بسم الله الرحمن الرحيم

Lecture # 1

Properties of Concrete

Introduction

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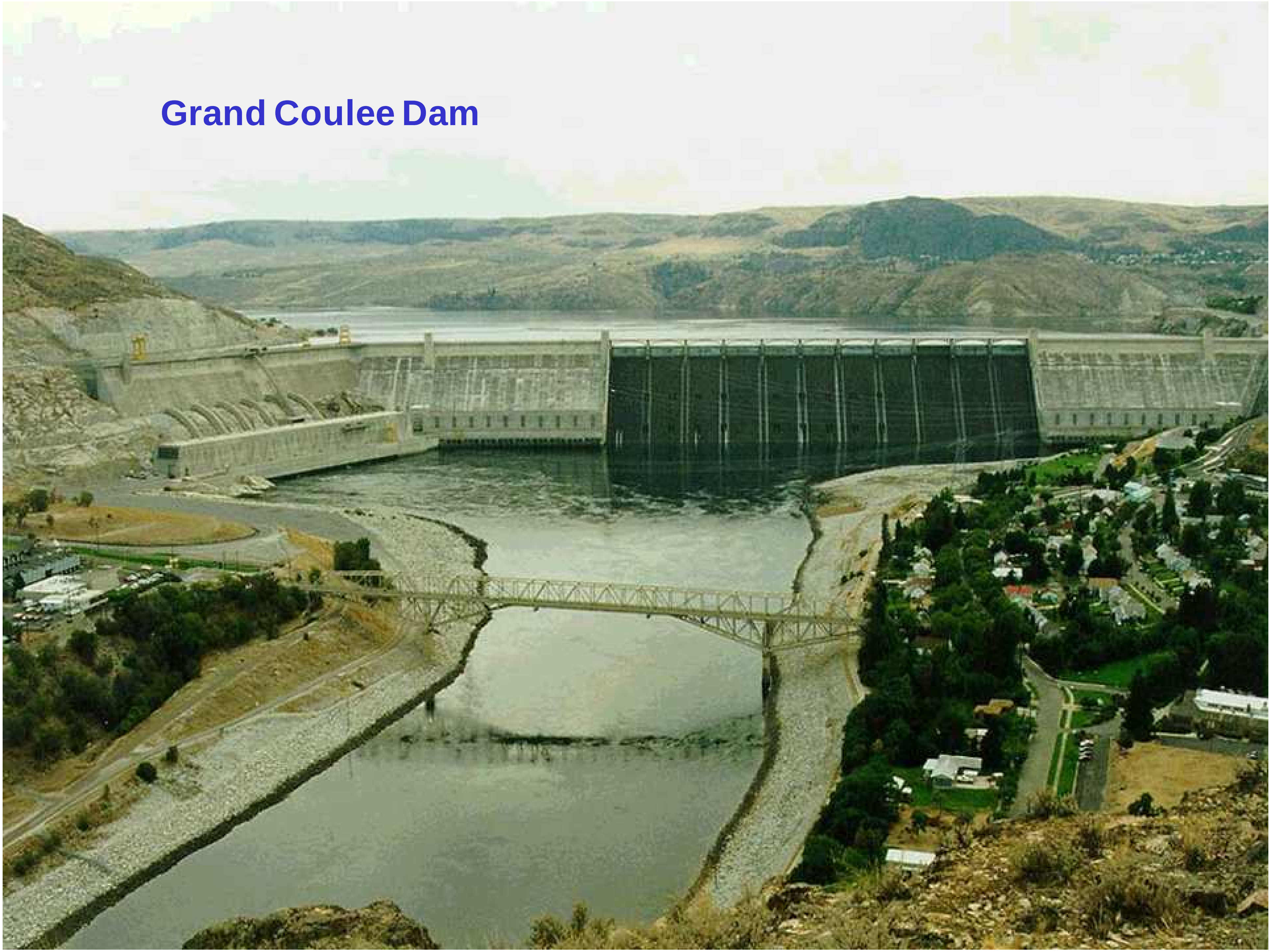
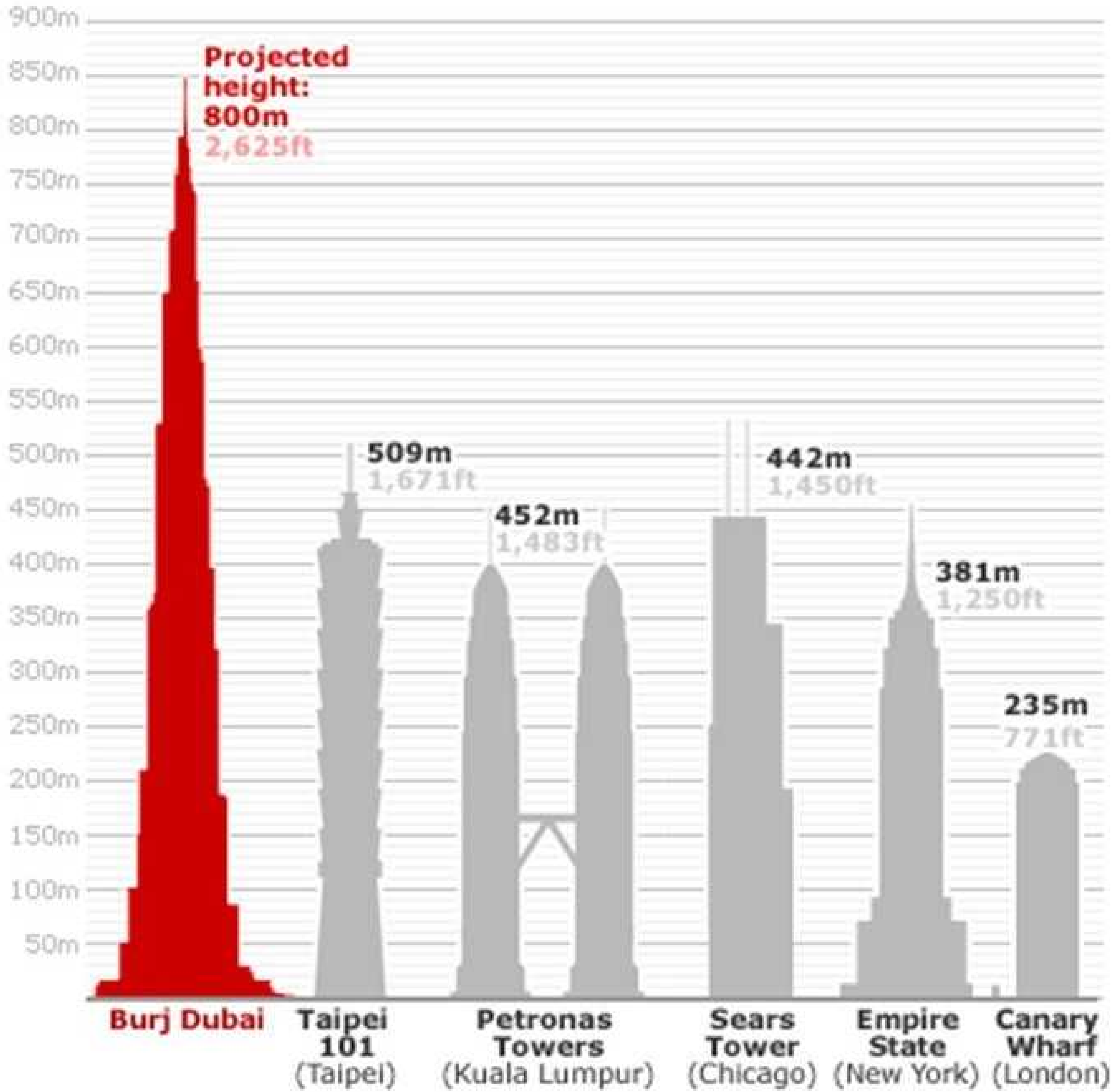
Concrete

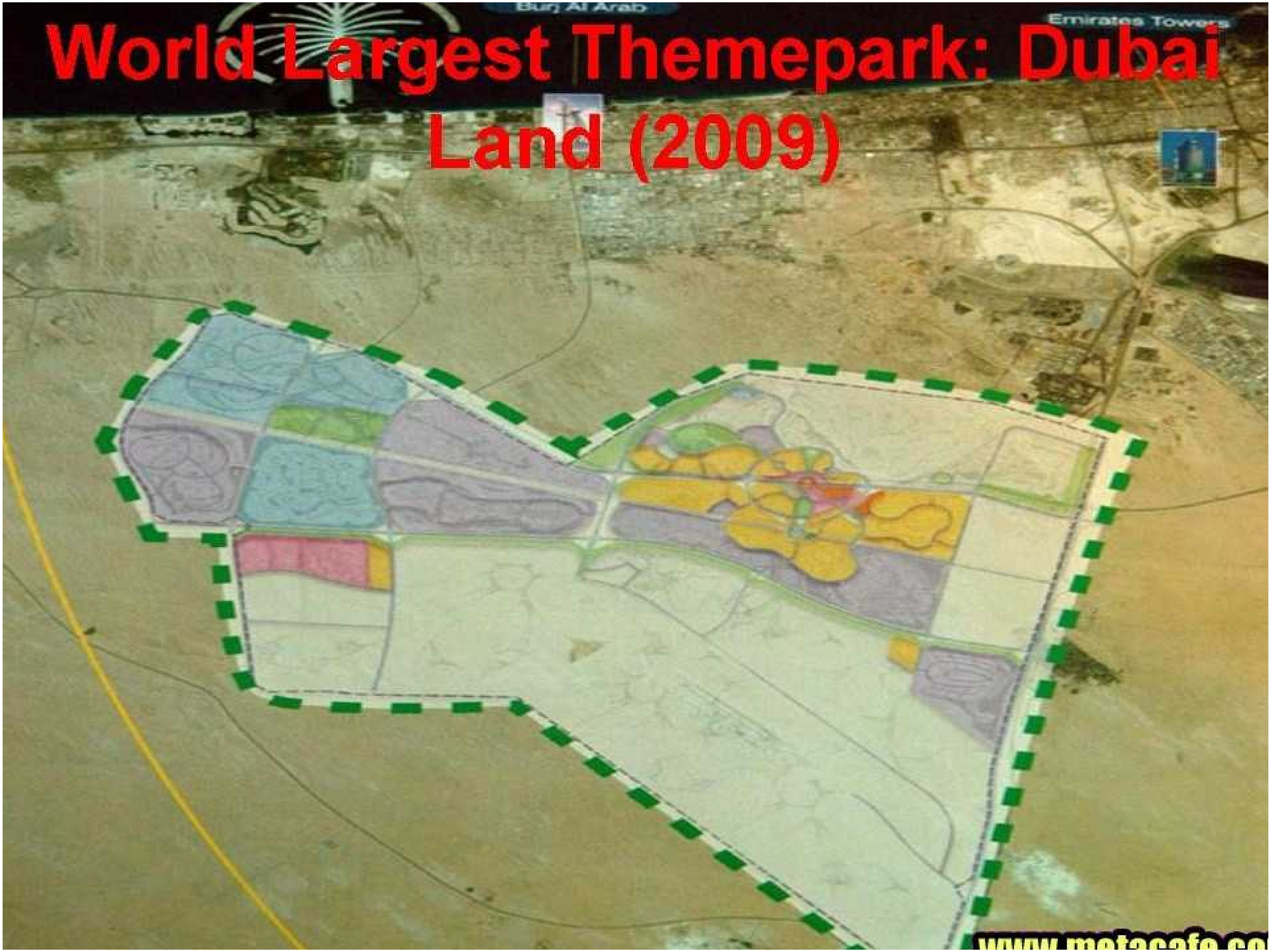
- is a mixture of Portland cement, water, aggregates, and in some cases, admixtures.
- The cement and water form a paste that hardens and bonds the aggregates together.
- Concrete is often looked upon as “man made rock”.
- Concrete is a versatile construction material, adaptable to a wide variety of agricultural and residential uses.
- Concrete has strength, durability, versatility, and economy.
- It can be placed or molded into virtually any shape and reproduce any surface texture.
- Concrete is the most widely used construction material in the world.
- In the United States almost twice as much concrete is used as all other construction materials combined. Demand for concrete with higher strength and better quality, coupled with larger and faster mixer trucks, led to the emergence of the ready-mix concrete industry in the post-World War II period.
- The ready-mix concrete producer has made concrete an appropriate construction material for many agricultural applications.

