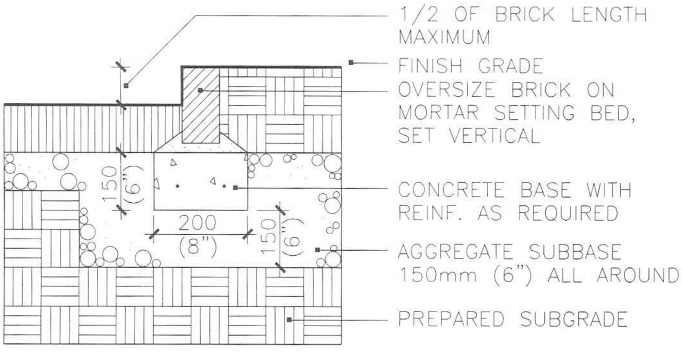


Figure 915-2. Vertical brick curb. *Brick has mortar joints and requires concrete grade beam. Not used in cold climates.*

SECTION 916

Steps

1:0 INTRODUCTION

Steps and ramps (Section 917) allow vertical circulation within the site. It is common practice to eliminate steps where ever possible, especially at entrances to avoid dual ramp and stair construction. Steps should be proportioned to provide graceful exterior scale strides, typically at a flatter angle of attack than interior stairs. Climate and maintenance are important considerations in site design with regard to placement of steps. The selected details illustrate typical materials and construction techniques used to build steps.

1.1 General Notes

Ramp steps should be spaced in multiples of human strides, typically 675 mm (27 in) riser to riser. Exterior steps have shorter risers than do interior steps, typically 125-150 mm (5-6 in). All treads should slope 2% for positive drainage. Sheet runoff should not be allowed to cascade over steps from above, especially in cold climates. All expansion joints should be sealed to prevent moisture intrusion. Cheek walls must bear on frost- free soil in cold climates. Rigid pavement abutting top and bottom stairs should sit on footing sills to maintain alignment and finish elevation. Limit stair runs to multiples of eye-level for best human scale.

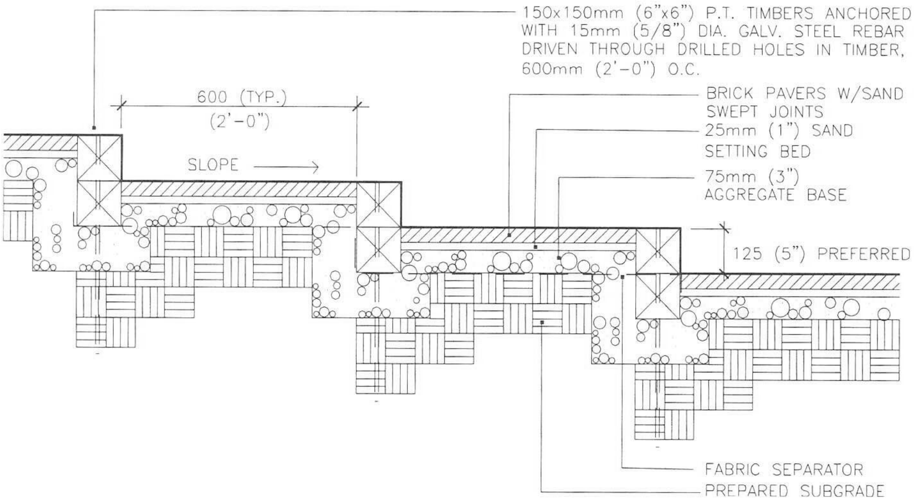


Figure 916-1. Wood/stone ramp steps. *Pins and fabric ties stabilize wood risers. Stone may be substituted.*

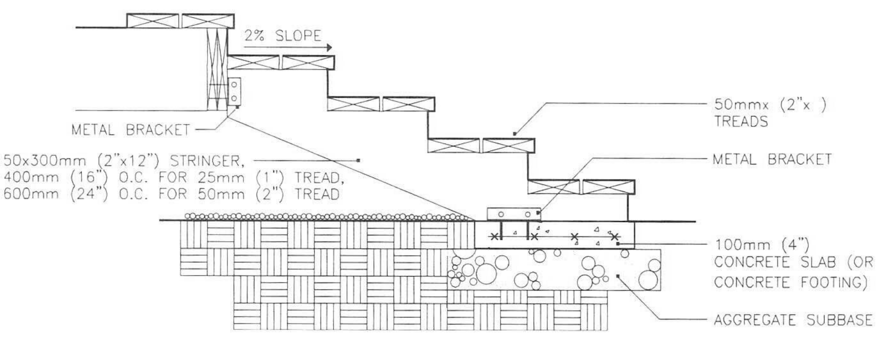


Figure 916-2. Wood steps with notched stringer. *Flanges secure stringers. Codes may require closed risers.*

SECTION 917

Ramps

1.0 INTRODUCTION

Ramps are regulated by statute. The same restrictions that apply to steps apply to ramps (Refer to Section 916). Because of the necessity of entrance ramps, careful consideration should be given to site design and placement. Long ramps with landings should be adequately drained to avoid runoff accumulation at the lower end. Selected details illustrate various materials and configurations used in ramp construction.

