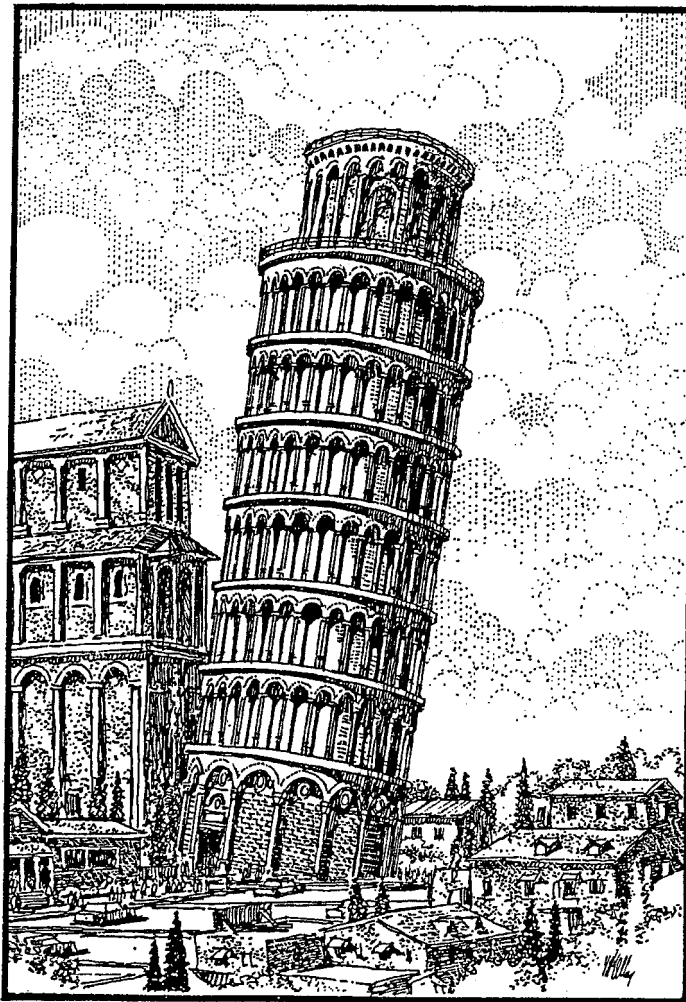




# **STRUCTURES**

## **Mock Exam**



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## The Registration Exam

The architectural registration examination has undergone many changes in the past 25 years. Yet, through all the changes, the subject matter tested has remained largely the same.

Currently, all 50 states, 5 territories, and participating Canadian provinces offer the uniform NCARB Architect Registration Examination (ARE). This exam consists of nine divisions as follows:

- Pre-Design
- Site Planning
- Building Planning
- Building Technology
- General Structures
- Lateral Forces
- Mechanical and Electrical Systems
- Materials and Methods
- Construction Documents & Services

Site Planning, Building Planning, and Building Technology require graphic solutions to several vignette graphic problems. All of the other exam divisions consist of multiple-choice questions. Candidates must pass all divisions of the ARE, and they may retake any division that they fail after a six-month wait.

Prior to 1997, the ARE was a pencil-and-paper exam given each June, with the graphic tests also offered in December. Since 1997, the ARE has been administered exclusively by computer. The exam is given at a network of computer test centers, and candidates may take the exam on any day, in any sequence, and at any test center they choose.

Since its inception in 1968, ALS has provided comprehensive study aids for the architectural exams to thousands of candidates throughout the United States and Canada. We offer a complete program of home study courses, handbooks, and reference books covering every subject of the exam, as well as computer programs for the six multiple-choice divisions.

For more information about the exam or our program, please write to ALS, 924 Westwood Blvd., Suite 840, Los Angeles, CA 90024, call us at (310) 208-7112, or send a fax message to (310) 824-7028. We also welcome your visit to our web site, [www.alsOnline.com](http://www.alsOnline.com)

If you have any questions about your own state's examination procedure or your eligibility to take the exam, we suggest that you contact your state board.





## Introduction

The structural tests are invariably among the most difficult for architectural candidates to pass. Therefore, candidates should embark on a systematic preparation program as early as possible, at least four to six months before the exam.

What preparation programs are available? Some schools of architecture and AIA Associates groups offer structural preparation courses or seminars, and information about these may be obtained from those organizations.