Grand Coulee Dam





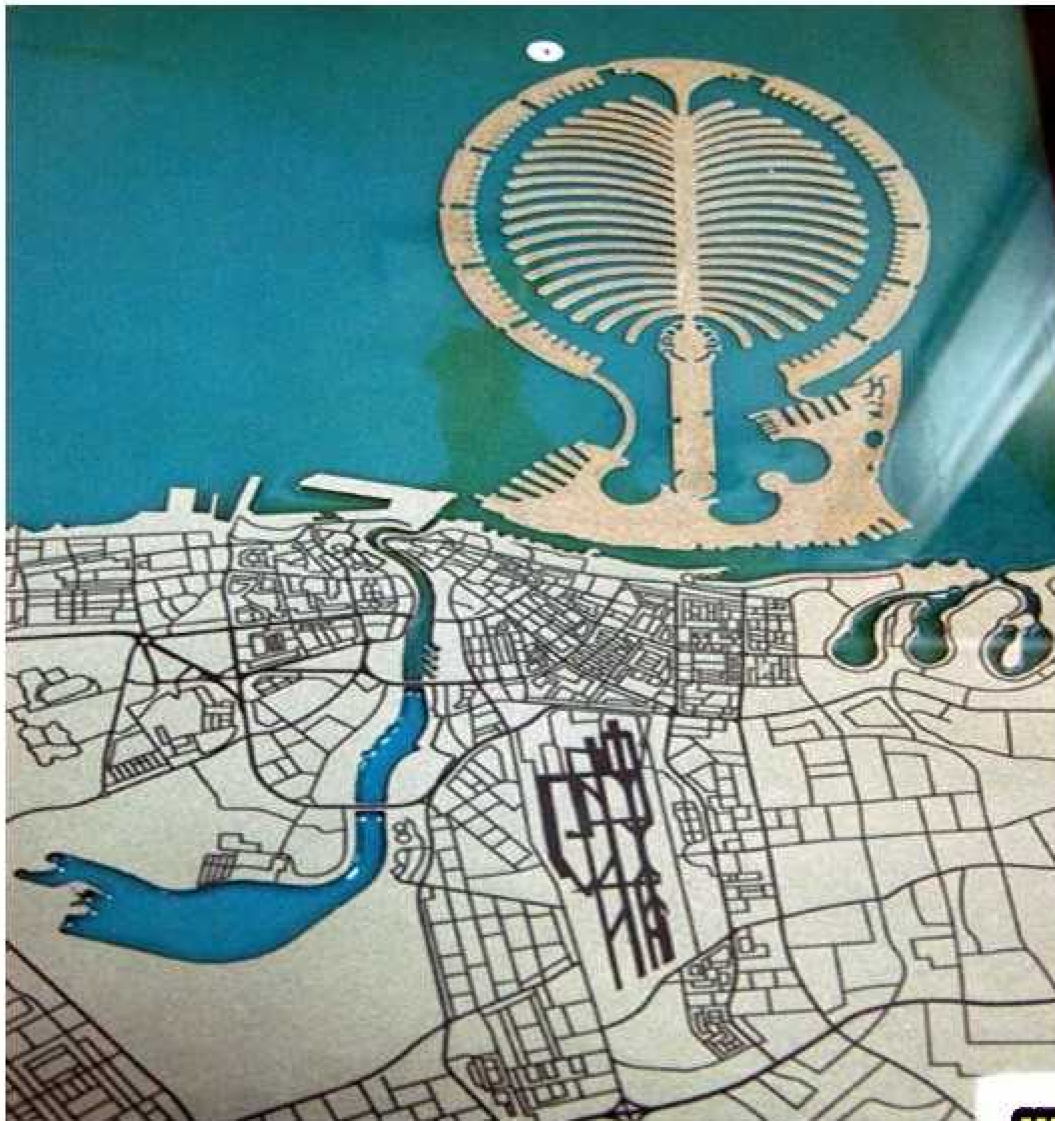
900m
850m
800m
750m
700m
650m
600m
550m
500m
450m
400m
350m
300m
250m
200m
150m
100m
50m
Projected height: 800m
2,625ft
509m
1,671ft
452m
1,483ft
442m
1,450ft
381m
1,250ft
235m
771ft
Burj Dubai
Taipei 101 (Taipei)
Petronas Towers (Kuala Lumpur)
Sears Tower (Chicago)
Empire State (New York)
Canary Wharf (London)


World Largest Themepark: Dubai
Land (2009)
Burj Al Arab
Emirates Towers

Dubai Marina Project
Jumeirah Beach Residences (40 blocks)


www.metacafe.co

Another Palm: Deira Palm (Largest):



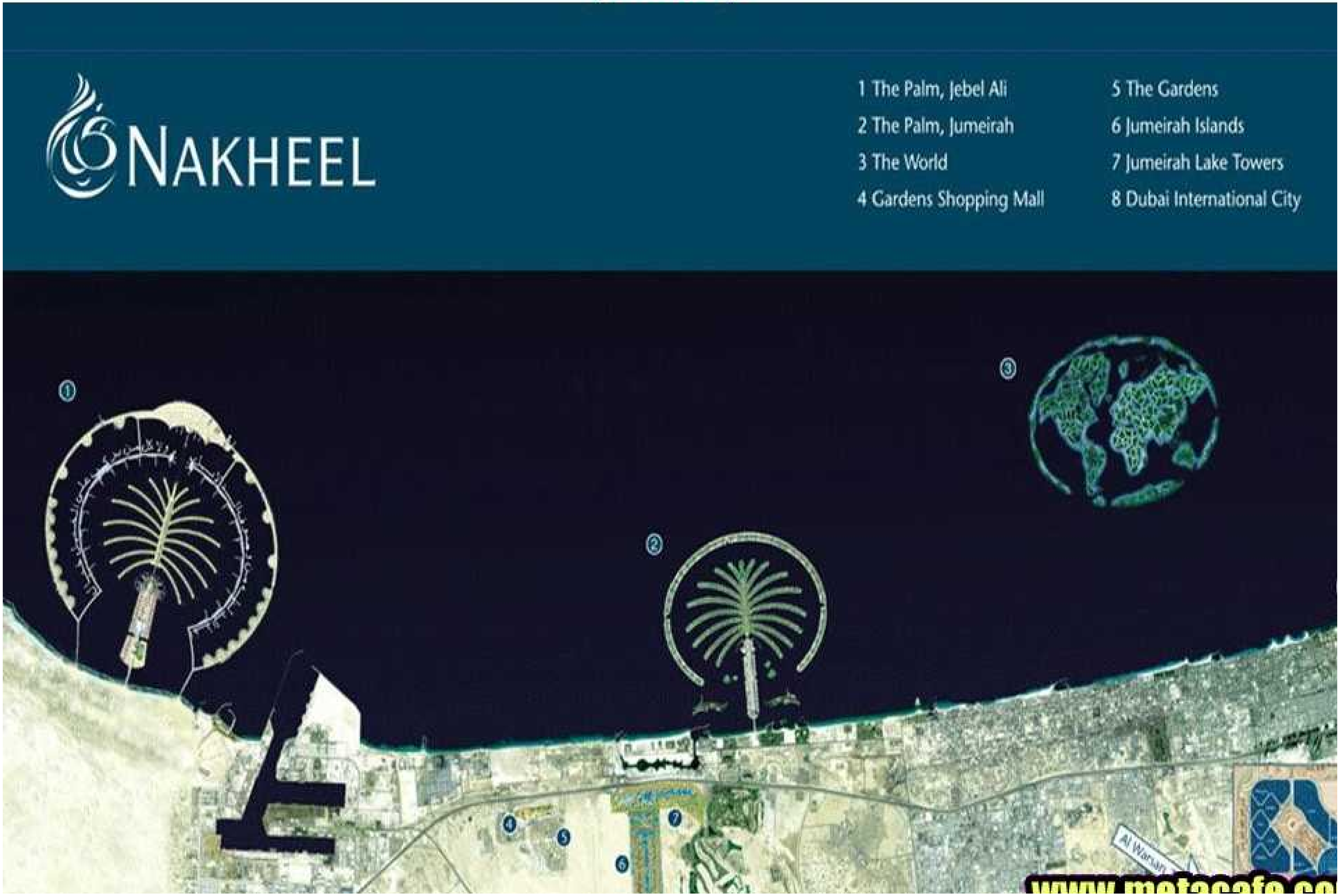
The World (Own an island for a price of US$ 7million/island)
To access your private island, get a helicopter or marine boat.
(in the making)


Burj Dubai Tower - World tallest
(2008)
www.metacafe.co

World Biggest Ski Dome (Within Mall of Emirates)

Features Real Size Dinosaurs Roam on Earth (Jurassic Park)

World Largest "Palms" - Jumeirah Palm, Jebel Ali Palm, , The World, Deira Palm (Hidden)



Properties of Concrete

- With proper materials and techniques, concrete can withstand many acids, silage, milk, manure, fertilizers, water, fire, and abrasion.
- Concrete can be finished to produce surfaces ranging from glass-smooth to coarsely textured, and it can be colored with pigments or painted.
- Concrete has substantial strength in compression, but is weak in tension.
- Most structural uses, such as beams, slats, and manure tank lids, involve reinforced concrete, which depends on concrete's strength in compression and steel's strength in tension.
- Since concrete is a structural material, strength is a desirable property.
- Compressive strengths of concrete generally range from 2000 to 5000 pounds per square inch (psi), but concrete can be made to withstand over 10,000 psi for special jobs.

Portland Cement

- Portland cement was named for the Isle of Portland, a peninsula in the English Channel where it was first produced in the 1800's.
- Since that time, a number of developments and improvements have been made in the production process and cement properties.
- The production process for Portland cement first involves grinding limestone or chalk and alumina and silica from shale or clay.
- The raw materials are proportioned, mixed, and then burned in large rotary kilns at approximately 2500 ° F until partially fused into marble-sized masses known as clinker.
- After the clinker cools, gypsum is added, and both materials are ground into a fine powder which is Portland cement.

Three Types of cement

- *Type I* cement is the general purpose and most common type. Unless an alternative is specified, Type I is usually used.
- *Type II* cement releases less heat during hardening. It is more suitable for projects involving large masses of concrete--heavy retaining walls, or dead men for suspension bridges.
- *Type III* cement produces concrete that gains strength very rapidly.
- It is very finely ground and sets rapidly, making it useful for cold weather jobs.

Water

- Good water is essential for quality concrete.
- It should be good enough to drink--free of trash, organic matter and excessive chemicals and/or minerals.
- The strength and other properties of concrete are highly dependent on the amount of water and the water-cement ratio.
- Potableie.
- Water suitable for drinking
    - Chloride < 0.05%
    - Sulfate < 0.08%
    - Organic salts < 0.05% (sugar)

Aggregates

- Aggregates occupy 60 to 80 percent of the volume of concrete.
- Sand, gravel and crushed stone are the primary aggregates used.
- All aggregates must be essentially free of silt and/or organic matter.
- Coarse Aggregate
  - Retained on #4 Sieve
  - Igneous, Sedimentary and Metamorphic rock
    - Granite
    - Limestone
    - River gravel

Aggregates

- Fine Aggregate
  - Passing #4 Sieve ~ ¼-in.
  - Natural Siliceous and Crushed Limestone
  - Graded according to ASTM C33
      - See next slide
    - Fineness modulus
      - Indication of the average particle size (2.0 to 3.0)

Fine Aggregate Grading Limits

Sieve size	% Passing
No. 4	95-100
No. 8	80-100
No. 16	50-85
No. 30	25-60
No. 50	5-30
No. 100	0-10

Recycled Concrete Aggregate

- Old concrete that has been removed and crushed to produce aggregate.
  - Coarse aggregate in new concrete
  - Fine aggregate in new concrete
    - Best combination is CA with natural fine aggregate
      - Good strength
      - Drying shrinkage problem
  - Base-coarse replacement for natural limestone

Admixtures

- Admixtures are ingredients other than portland cement, water, and aggregates.
- Admixtures are added to the concrete mixture immediately before or during mixing.

Properties of Concrete

Fresh Properties

- Slump
- Temperature
- Density & Yield
- Air Content
- Time of Setting

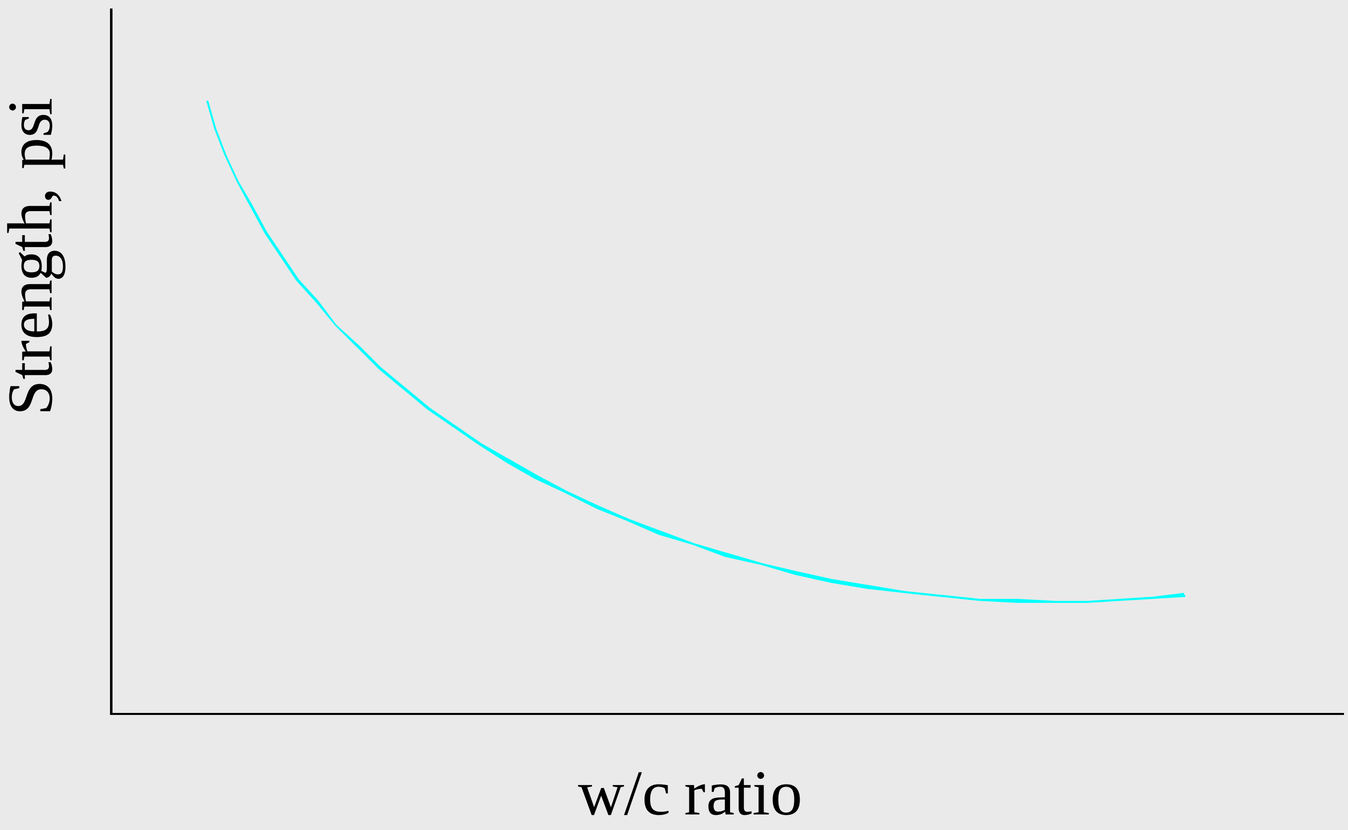
Hardened Properties

- Strength
- Air Content
- Density, Absorption and Voids
  - Heavy ~ 150 pcf or about 2 tons pcy
- Volume Change
- Durability
- Permeability

How does Concrete Get Its Strength

- PC + water = hydration reaction > GLUE + Heat
- Cementitious material literally glues all of the inert (non-reactive) aggregates together to produce a solid load bearing mass that we call PCC
- Strength is inversely proportional to the water-to-cement ratio

Strength vs. w/c Ratio for PCC



What's Important for producing good quality concrete

- Good quality materials
  - PC, water, coarse aggregate, and fine aggregate
- Proper Proportioning of the Materials
- Proper Mixing
- Placing and Finishing
- Proper Curing
- QC Testing

How about the Costs?