1.1 General Notes

Conservative estimates of structural loading on ramps should be used to anticipate pedestrian crowding and periodic furniture delivery. Typically, commercial loading values should apply. Ramp surface should provide traction, especially in cold climates. If a unit paver surface is used, an interlocking pattern provides better results due to its resistance to creeping along the slope. A secure base grade beam or other restraining device is recommended. Wood ramps should be secured to concrete footings and threshold blocks for longer service and structural integrity.

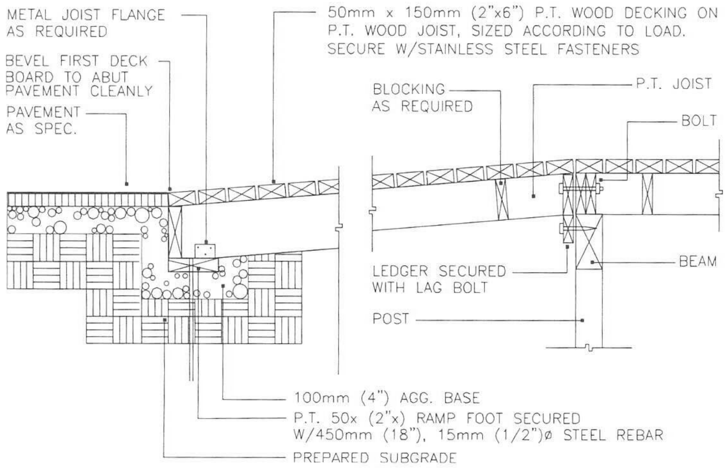


Figure 917-1. Wood ramp with flush pavement. *Simple informal treatment in warm climate and well drained soils.*

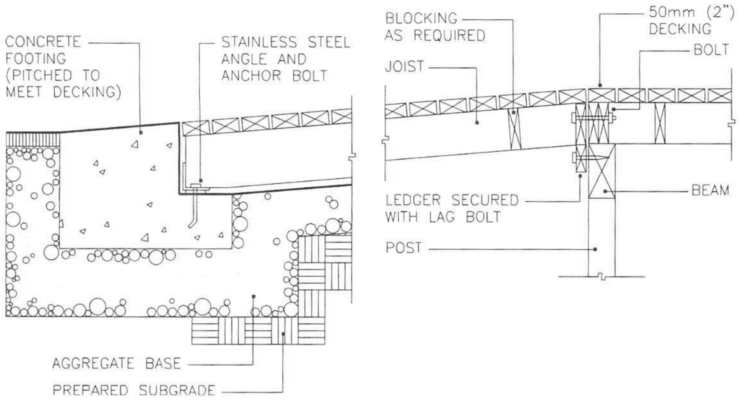


Figure 917-2. Wood pedestrian ramp with concrete apron. *Used in more formal settings and in cold climates to insure longer wood service.*

Fences

1.0 INTRODUCTION

Fences range in height from 900-2 400 mm (3-8 ft) and are constructed of wood, metal, plastics and combinations of each with masonry piers. Fences are characteristically composed of panels spanning between posts, and often contain gates and other associated structures. Structural design is determined by height and wind loads, and in the case of masonry pier, by soil bearing. The selected details illustrate a range of materials and applications.

1.1 General Notes

Simple wood fences may use direct burial posts which are either pressure treated or decay resistant wood. Long term fencing and commercial applications typically require concrete pier footings with metal attachment devices to secure posts to footings. Steel may be attached to the posts and set in set concrete, or steel may be set in concrete and attached to posts after the concrete cures. Steel may be routed into the wood for a more finished appearance. All exposed metal should be cleaned, primed, and coated prior to attachment. All wood surfaces should be milled to shed water for longer service. Iron fences attached to masonry piers are typically attached to metal flanges set into the masonry piers during their construction. Footing depths range from 600-900 mm (2-3 ft) depending on wind loads and frost depth..

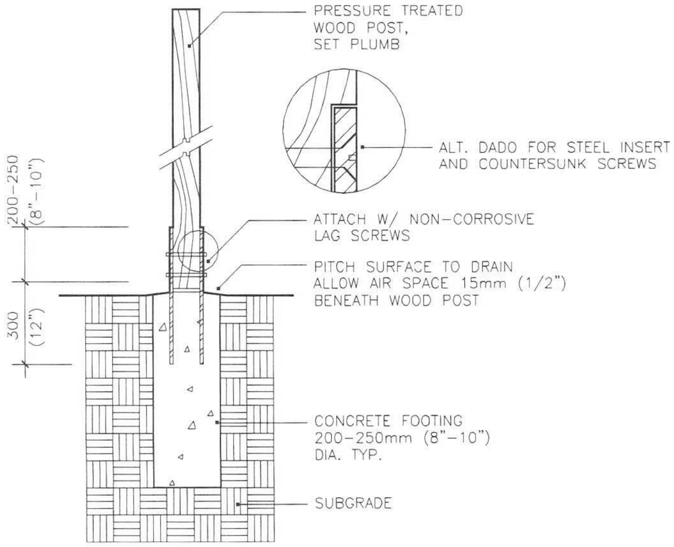


Figure 918-1. Wood fence post-metal anchor in concrete. *Preferred method of attachment for long service life and ease of repair.*