The basic ALS program consists of two home study courses, *Structural Technology 1* and *Structural Technology 2*, which provide comprehensive coverage of the subject matter in the two structural tests.

Over the years, we have found that one very effective study technique is to practice answering questions that are similar to actual test questions. With this in mind, in past years we developed two structural handbooks: *Structural Questions & Answers* and *Structural Questions and Answers II*, which are among the most popular handbooks we have ever published.

In response to numerous requests from candidates for more simulated structural test questions, we then developed this *Structures Mock Exam*, which closely simulates the General Structures division.

There are 135 multiple-choice questions in this mock exam, they are in the same style as the actual exam, and they cover every aspect of structures likely to be tested. A detailed explana-

tion of each answer is provided in a separate booklet.

In the multiple-choice format, each question is followed by four choices (A, B, C, and D), only one of which is the correct answer. There is a great variety of question types possible using this format. Among these are negatively-worded questions, combination-answer questions, as well as straightforward multiple-choice questions.

Negatively-worded questions typically present three correct choices and one incorrect choice. In combination-answer questions, several choices are given, which usually have Roman numeral designations (I, II, III, etc.). The candidate must select the correct combination of choices, such as I and II, II and III, etc. The most straightforward kind of multiple-choice question simply asks you to select the most correct answer, from among the four choices presented.

When you take the exam, you may be tempted to race through the questions in order to avoid running out of time. This is the wrong approach: you should carefully read each question, understand what is being asked, and then choose the best answer. Otherwise, you run the risk of misreading or misunderstanding some questions. Since you have an average of 1.5 minutes for each exam question, you should have enough time to do this, if you budget your time.

The examination is graded by the computer,



and no part credit is given—each answer is either right or wrong. And since only the correct answers are counted, not the incorrect ones, you should answer every question, even if you have to guess. Of course, only one answer to each question should be marked.

We urge you to answer all the questions in this *Structures Mock Exam* before you look at the answers. In that way, you will simulate the test-taking experience and also discover what you know, or don't know. Allow 3-1/2 hours; this will help you become familiar with the pace of the actual exam and acquire a feel for the exam experience.

We do not suggest that studying the questions in this mock exam will provide total preparation for the General Structures test. However, it will increase your knowledge, and also indicate those areas in which further study may be worthwhile. For the best preparation, therefore, candidates are encouraged to use this mock exam in conjunction with other, more detailed study material, such as our home study courses.

As always, we stand ready to help you in any way we can. If you have any questions about this mock exam, or if you wish us to review and make appropriate comments about your answers, do not hesitate to contact us.

If you are also preparing for the Lateral Forces test, you may be interested in the *Lateral Forces Mock Exam*, which closely simulates that test.

You are now ready to take the *General Structures Mock Exam*. Good luck!





## Answer Sheet

**Directions:** Read each question and its lettered answers. When you have decided which answer is correct, blacken the corresponding space on this sheet. After completing the exam, you may grade yourself; complete answers and explanations will be found in the accompanying booklet.