Item	% of Total Cost
Concrete Materials	24%
Labor & Equipment	8%
Reinforcing Steel	12%
Labor & Equipment	7%
Formwork Materials	10%
Labor & Equipment	39%

Other Types of Concrete

– Lightweight Concrete
– Structural and Non-structural (120 – 50 pcf)
– High Density Concrete (400 pcf)
– Mass Concrete
– Pre-placed Concrete
– No Slump Concrete
– Roller-Compacted Concrete
– Shotcrete (Wet and Dry)

Mineral Admixtures

- Pozzolanic (cement replacement)
  - Class C Fly ash –15 to 40% bwc
  - Class F Fly ash – 15 to 25% bwc
- Blast Furnace Slag (cement replacement)
  - 25 to 70% bwc
- Silica Fume (cement addition)
  - 6 to 12% bwc

Chemical Admixtures

- ASTM C-494 and Table 6-1
- Water Reducing – Type A
- Set Retarding – Type B
- Set Accelerating – Type C
- Water Reducer-Set Retarding – Type D
- Water Reducer-Accelerating – Type E
- High Range Water Reducers – Type F
- HR Water Reducer-Set Retarding -Type G

Air-Entraining Agents

- ASTM C260
- Admix that produces stable bubble system
- Liquid and solid
- Low dosage rates relative to other chemical admixtures (0.005 to 0.05% bwc).
- Increase in durability – @freeze/thaw
- Reduces compressive strength
  – 5% per percent of entrained air

Fibers

- Steel
  - Individual and bundled
- Glass – “alkali attack”
- Synthetic – 1 to 1.5 lb per cu. yd.
  - polypropylene
  - nylon
- Natural – “Egyptian pyramids”
  - Straw, bamboo, and wood

Concrete Building Systems

- Beam and Girder Floor system
- Composite construction with Steel Beams
- One-way joist floor
- Flat Slabs
- Flat Plate slabs
- Two-way joist floor
- Precast and Prestressed concrete
- Connections

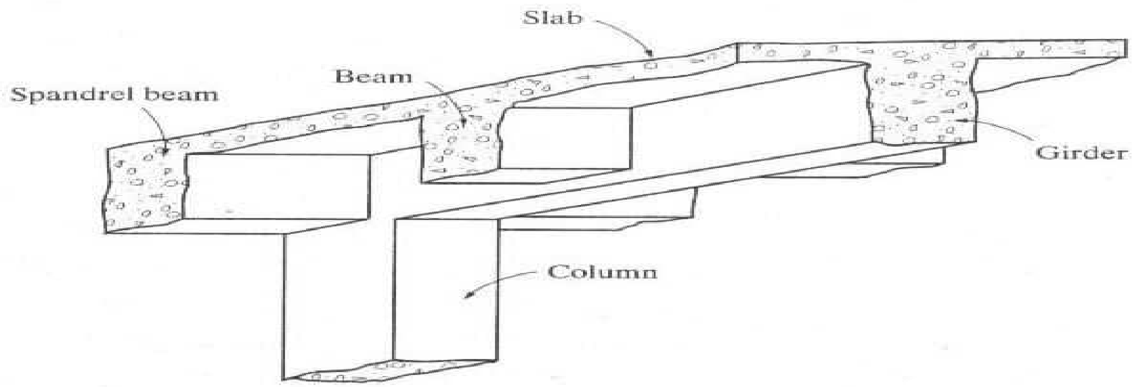


FIGURE 3-1 Beam and girder floor system.

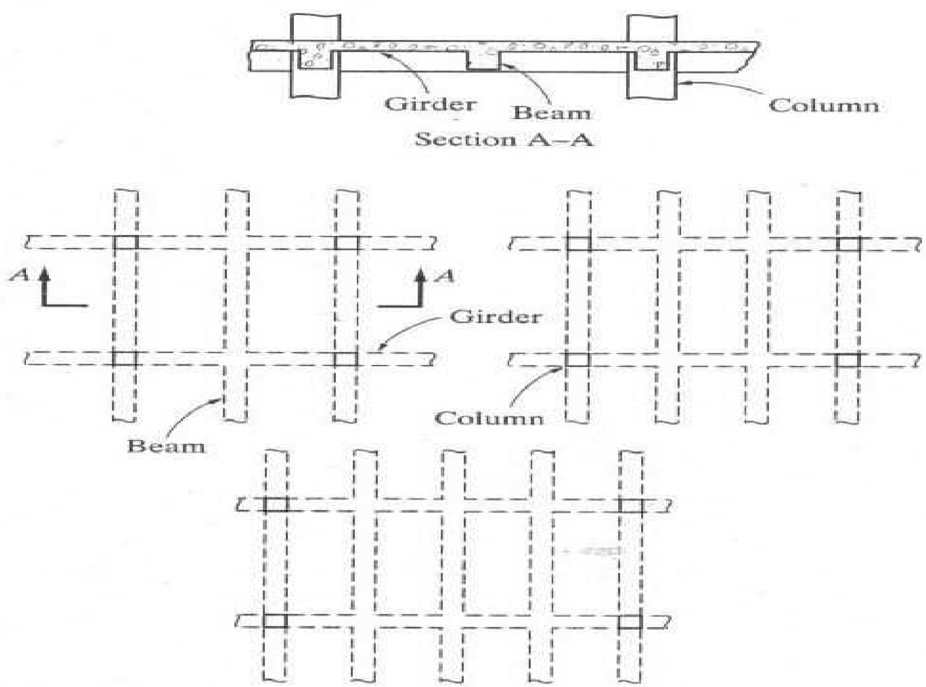
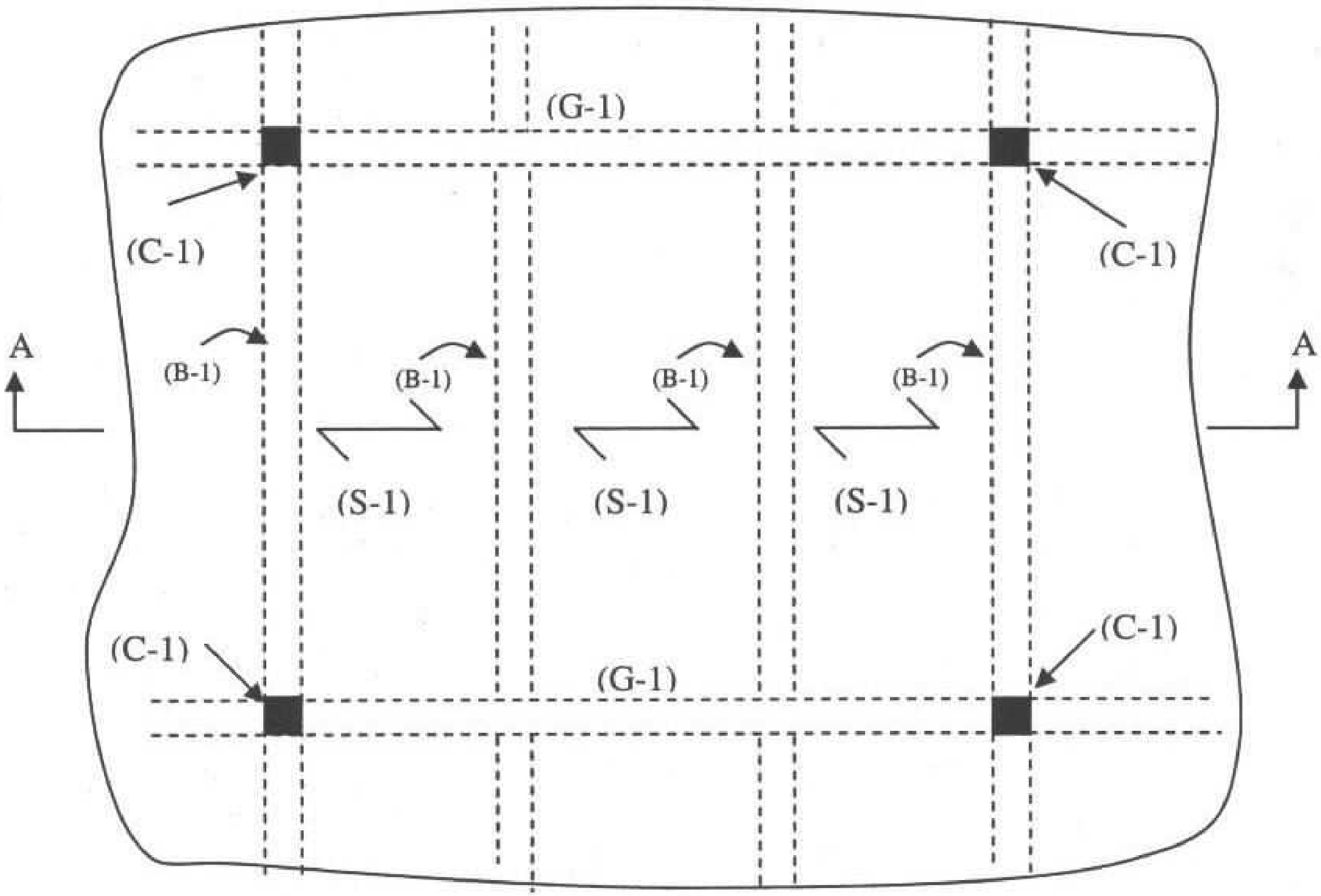
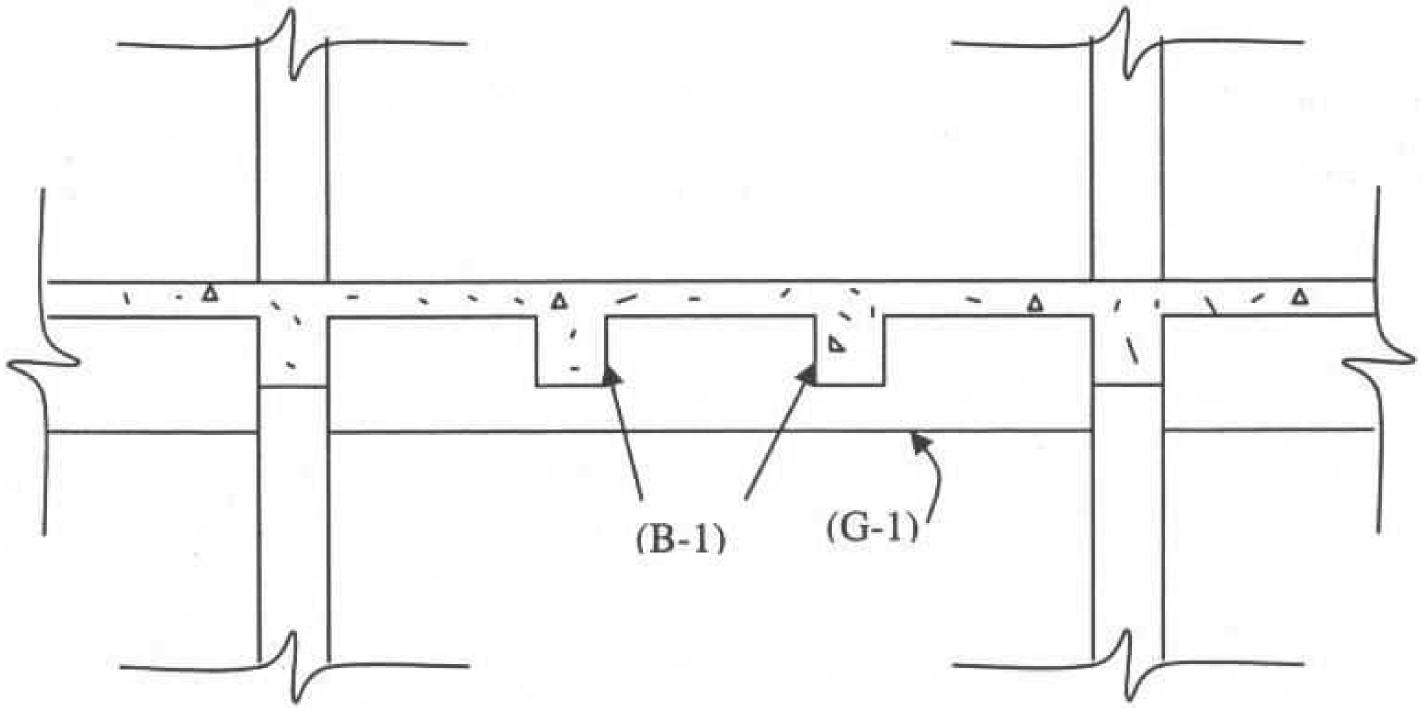


FIGURE 3-2 Common beam and girder layouts.