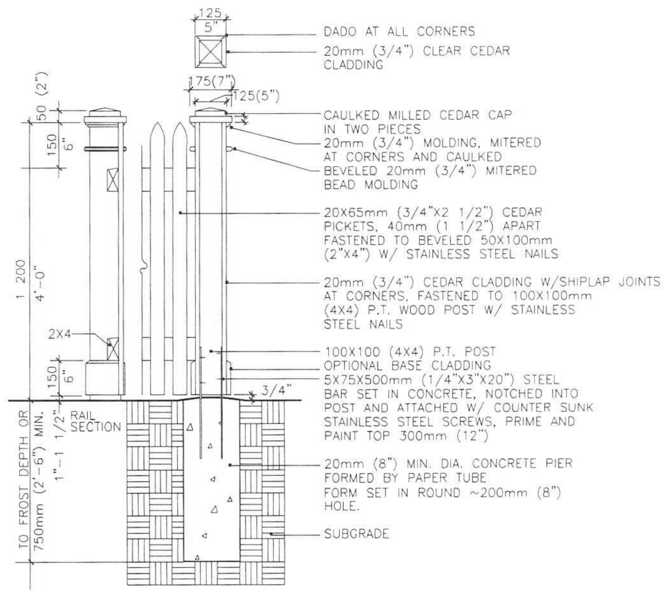


Figure 918-2. Wood clad picket fence with concrete pier. *Classic built-up post and wood trim. Requires periodic coating to retain integrity.*

SECTION 919

Walls

1.0 INTRODUCTION

Free standing barrier walls may vary in height from 900-2 400 mm (3-8 ft). They are typically constructed from masonry, stone, or concrete. Design is governed by porosity and bearing capacity of site soils, and wind load conditions. With the exception of dry laid stone walls, all such barrier walls require footings and tensile reinforcement. Selected details illustrate typical applications of these walls and materials.

1.1 General Notes

Stone walls should be built of stones from the local region. Larger stones are typically laid in bottom courses. Periodic single course tie stones are useful for holding dry laid walls together, especially in cold climates. Mortared stone walls require footing below frost line in cold regions. Rake and tool all joints to avoid moisture penetration, especially at top of wall. Single width cap stone is preferred over small fitted pieces. Cap stone thickness is typically 50-100 mm (2-4 in) minimum. Avoid thin veneer caps. Small concrete walls may not require a spread footing. All walls subject to wind loads typically require a spread footing, with depth calculated for lateral sheer, or frost depth (which ever is greater). Masonry walls require steel reinforcing and fully grouted cavities, sealed with a cut cap stone or precast coping sloped to drain.

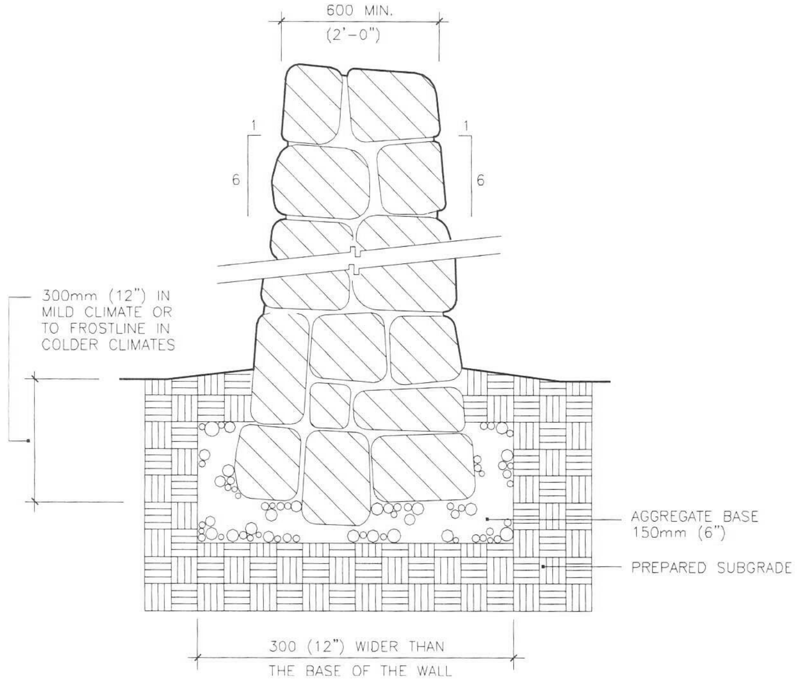


Figure 919-1. Dry laid stone wall. *Lay stone on aggregate base below frost in cold climates. Batter both sides.*