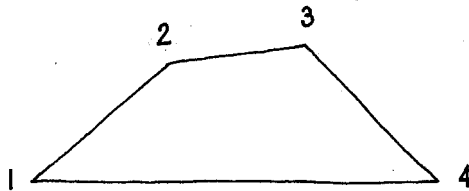
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|-----------------|-----------------|-----------------|------------------|------------------|
| 1 (A)(B)(C)(D)  | 31 (A)(B)(C)(D) | 61 (A)(B)(C)(D) | 91 (A)(B)(C)(D)  | 121 (A)(B)(C)(D) |
| 2 (A)(B)(C)(D)  | 32 (A)(B)(C)(D) | 62 (A)(B)(C)(D) | 92 (A)(B)(C)(D)  | 122 (A)(B)(C)(D) |
| 3 (A)(B)(C)(D)  | 33 (A)(B)(C)(D) | 63 (A)(B)(C)(D) | 93 (A)(B)(C)(D)  | 123 (A)(B)(C)(D) |
| 4 (A)(B)(C)(D)  | 34 (A)(B)(C)(D) | 64 (A)(B)(C)(D) | 94 (A)(B)(C)(D)  | 124 (A)(B)(C)(D) |
| 5 (A)(B)(C)(D)  | 35 (A)(B)(C)(D) | 65 (A)(B)(C)(D) | 95 (A)(B)(C)(D)  | 125 (A)(B)(C)(D) |
| 6 (A)(B)(C)(D)  | 36 (A)(B)(C)(D) | 66 (A)(B)(C)(D) | 96 (A)(B)(C)(D)  | 126 (A)(B)(C)(D) |
| 7 (A)(B)(C)(D)  | 37 (A)(B)(C)(D) | 67 (A)(B)(C)(D) | 97 (A)(B)(C)(D)  | 127 (A)(B)(C)(D) |
| 8 (A)(B)(C)(D)  | 38 (A)(B)(C)(D) | 68 (A)(B)(C)(D) | 98 (A)(B)(C)(D)  | 128 (A)(B)(C)(D) |
| 9 (A)(B)(C)(D)  | 39 (A)(B)(C)(D) | 69 (A)(B)(C)(D) | 99 (A)(B)(C)(D)  | 129 (A)(B)(C)(D) |
| 10 (A)(B)(C)(D) | 40 (A)(B)(C)(D) | 70 (A)(B)(C)(D) | 100 (A)(B)(C)(D) | 130 (A)(B)(C)(D) |
| 11 (A)(B)(C)(D) | 41 (A)(B)(C)(D) | 71 (A)(B)(C)(D) | 101 (A)(B)(C)(D) | 131 (A)(B)(C)(D) |
| 12 (A)(B)(C)(D) | 42 (A)(B)(C)(D) | 72 (A)(B)(C)(D) | 102 (A)(B)(C)(D) | 132 (A)(B)(C)(D) |
| 13 (A)(B)(C)(D) | 43 (A)(B)(C)(D) | 73 (A)(B)(C)(D) | 103 (A)(B)(C)(D) | 133 (A)(B)(C)(D) |
| 14 (A)(B)(C)(D) | 44 (A)(B)(C)(D) | 74 (A)(B)(C)(D) | 104 (A)(B)(C)(D) | 134 (A)(B)(C)(D) |
| 15 (A)(B)(C)(D) | 45 (A)(B)(C)(D) | 75 (A)(B)(C)(D) | 105 (A)(B)(C)(D) | 135 (A)(B)(C)(D) |
| 16 (A)(B)(C)(D) | 46 (A)(B)(C)(D) | 76 (A)(B)(C)(D) | 106 (A)(B)(C)(D) |                  |
| 17 (A)(B)(C)(D) | 47 (A)(B)(C)(D) | 77 (A)(B)(C)(D) | 107 (A)(B)(C)(D) |                  |
| 18 (A)(B)(C)(D) | 48 (A)(B)(C)(D) | 78 (A)(B)(C)(D) | 108 (A)(B)(C)(D) |                  |
| 19 (A)(B)(C)(D) | 49 (A)(B)(C)(D) | 79 (A)(B)(C)(D) | 109 (A)(B)(C)(D) |                  |
| 20 (A)(B)(C)(D) | 50 (A)(B)(C)(D) | 80 (A)(B)(C)(D) | 110 (A)(B)(C)(D) |                  |
| 21 (A)(B)(C)(D) | 51 (A)(B)(C)(D) | 81 (A)(B)(C)(D) | 111 (A)(B)(C)(D) |                  |
| 22 (A)(B)(C)(D) | 52 (A)(B)(C)(D) | 82 (A)(B)(C)(D) | 112 (A)(B)(C)(D) |                  |
| 23 (A)(B)(C)(D) | 53 (A)(B)(C)(D) | 83 (A)(B)(C)(D) | 113 (A)(B)(C)(D) |                  |
| 24 (A)(B)(C)(D) | 54 (A)(B)(C)(D) | 84 (A)(B)(C)(D) | 114 (A)(B)(C)(D) |                  |
| 25 (A)(B)(C)(D) | 55 (A)(B)(C)(D) | 85 (A)(B)(C)(D) | 115 (A)(B)(C)(D) |                  |
| 26 (A)(B)(C)(D) | 56 (A)(B)(C)(D) | 86 (A)(B)(C)(D) | 116 (A)(B)(C)(D) |                  |
| 27 (A)(B)(C)(D) | 57 (A)(B)(C)(D) | 87 (A)(B)(C)(D) | 117 (A)(B)(C)(D) |                  |
| 28 (A)(B)(C)(D) | 58 (A)(B)(C)(D) | 88 (A)(B)(C)(D) | 118 (A)(B)(C)(D) |                  |
| 29 (A)(B)(C)(D) | 59 (A)(B)(C)(D) | 89 (A)(B)(C)(D) | 119 (A)(B)(C)(D) |                  |
| 30 (A)(B)(C)(D) | 60 (A)(B)(C)(D) | 90 (A)(B)(C)(D) | 120 (A)(B)(C)(D) |                  |