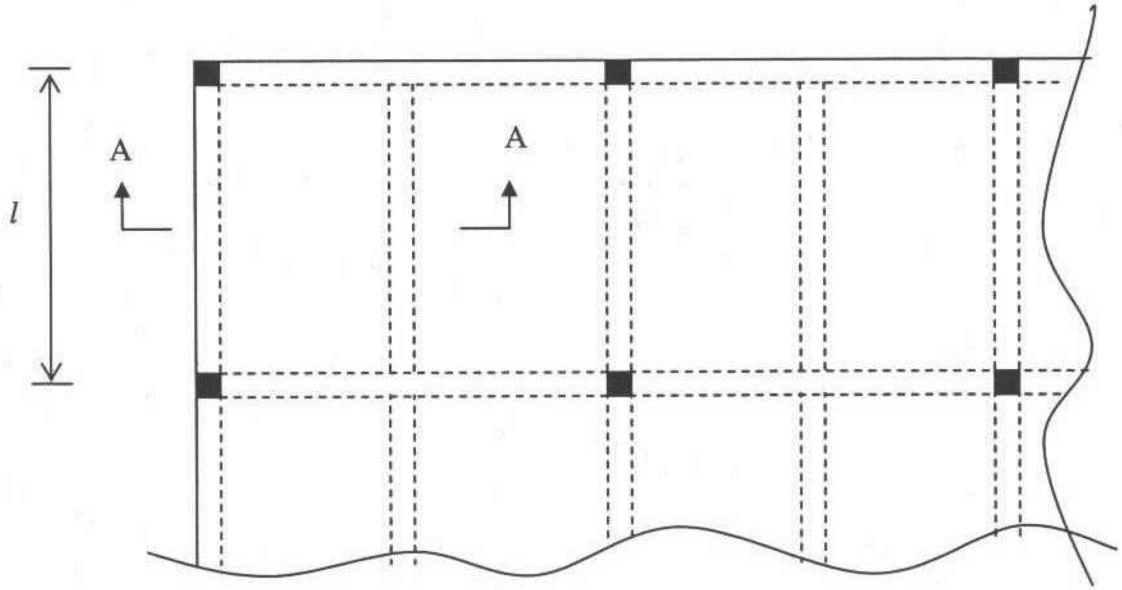


a. Typical Framing Plan

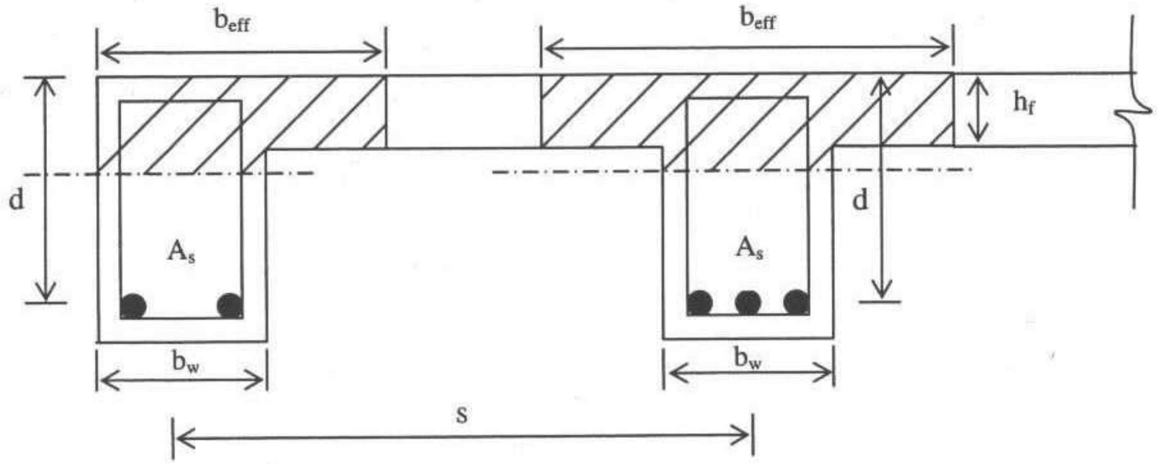


b. Section A-A

Figure 3.1 Beam-Girder Floor System



PLAN



Section A - A

FIGURE 18.3
Framing of beam-and-girder floor: (*a*) plan view; (*b*) section through beams; (*c*) section through girders.

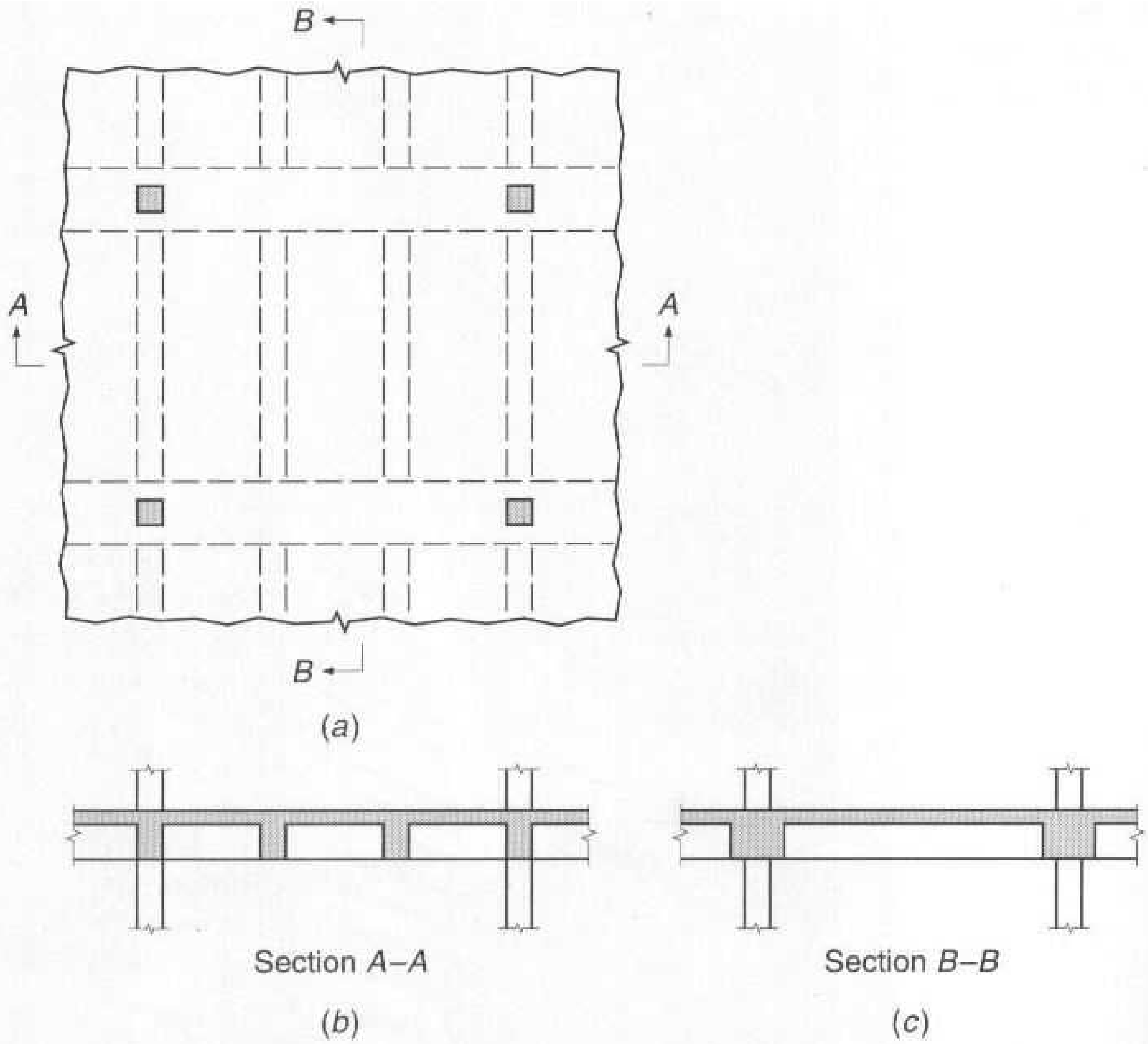


FIGURE 18.5
Composite beam-and-slab floor.

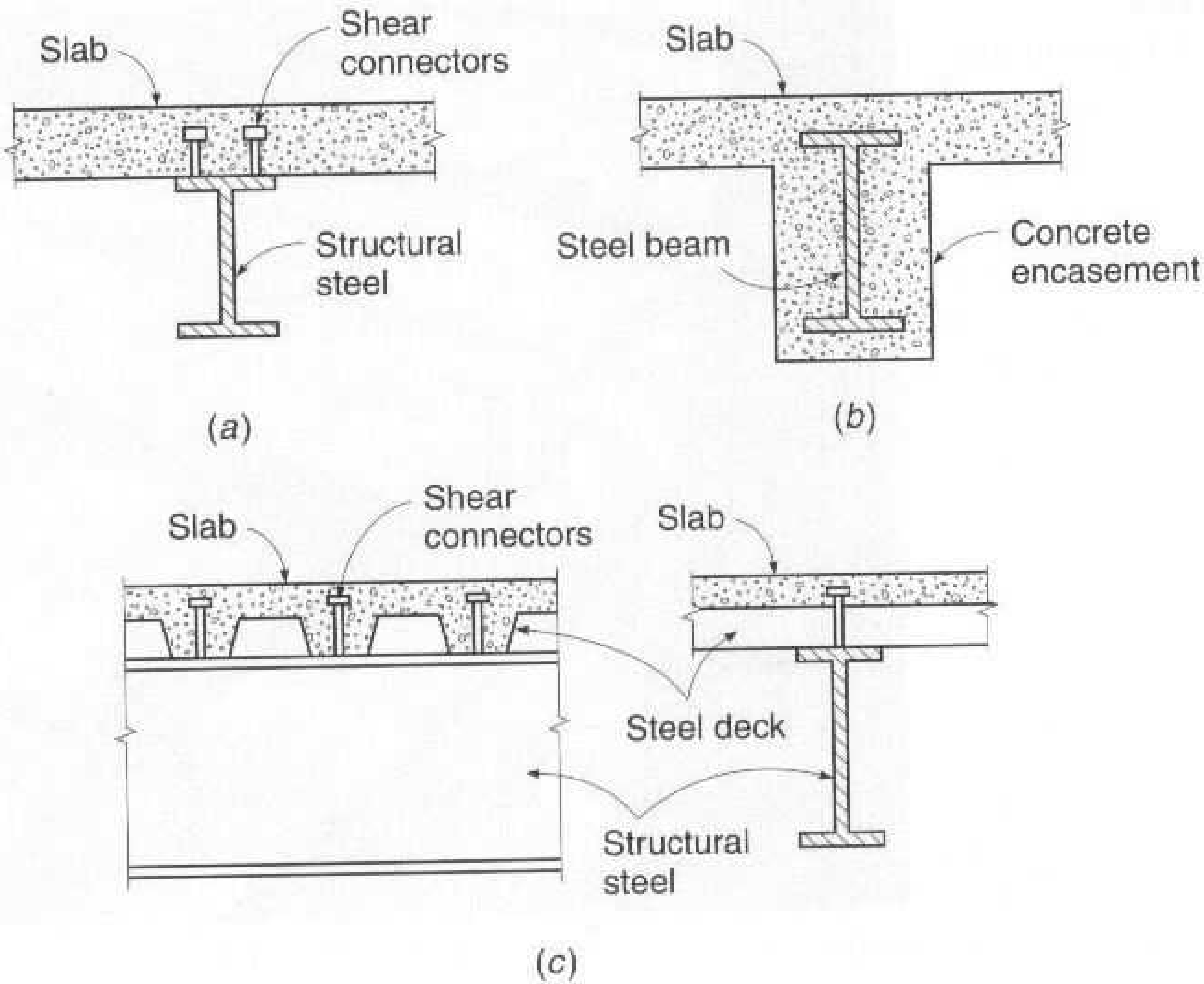


FIGURE 18.6
Steel forms for one-way joist floor.

Standard forms for the void spaces between ribs are either 20 or 30 in. wide, and 8, 10, 12, 14, 16, or 20 in. deep. They are tapered in cross section, as shown in Fig. 18.7, generally at a slope of 1 to 12, to facilitate removal. Any joist width can be obtained by varying the width of the soffit (bottom) form. Tapered end pans are used where it is desired to obtain a wider joist near the end supports, such as may be required for high shear or negative bending moment. After the concrete has hardened, the steel pans are removed for reuse.

FIGURE 18.11
Two-way joist floor under construction with steel dome forms. (*Courtesy of Ceco Corporation.*)

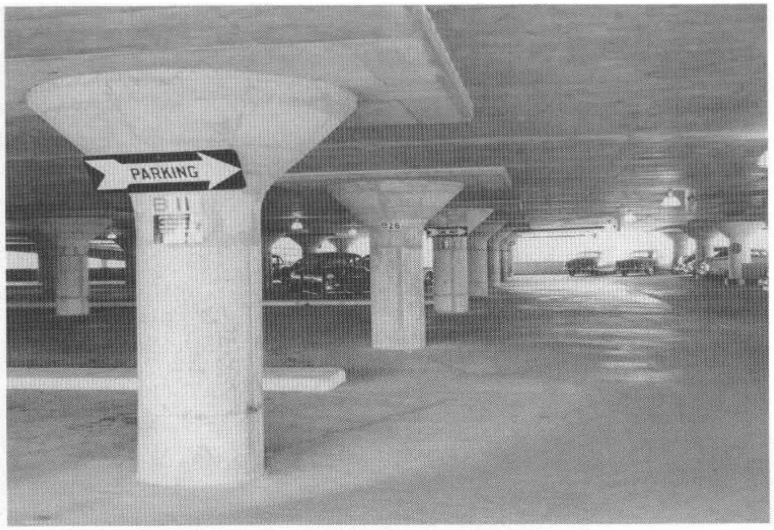


FIGURE 18.8
Flat slab garage floor with both drop panels and column capitals. (*Courtesy of Portland Cement Association.*)

column and they provide increased effective depth for the flexural steel in the region of high negative bending moment over the support. Beamless systems with drop panels or column capitals or both are termed *flat slab systems* (although almost all slabs in structural engineering practice are "flat" in the usual sense of the word), and are differentiated from flat plate systems, with absolutely no projections below the slab, which are described in the following section.

In general, flat slab construction is economical for live loads of 100 psf or more and for spans up to about 30 ft. It is widely used for storage warehouses, parking garages, and below-grade structures carrying heavy earth-fill loads, for example. For lighter loads such as in apartment houses, hotels, and office buildings, flat plates (Section 18.2g) or some form of joist construction (Sections 18.2d and h) will usually prove less expensive. For spans longer than about 30 ft, beams and girders are used because of the greater stiffness of that form of construction.

Flat slabs may be designed by the direct design method or the equivalent frame method, both described in detail in Chapter 13, or the strip method described in Chapter 15.

g. Flat Plate Slabs

A flat plate floor is essentially a flat slab floor with the drop panels and column capitals omitted, so that a floor of uniform thickness is carried directly by prismatic columns. Flat plate floors have been found to be economical and otherwise advantageous for such uses as apartment buildings, as shown in Fig. 18.9, where the spans are

FIGURE 18.9
Flat plate floor construction.
(*Courtesy of Portland Cement Association.*)

FIGURE 18.16
Precast floor and roof elements.