SECTION 920

Retaining Walls

1.0 INTRODUCTION

Retaining walls and embankment stabilizing structures are designed to hold back vertical cuts and steep embankments required by designs in sloping terrain. The principle structural systems employ static equilibrium achieved through gravitational weight (gravity walls and riprap), tensile reinforcement and friction (Horizontal fabric and controlled aggregate lifts), and a combination of steel reinforcement and weight (reinforced concrete cantilevered wall). All systems are derived from soil mechanics of specific soil groups. Final proportions and dimensions are determined from such structural soil properties as cubic weight, bearing capacity, shearing or internal friction angle, friction coefficient, and permeability. Soils are divided into colloidal and granular types for the purpose of design. The selected details in this section display examples of these common structural systems.

1.1 General Notes

Embankments greater than 1:1.5 typically exceed the natural angle of repose of most soils. Bank reinforcement in such circumstances usually consists of aggregates, stone, or masonry units of sufficient weight to counteract the slope's tendency to slip along its shearing plane. The top of slope should be graded to prevent sheet flow runoff from washing across the slope. The toe of slope often requires a grade beam or stone reinforcement to withstand the accumulated embankment surface weight. Vegetative reinforcement may require irrigation. Dry soil plants are recommended. Gravity wall base is typically 0.45 to 0.60 H, depending on soil type. Stone walls typically require a 600 mm (2 ft) top width. Dry stone walls usually require no footings. Mortared or concrete gravity walls require footings below local frost depth. Most codes require at least a 300 mm (12 in) soil cover over top of footing in warm climates. Cantilevered walls and all rigid construction require weep hole and back drains to relieve hydrostatic pressure when applicable. Tops of walls should slope back away from the face to prevent staining. Some conditions may require an impermeable swale at top of wall to prevent infiltration in cold or colloidal soil conditions.

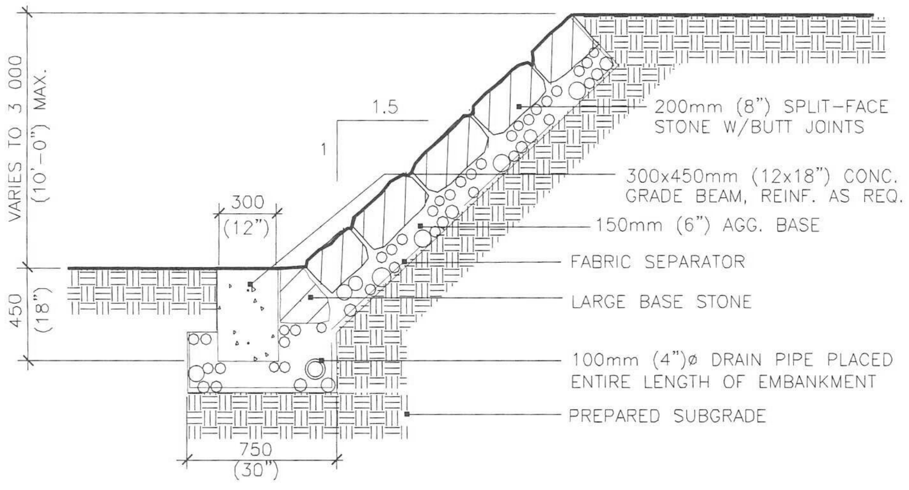


Figure 920-1. Stone retaining embankment. *Stone thickness and weight are determined by soil pressure. Non-porous stone preferred.*

SECTION 922

Lighting

1.0 INTRODUCTION

Site lighting includes accent ornamental lighting for plantings and buildings, pedestrian circulation lighting, vehicular lighting, and large area lighting associated with athletic events or major facilities and industrial plants. Site lighting requires organization of fixtures to create the specified coverage and light intensities, and organization of conduits to avoid conflicts with other utility systems. Fixture designs are specific for glare control and illumination pattern to comply with code restrictions and should be selected accordingly. Low voltage systems should be used whenever possible to reduce energy consumption. The following selected details illustrate examples from these categories.

1.1 General Notes

Small fixtures are typically direct burial systems. Commercial grade fixtures are typically mounted on a concrete pier with cast-in-place conduit feeds. Most conduits under paved surfaces require at least 600 mm (2 ft) of soil cover. Residential wiring may allow direct burial in non-paved areas. Conduits are recommended for high quality site work. Post and pole piers are typically 10% of the pole height plus 600 mm (2 ft) in depth. Clay soils and windy sites may require deeper and thicker piers. In cold climates, all pier footings are set below frost line to prevent heaving and to maintain plumb alignment.