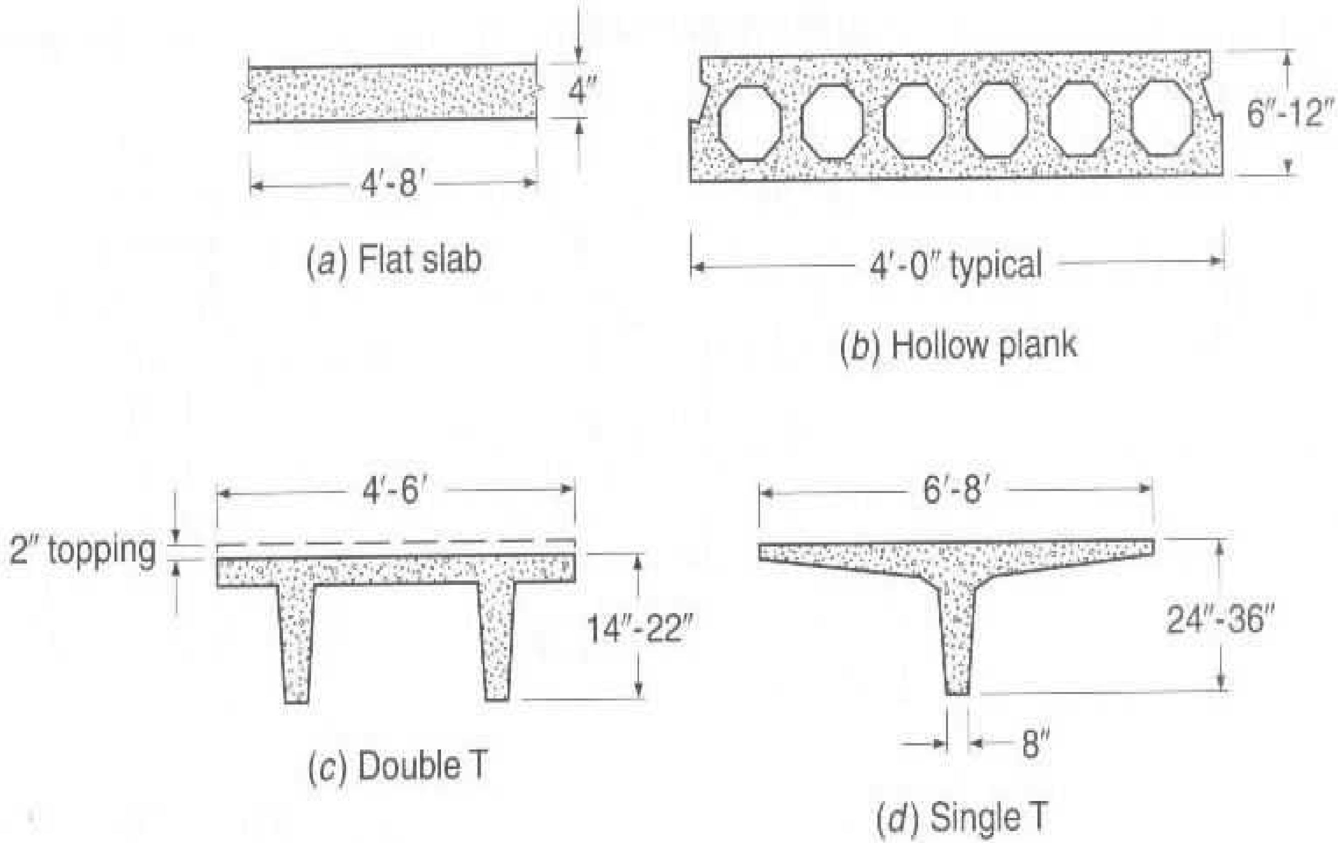


FIGURE 18.17
Precast beams and girders.

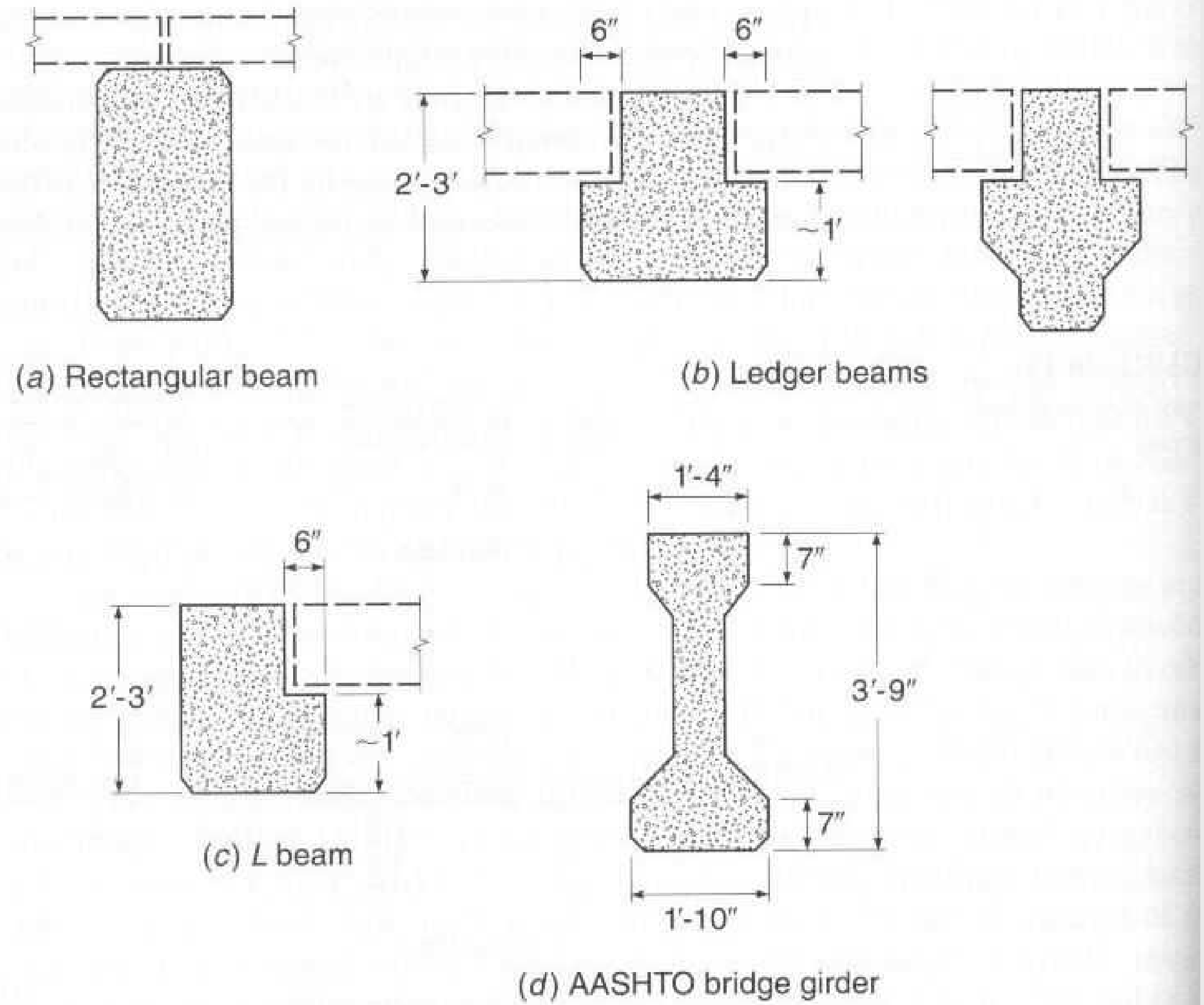
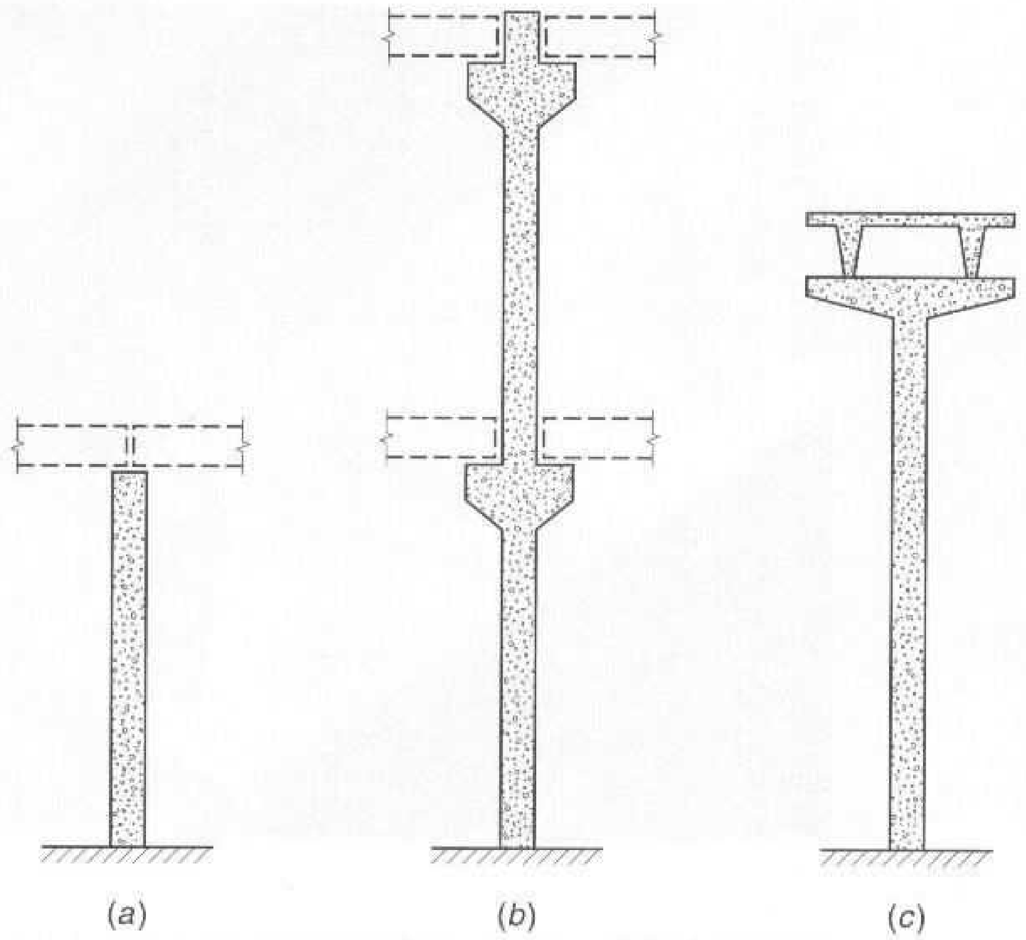
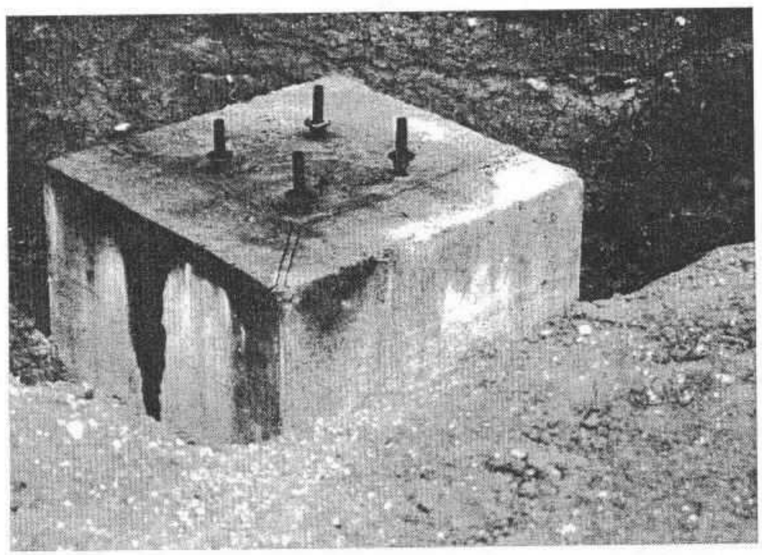


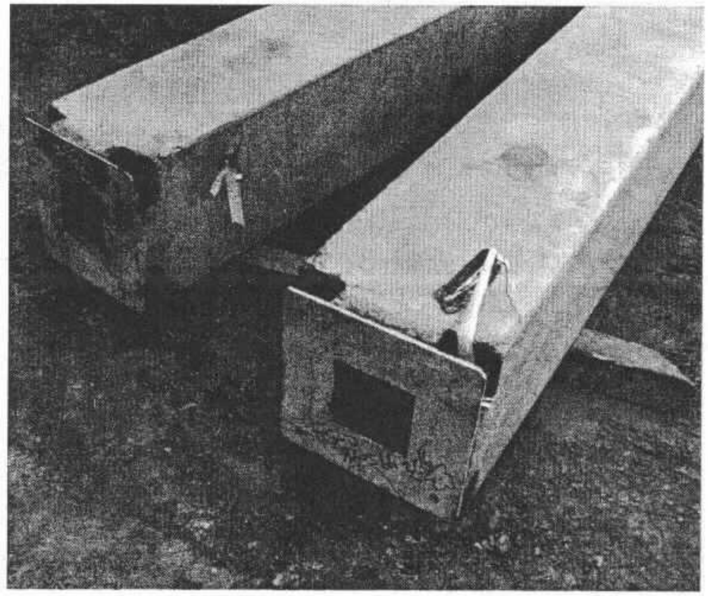
FIGURE 18.18
Precast concrete columns.



Columns are vertically positioned structural members that support girders. Columns transfer building loads to individual foundations located at the base of each column.

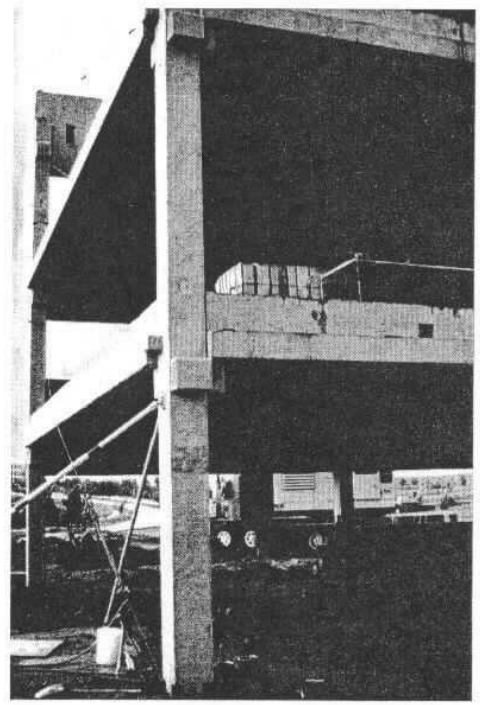


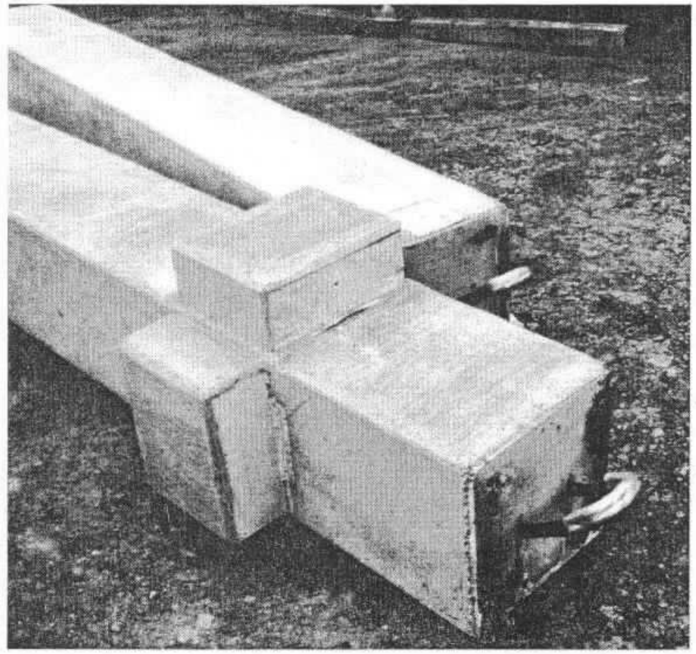
A foundation pedestal. Anchor bolts extend from the top of the foundation pedestal to accept and secure the column base.



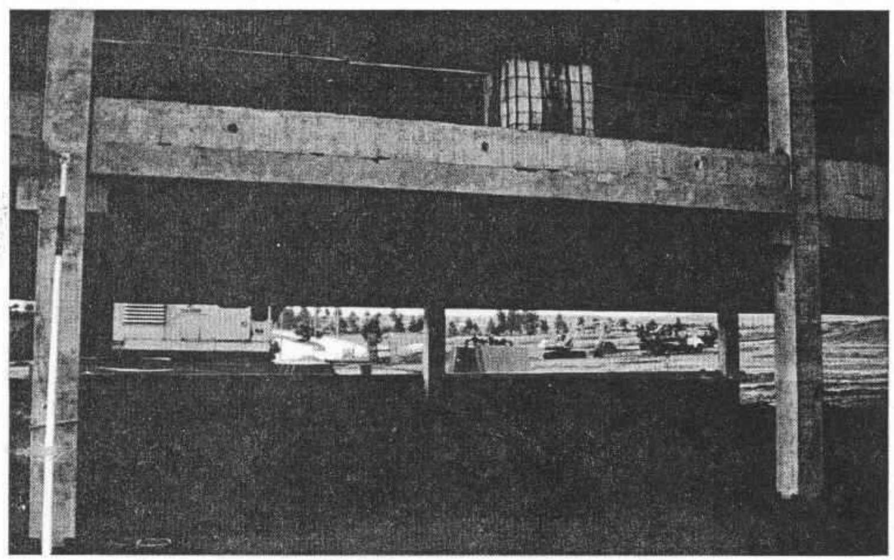
Steel base plates are cast into the bottom of the concrete column. Holes in the plates accept anchor bolts when the column is secured to the foundation pedestal.

Columns are vertically positioned structural members that support horizontally positioned girders. The girders support double tees that make up the floor and roof structural platform. Temporary column bracing and cabling support the columns during erection.

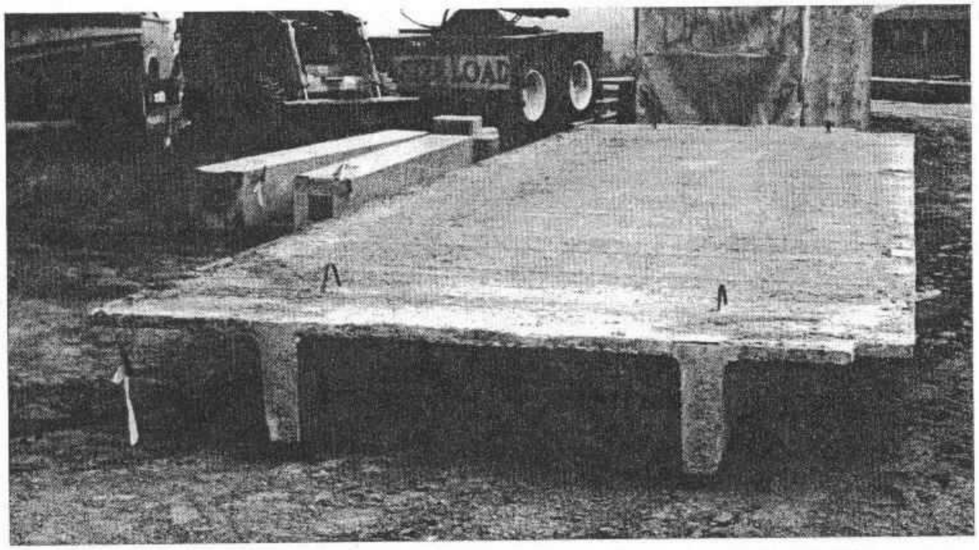




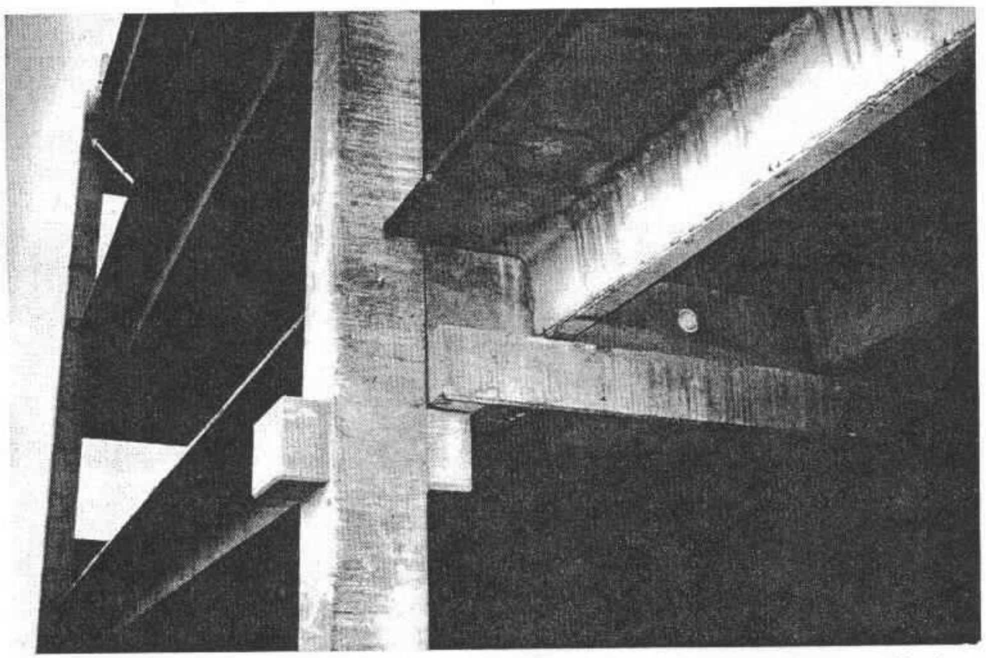
Square-shaped column haunches are cast as an integral part of the column. A column haunch serves as a ledger to provide support for the girders. U-shaped hooks called picks are cast in concrete structural members to make erection easier. These picks are cut and removed after the member is placed.



Girders span longitudinally between columns and bear on column haunches.

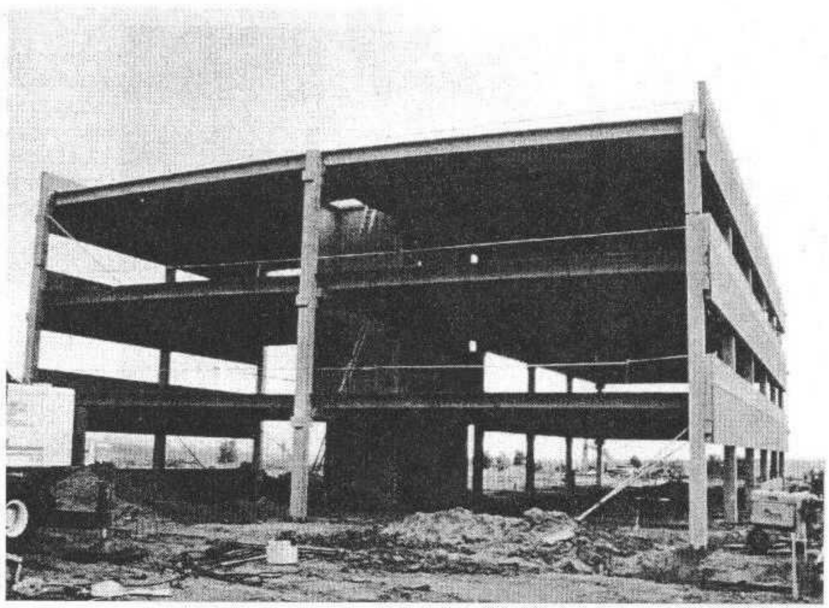


A concrete double tee that makes up the floor and roof structure. U-shaped picks are cast in the double tee to make erection easier.



Concrete double tees bear on a haunch that runs continuously along the bottom of both sides of the inverted tee girder. The haunch is an integral part of the girder.

The finished envelope of a precast concrete building.



A transverse view of the structural system of a precast concrete structure during construction four months before the photograph above was taken. Concrete double tees make up the structure of the floor and roof platforms and span transversely between girders. Inverted tee girders in the center of the structure and exterior spandrel girders span longitudinally between vertically positioned columns.

FIGURE 19.4
Prestressing methods:
(*a*) post-tensioning by jacking against abutments;
(*b*) post-tensioning with jacks reacting against beam;
(*c*) pretensioning with tendon stressed between fixed external anchorages.

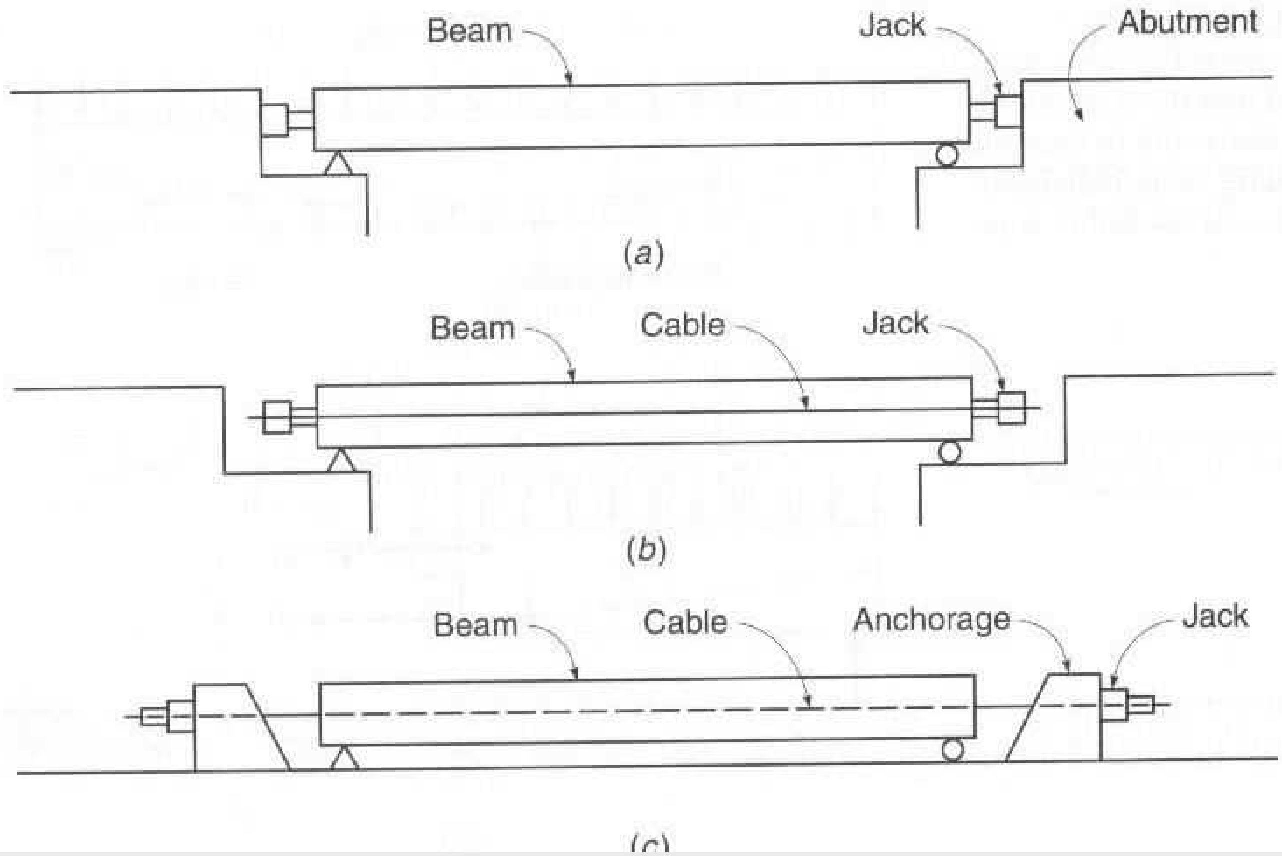


FIGURE 19.6
Post-tensioning a bridge girder using a portable jack to stress multistrand tendons. (*Courtesy of Concrete Technology Corporation.*)

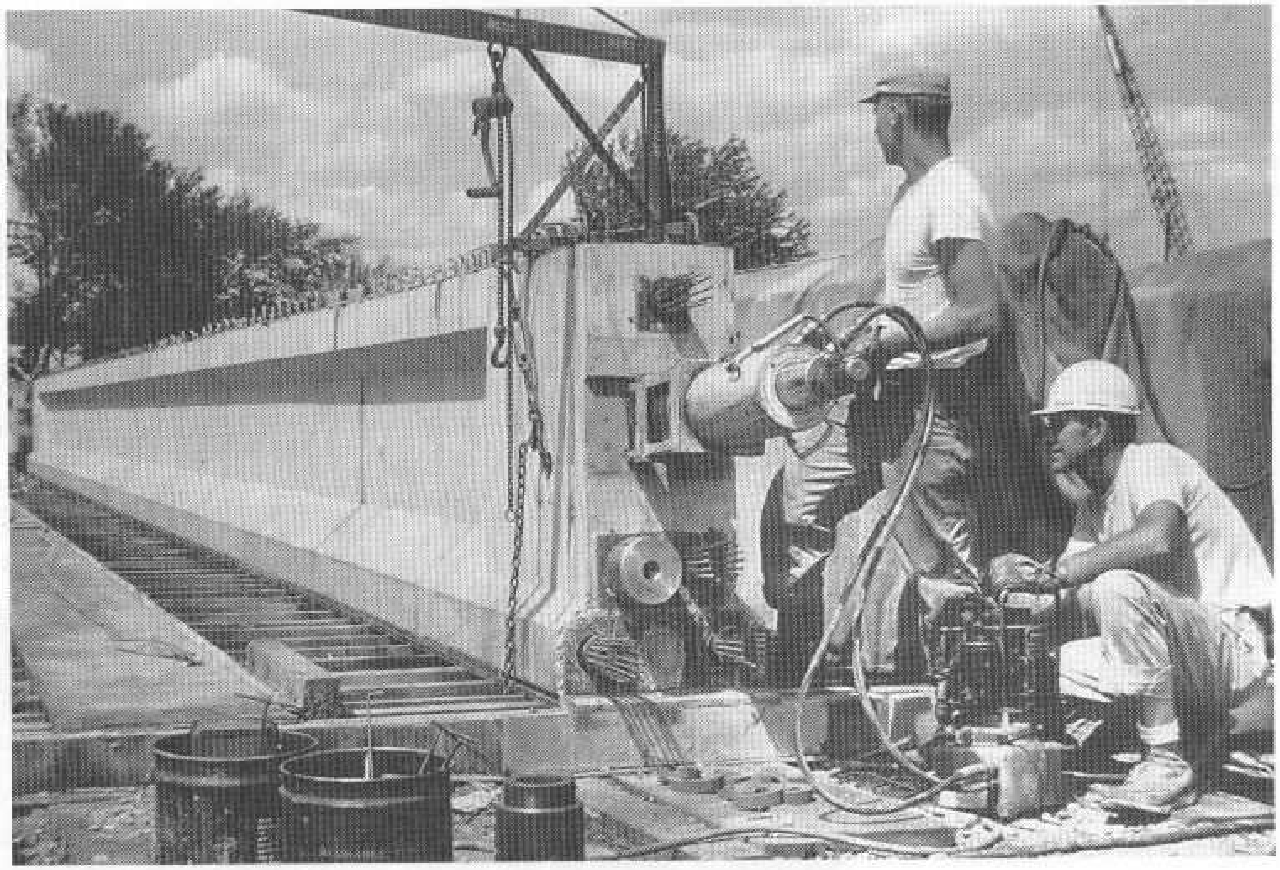


FIGURE 18.28
Column base connections.