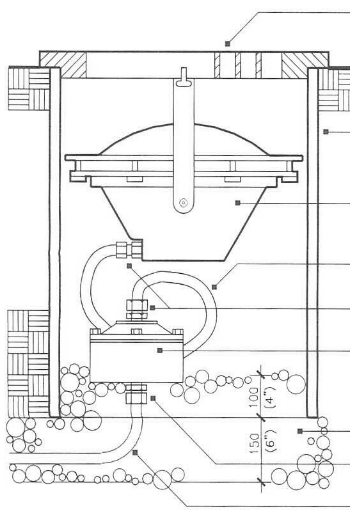


Figure 922-1. Up light-below grade in planting bed. *Pre-formed casings are set on aggregate base to house waterproof junction and fixture.*

SECTION 923

Planting

1.0 INTRODUCTION

Planting typically encompasses large, medium, and small trees, shrubs, ground covers, grasses and turf, herbaceous perennials, bulbs, corms, and annuals. American practices are guided by the American Nurseryman's Association Standards with regard to plant material sizes and planting procedures. The planting details presented in this section refer to selected large trees and shrubs.

1.1 General Notes

Successful tree planting begins with healthy plant material which has been protected from transportation stress. Tree pits should be at least twice the size of the container or tree ball, but three to four times the diameter is recommended where space permits. Large trees should be placed directly on prepared subgrade at the tree pit center to avoid settlement. Inorganic containers and wrappings should be removed, while the top third of cloth wraps should be cleanly cut and removed before back filling. Backfill soil should be screened and prepared to specification as per species requirements, and placed in controlled 150 mm (6 in) lifts to avoid air pockets and to anchor the rootball to prevent lateral shifting. Palms may require water jet saturation for proper seating. It is common practice to place the root crown level with, or slightly above finish grade. In all cases except pavement plantings, a tamped soil saucer rim should be formed around the tree pit surface to retain water. Mulching is recommended for lowering root temperature and preventing evaporation. Staking and guying are only recommended for windy sites. Trunk wrapping is not generally recommended.

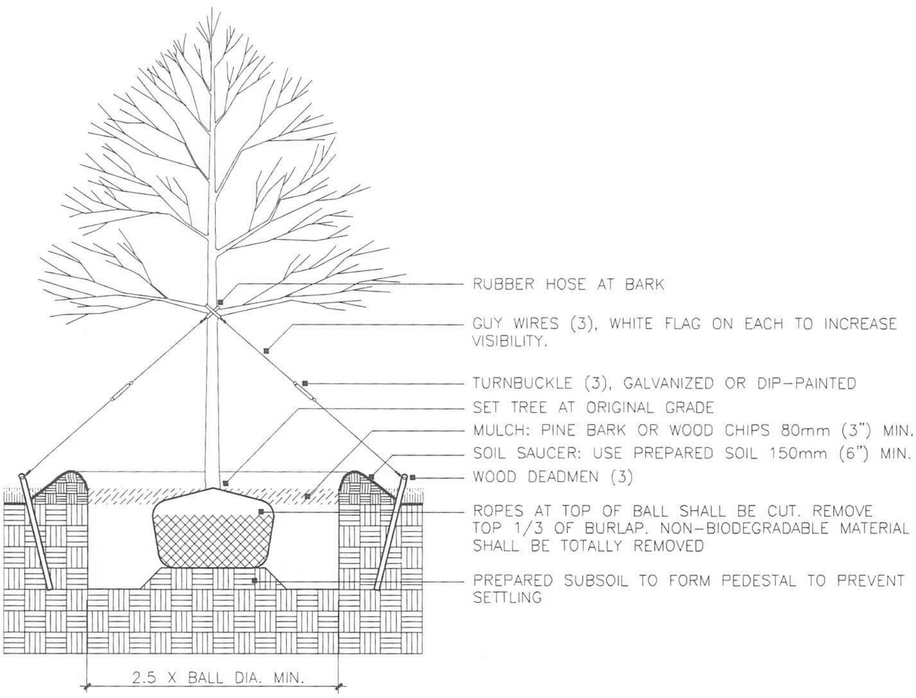


Figure 923-1. Deciduous tree planting. *Large tree staked and guyed for windy site.*

SECTION 924

Drains

1.0 INTRODUCTION

Site drains receive water at low points for infiltration, diversion, or disposal to site outfalls. Drain inlets should be durable and appropriate for the climate zone. Infiltration devices should only be used in sufficiently porous soils. Long term care requires periodic cleaning and sealing of joints and re-setting of grates and finish pavements or turf grades due to settlement or silting. Selected details illustrate a range of drain types for various applications.