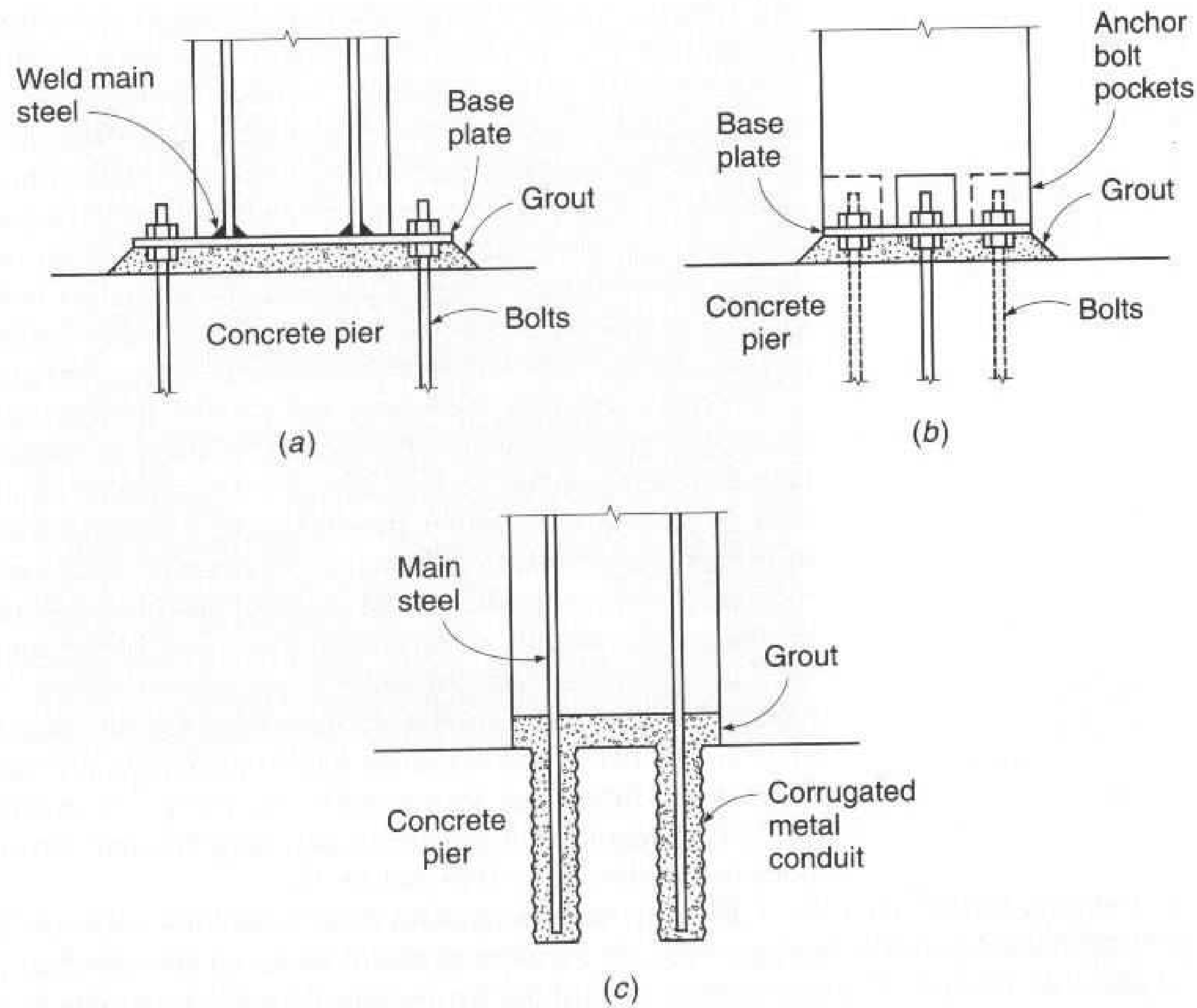


FIGURE 18.30
Beam-to-column connections.

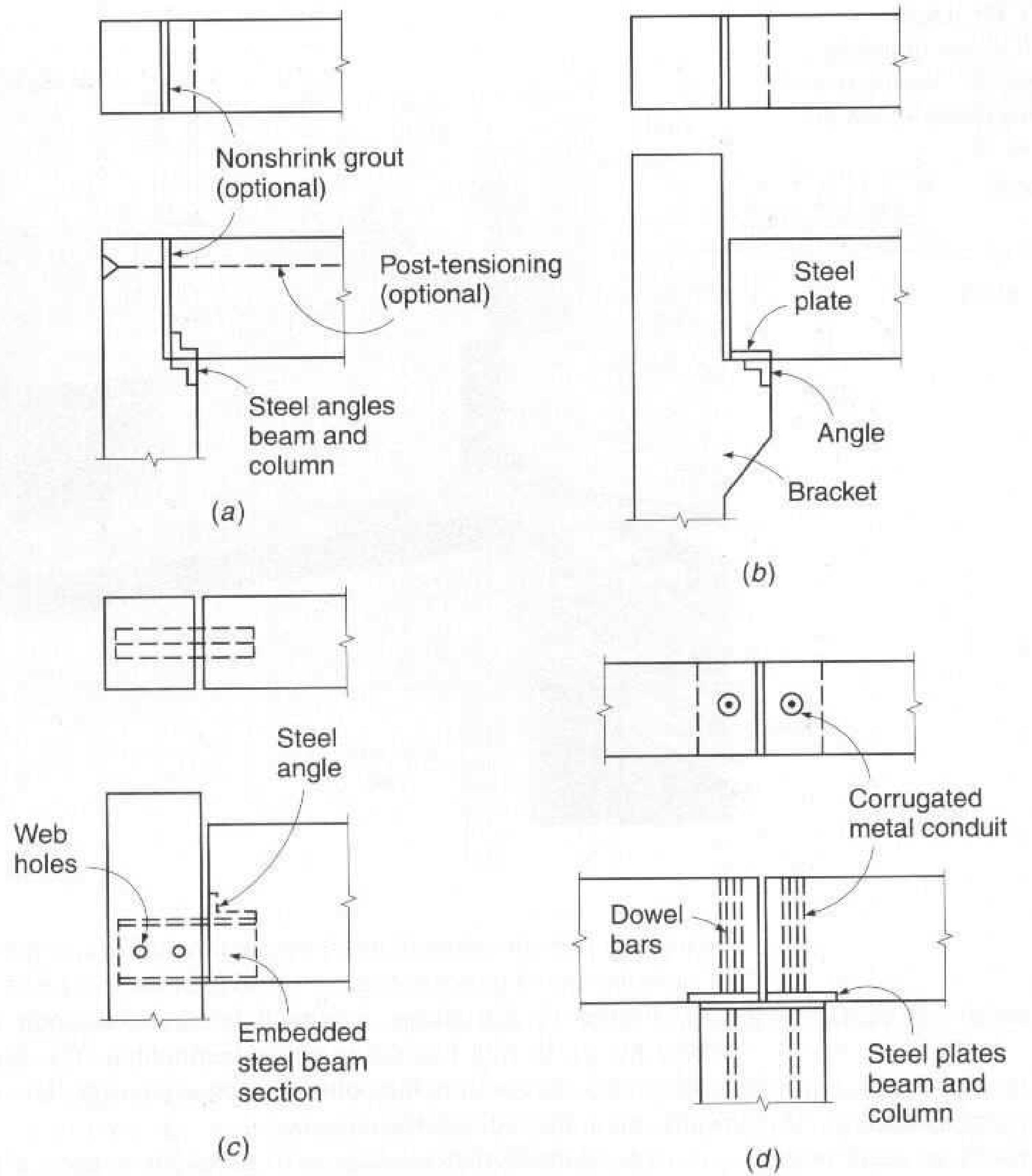
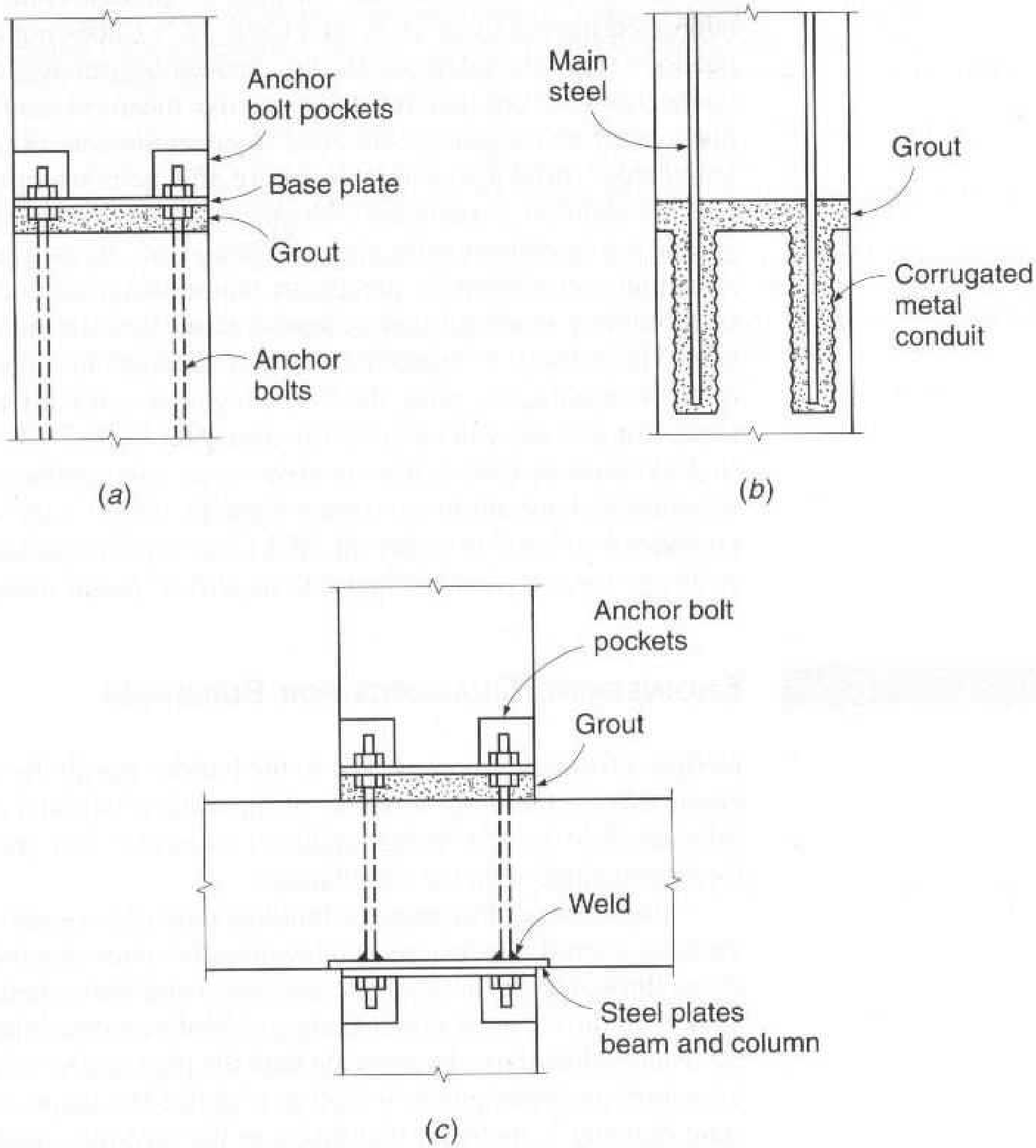


FIGURE 18.31
Column-to-column connections.



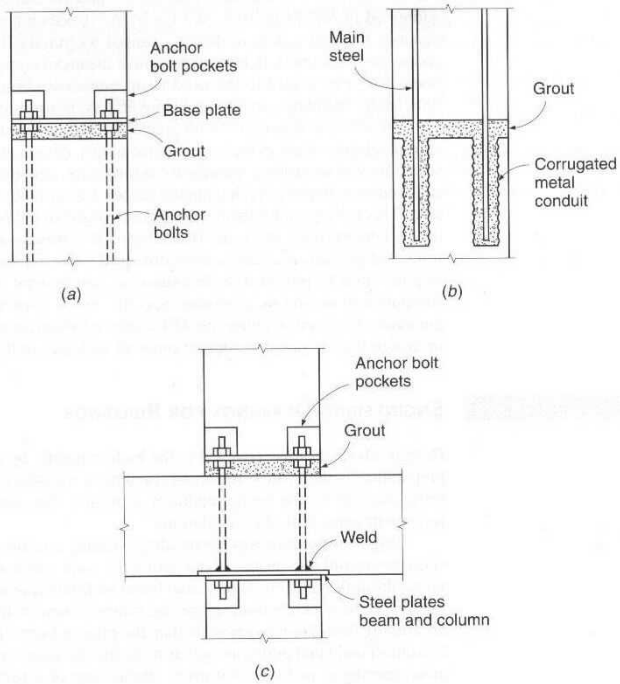


FIGURE 18.31
Column-to-column connections.