1.1 General Notes

Locate drains at the edge of use areas. Drain pavements onto turf areas before collecting if possible. Avoid discharging sheet flow runoff from turf areas onto pavements to avoid silting and staining, especially in freeze/thaw regions. Allow 750 mm (2 ft-6 in) soil cover over pipes subject to vehicular loading. Set inlet footings below frost in cold regions. Plastic grates and frames should be confined to turf areas in cold regions. Warm regions may set drain pipes at shallow depths, but care should be taken to guard against crushing in pedestrian walking zones. When joining a small pipe to a large pipe, the crown of the small pipe can be set no lower than the crown of the large discharge pipe within a basin.

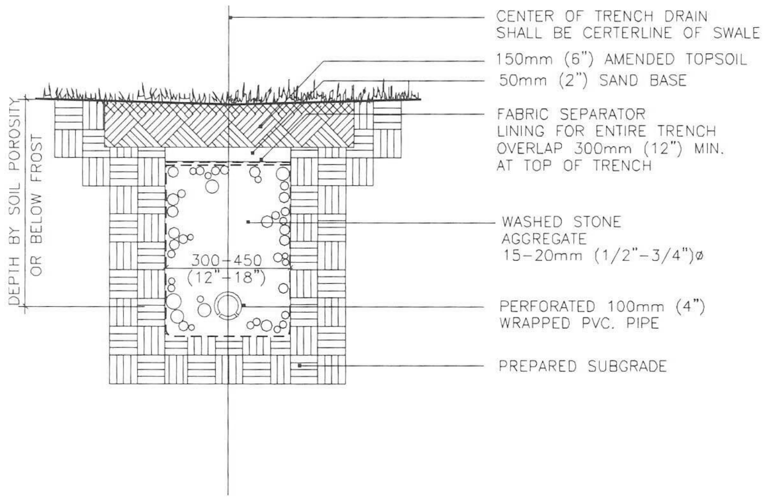


Figure 924-1. Perforated pipe curtain drain. *For infiltration and for draining moist soils. Sand filter required for fine soils.*

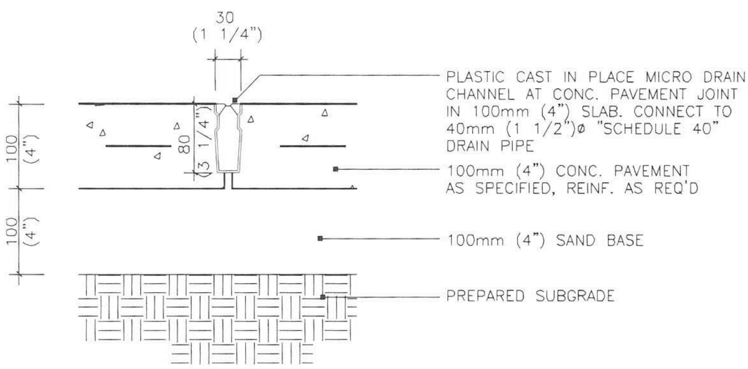


Figure 924-2. Polymer pavement strip drain. *Various sizes for cast slab applications available. Warm climates only.*

SECTION 925

Swales

1.0 INTRODUCTION

Drainage swales vary in design by lining type, cross section shape, volume, and velocity potential. It is a general practice to create broad low velocity swales with high infiltration capacity to reduce over-all runoff volume when ever possible. Some swales serve as channels to deposit large volumes of water into detention or retention ponds and require impermeable or erosion resistant linings. The details selected illustrate heavy duty applications using various lining and cross section strategies.

1.1 General Notes

A parabolic turf swale is ideal for achieving low velocity moderate volume runoff capacity. Generally, a swale velocity of a given slope, for a given volume may be reduced by broadening its cross section and reducing its full flowing depth. High velocity swales require durable lining to withstand the scouring potential of moving water. Deposition of fines occur at about .75 m/sec (2.5 ft/sec), and severe scouring of structural linings can occur at 3-4.5 m/sec (10-15 ft/sec). Maintain swale velocity approaching an outfall to prevent silt deposition. Infiltration swales usually require a fabric separator under stone to prevent upward migration of fines into the water stream when at full capacity. Fiber matting, hydro-seeding, or sodding help to hold the swale channel while seeding germinates.

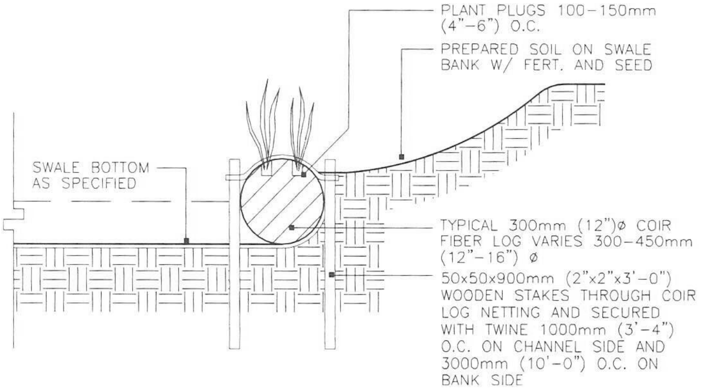


Figure 925-1. Swale with fiber-log channel edge. *Swale channel requires permanent pool level to support initial plant growth in fiber log.*

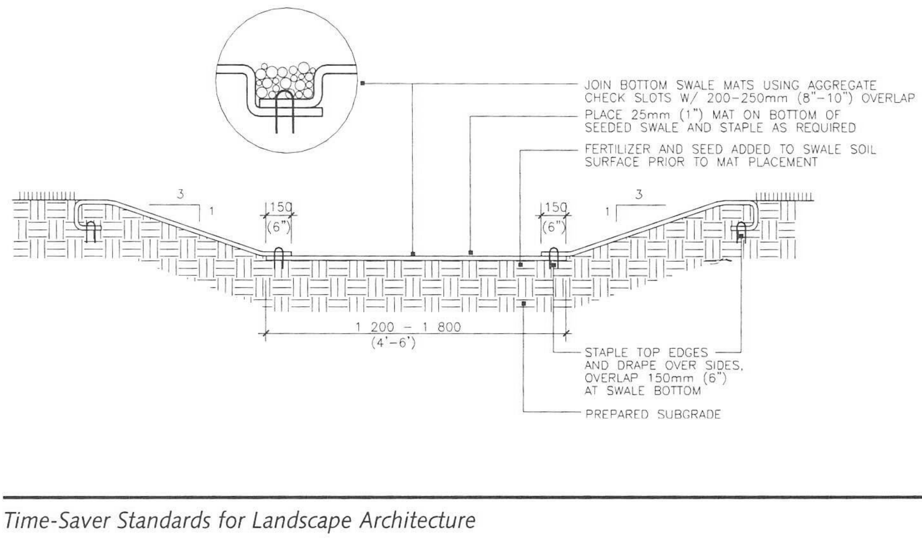


Figure 925-2. Fiber-mat swale reinforcing. *Used in highly erodable soils to protect swale banks during seed germination.*

Pools

1.0 INTRODUCTION

Pools typically require full filtration and circulatory systems to regulate particulate matter, pH, temperature, algae, and bacterial organisms. Pools may accommodate swimming, may be ornamental, or may support aquatic life. In each case they must be of water proof construction and be adapted to the local climate and soils. All types require provisions for periodic draining, cleaning, and sealing or coating to maintain structural integrity, appearance, and operation.

1.1 General Notes

Flexible liners may be used on-grade for temporary installations using submersible pumps and exposed pipes to protect the liner integrity. Stones placed on liners must rest on a drain mat or sand cushion . Heavy stones may require a sand base beneath the liner as well. Custom built liners may be used in conjunction with rigid structures to allow for circulation intake and drain hardware to be bonded on-site. Rigid construction requires provision for draining of aggregate base to relieve hydro-static soil pressure, especially during seasonal drawdown or cleaning periods. Footings must extend to undisturbed earth or below frost lines. If placed in segments, all joints must be fully keyed and gasketted. All reinforcing steel must be covered with at least 50 mm (2 in) of concrete. Waterlines are usually vertical surfaces finished with tile or polished stone for ease of cleaning.

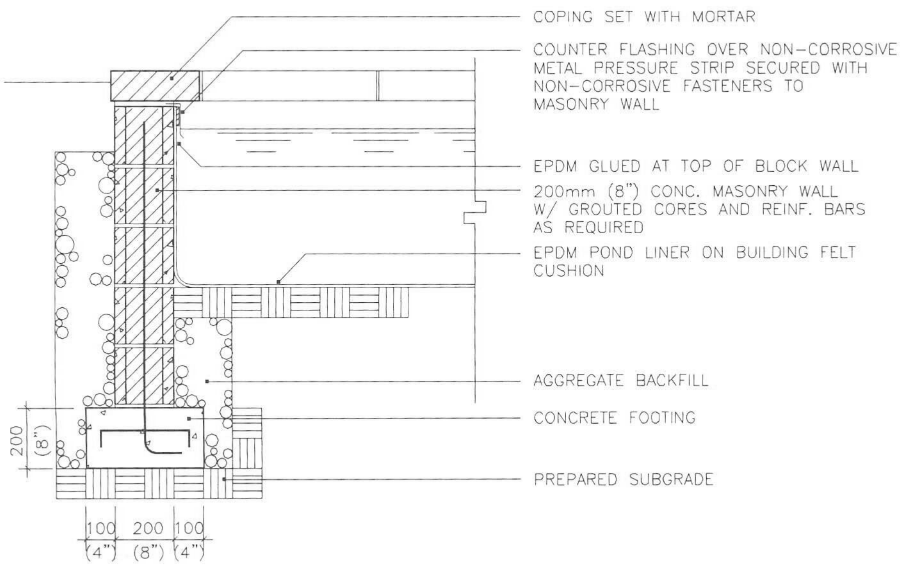


Figure 926-1. Concrete masonry garden pool. *Grouted reinforced concrete block walls. Membrane glued to top of wall at pressure bar.*

SECTION 927

Ponds

1.0 INTRODUCTION

Ponds refer to augmented or constructed wetlands designed to retain, detain, settle, or infiltrate site stormwater runoff. The selected details assembled below illustrate augmented wetland edges, selected liners for both retention and detention, and erosion protection edges for infiltration.