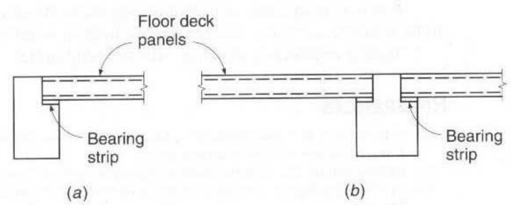


FIGURE 18.32
Slab-to-beam connections.

c. Structural Integrity

Precast concrete structures normally lack the joint continuity and high degree of redundancy characteristic of monolithic, cast-in-place reinforced concrete construction. Progressive collapse in the event of abnormal loading, in which the failure of one element leads to the collapse of another, then another, can produce catastrophic results.

FIGURE 16.5
Types of single-column footings.

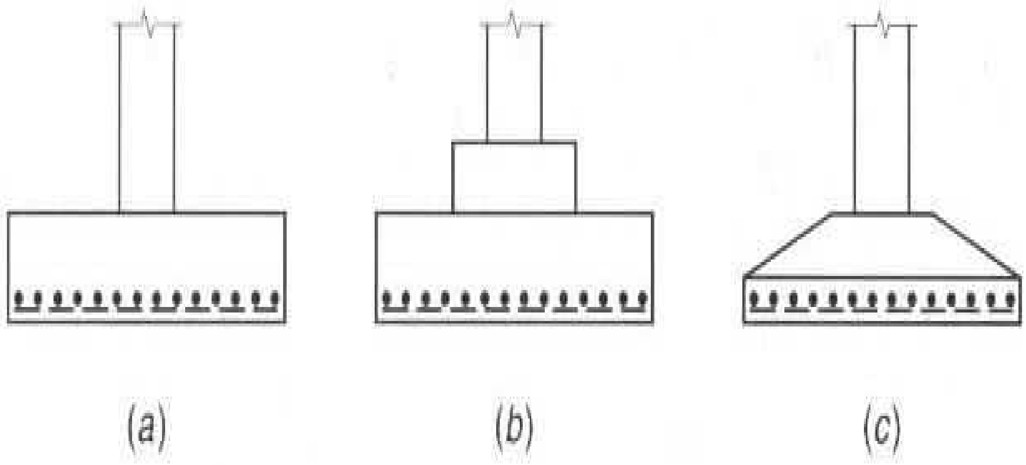


FIGURE 16.18
Strap footing in Example 16.4.

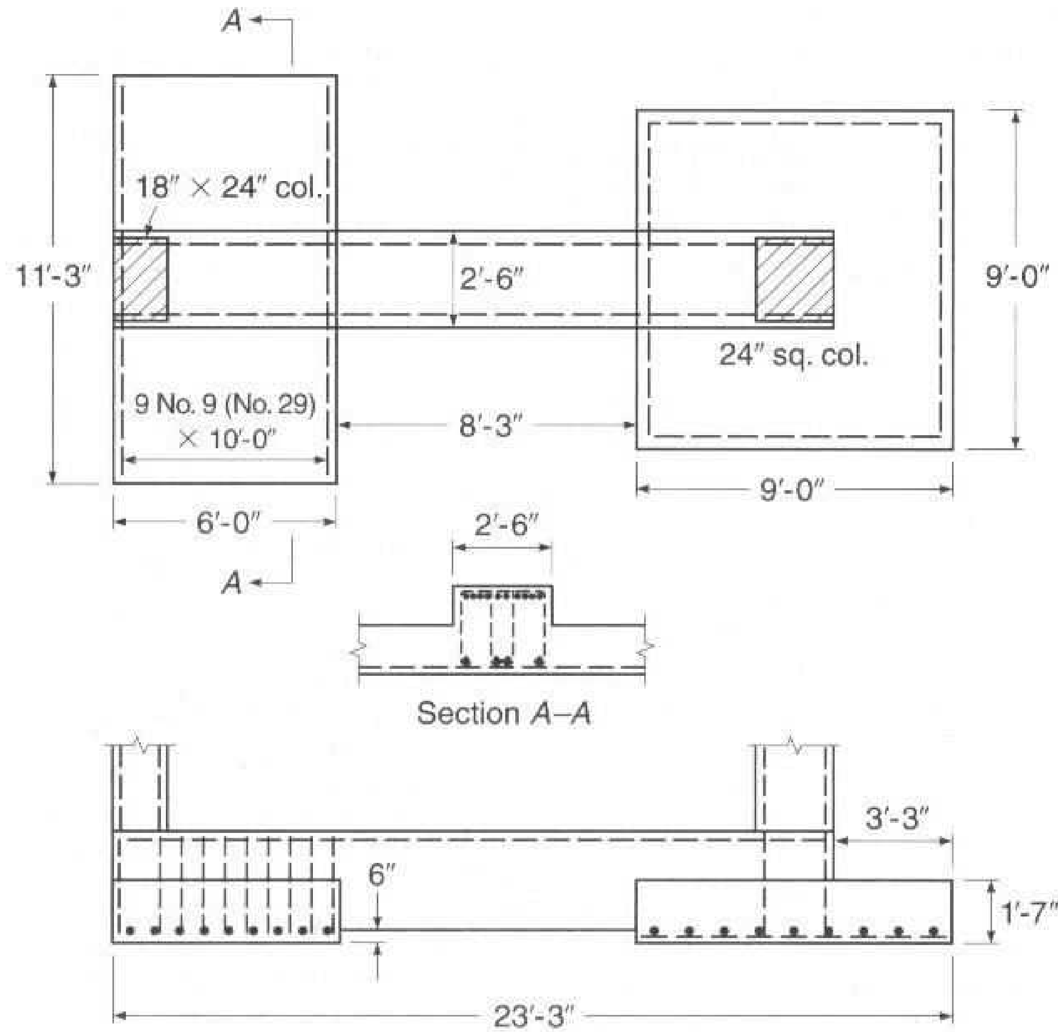


FIGURE 16.12
Grid foundation.

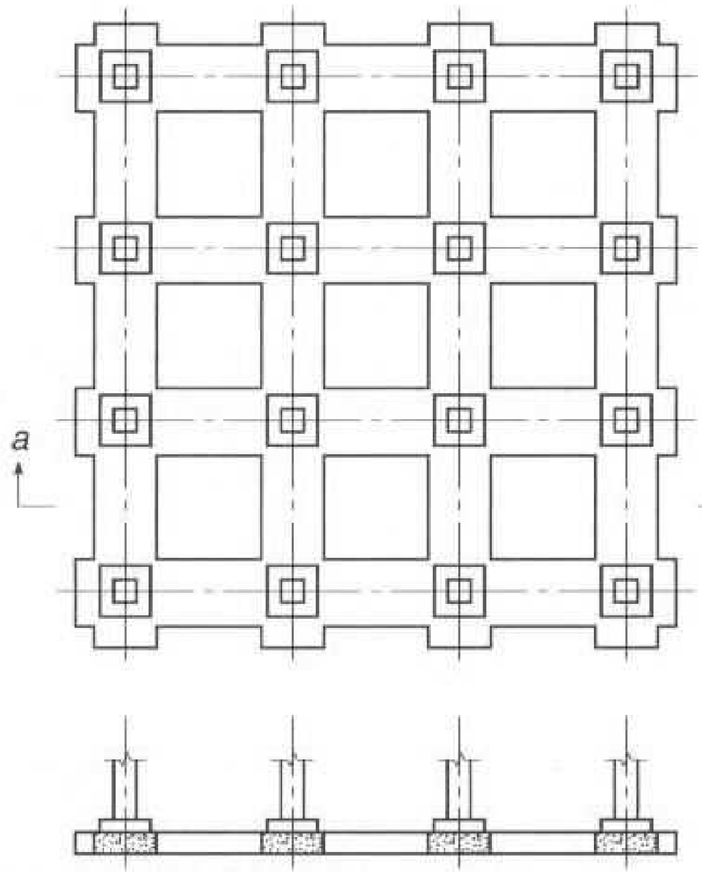
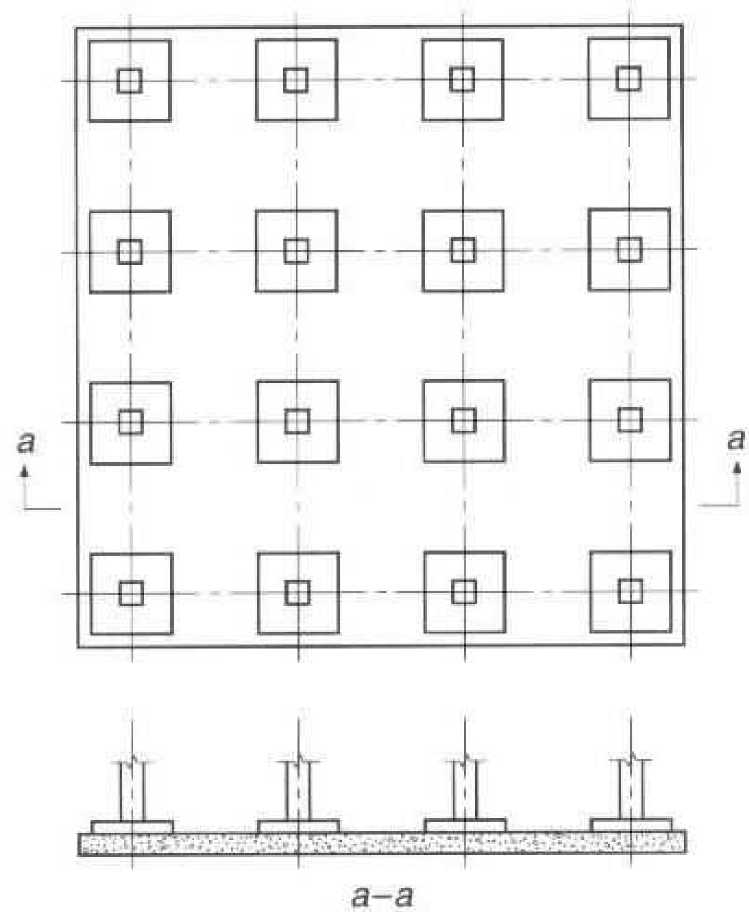


FIGURE 16.13
Mat foundation.



Goals:

- To determine the most economical and practical combination of readily available materials.
- To produce a concrete that will meet requirements under specific conditions of use.

- The majority of concrete used for agricultural applications is supplied by ready-mix producers.
- With an understanding of these goals, the customer can communicate better with the ready-mix supplier, and obtain concrete that is suited to the project at hand.

- A properly proportioned concrete mix will provide:
  - **Workability** of freshly mixed concrete.
  - **Durability**, strength, and uniform appearance of hardened concrete.
  - **Economy**

Workability

- Workability is the property that determines the ease with which freshly mixed concrete can be placed and finished without segregation.
- Workability is difficult to measure but redi-mix companies usually have experience in determining the proper mix.
- Therefore, it is important to accurately describe what the concrete is to be used for, and how it will be placed.

Durability

- If acceptable materials are used, the properties of concrete, such as durability, freeze/thaw resistance, wear resistance, and strength depend on the cement mixture.
- A mixture with a sufficiently low ratio of water to cement plus entrained air, if specified, is the most desirable.

- These properties--and thus the desired concrete quality--can only be fully achieved through proper placement and finishing, followed by prompt and effective curing.

Economy

- Proportioning should minimize the amount of cement required without sacrificing quality.
- Quality depends on the amount of cement and the water-cement ratio.
- Hold the water content to a minimum to reduce the cement requirement.

Minimizing water and cement requirements:

- **Use:**
  - – the stiffest practical mixture
  - – the largest practical maximum size of aggregate
  - – the optimum ratio of fine-to-coarse aggregates

- The lower limit of cement required is specified as a minimum cement content in bags per cubic yard.
  - A bag of cement weighs 94 lbs. Typical concrete mixtures include between 5 and 6.5 bags per cubic yard of concrete.
  - A minimum cement content assures desirable concrete properties, such as workability, durability, and finishability.

- A minimum amount of cement is required in order to adequately coat all aggregate particles and provide proper bonding.

Determining Aggregate Size:

- Aggregate size depends on the end use:
  – The maximum aggregate size should be no larger than one-third the thickness of the concrete.
  – Aggregate size should also be less than three-fourths the clear space between reinforcing bars where rebar is used.

Water to Cement Ratio

- Should be kept as low as possible
- 5-6 gallons per sack of cement is acceptable

Curing

- Concrete that has been specified, batched, mixed, placed, and finished "letter-perfect" can still be a failure if improperly or inadequately cured.
- Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals.

- Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing.

- Proper concrete curing for agricultural and residential applications involves keeping newly placed concrete moist and avoiding temperature extremes (above 90 ° F or below 50 ° F) for at least three days.
- A seven-day (or longer) curing time is recommended.

Two general methods of curing can be used:

- Keep water on the concrete during the curing period.
- These include
  - ponding or immersion,
  - spraying or fogging, and
  - saturated wet coverings.
  - Such methods provide some cooling through evaporation, which is beneficial in hot weather.

- Prevent the loss of the mixing water from concrete by sealing the surface.
- Can be done by:
  - covering the concrete with impervious paper or plastic sheets,
  - applying membrane-forming curing compounds.

- The best curing method depends on:
  - cost,
  - application equipment required,
  - materials available,
  - Size and shape of the concrete surface.

- Begin the curing as soon as the concrete has hardened sufficiently to avoid erosion or other damage to the freshly finished surface.
- This is usually within one to two hours after placement and finishing.

Summary

- Concrete is a highly versatile construction material, well suited for many agricultural applications.
- It is a mixture of portland cement, water, aggregates, and in some cases, admixtures.
- Strength, durability, and many other factors depend on the relative amounts and properties of the individual components.

- A perfect mix can result in poor quality concrete if correct placement, finishing, and curing techniques under the proper conditions of moisture and temperature are not used.

- When specifying and ordering concrete, the customer should be prepared to discuss such things as:
  - 1. Amount of concrete required,
  - 2. use of the concrete,
  - 3. type of cement,

– 4. minimum amount of cement per cubic yard
– 5. maximum water-cement ratio
– 6. any special admixtures,
– 7. amount of air entrainment,
– 8. desired compressive strength,
– 9. amount of slump, and
– 10. any special considerations or restrictions

End