1.1 General Notes

All wetland plants have specific soil, moisture, and depth tolerances. Use local native species for best results. Cut embankments are commonly seeded and covered with protective matting. Planted waterline slopes are graded to a gradual depth of 450 mm (18 in) to receive cattail or other local aquatic plants. Infiltration ponds and clay lined retention ponds, typically use a fabric separator over subgrade before filtering, or ballast aggregates are placed to reduce turbidity during stormwater infusion. Single ply EPDM or other polymer liners may require a sand cushion prior to placement if subgrade is too course. A permanent pool depth of 2 100-3 000 mm (7-10 ft) is required to attain temperature stratification and support biological cycles. All such construction is subject to local and federal permitting processes, which may prescribe regionally specific construction procedures.

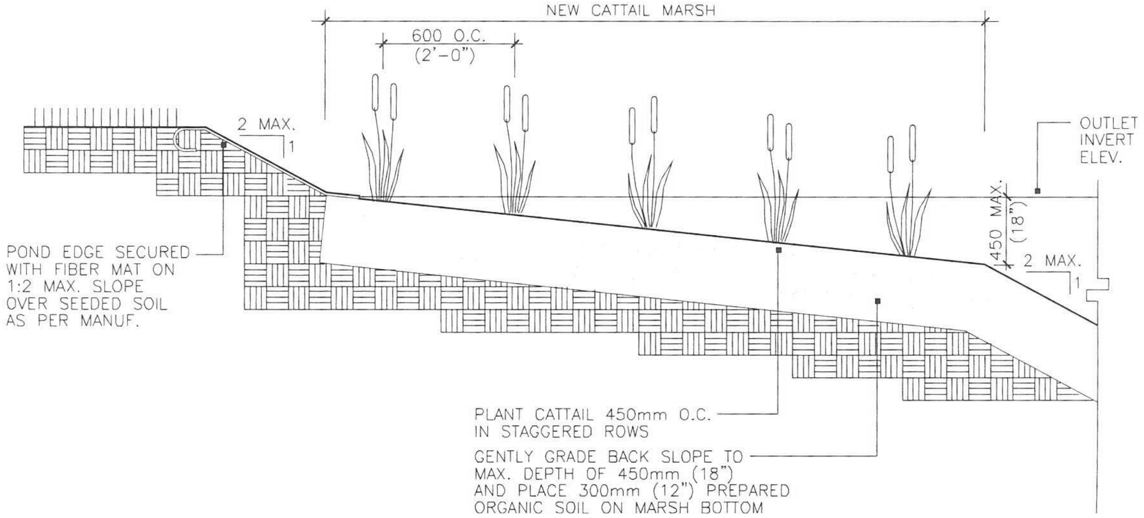


Figure 927-1. Augmented wetland pond edge. *Augmented existing wetland edge using prepared planting soil and fiber mat stabilization.*

Landscape Architecture

The site design and construction reference of the design professions

Newly designed and containing 40 percent completely new content, *Time-Saver Standards for Landscape Architecture,* Second Edition, continues to be the most complete source of site construction standards and data for the design and planning professions and related academic disciplines. It maintains and enhances its emphasis on promoting environmentally suitable techniques, processes, and materials aimed at mitigating the impact of construction intervention.

This essential and comprehensive Second Edition not only covers the major changes that have occurred in the last decade, it also serves as a framework for future trends. It is fully metric, to meet Federal and International requirements, with expanded coverage of handicapped access and human dimensional standards. *Time-Saver Standards for Landscape Architecture,* Second Edition, features increased coverage of:

- ***Site storm water "best management" practices***
- ***New urban tree planting and xeriscape concepts***
- ***Earth retaining structures and pavement design***
- ***Land reclamation, including soil and vegetation restoration***
- ***Metric site layout practices, including recreation facilities***
- ***Energy and resource conservation***
- ***Natural processes and site construction procedures***
- ***New expanded construction details***
- ***Simplified construction materials data***

In the time honored tradition of Time-Saver Standards, this Second Edition combines the expertise of over 200 design professionals to create a working resource for all who plan, design, manage, and build human landscapes. Over 50 sections provide concise tables, checklists, "Key Point" text summaries, and illustrations to provide an invaluable information resource for offices and classrooms throughout the world.

Cover Design: Margaret Webster-Shapiro. Cover Photo: SuperStock, Inc.

ISBN 0-07-017027-4

90000

9 780070 170278

Visit us on the World Wide Web at
www.books.mcgraw-hill.com

McGraw-Hill
A Division of The McGraw-Hill Companies