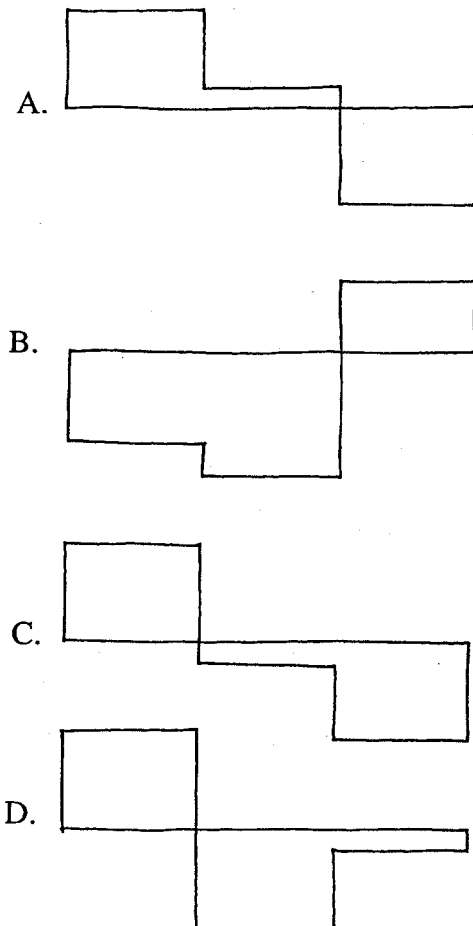


## Mock Exam

1. The moment diagram for a beam is shown below.



Which of the following is the corresponding shear diagram?



2. A structural steel beam spans 28 feet and supports a uniformly distributed load of

1500 pounds per lineal foot. The maximum permissible deflection of the beam is 1 inch. What is the required  $I$  for the beam, if the value of  $E$  is 29,000,000 psi? Use the formula  $\Delta = 5wL^4/384EI$ .

- A. 255 in.<sup>4</sup>      C. 858 in.<sup>4</sup>  
B. 715 in.<sup>4</sup>      D. 2747 in.<sup>4</sup>

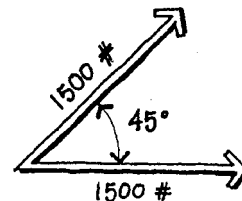
3. Select the correct statement about reinforced concrete columns.

- A. Reinforced concrete columns are normally designed for axial compression only.  
B. Spiral columns have greater axial load capacity than tied columns.  
C. Spiral and tied columns are both designed with the same strength reduction factor  $\phi$ .  
D. Tied columns are more expensive than spiral columns.

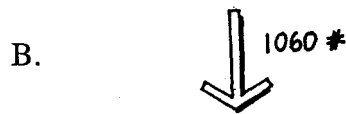
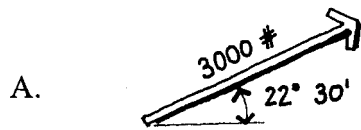
4. Which of the following connectors are generally NOT used in moment-resisting structural steel connections?

- A. ASTM A325-SC high-strength bolts  
B. ASTM A307 machine bolts  
C. Full penetration groove welds  
D. Fillet welds

5.



Which of the following is the resultant of the two forces shown above?



6. All of the following may increase the sliding resistance of a retaining wall, EXCEPT

- A. adding an integral key to the footing.
- B. making the footing wider.
- C. making the footing deeper.
- D. increasing the amount of reinforcing steel in the footing.

7. What is the principal reason that Type III portland cement is used?

- A. It is less expensive than other types of cement.
- B. Concrete made from Type III cement develops greater compressive strength.
- C. The concrete formwork can be removed earlier.
- D. It is the most readily available type of cement.

8. What is the principal purpose of a base plate under a steel column?

- A. To act as a template for the anchor bolts.
- B. To provide fixity for the column.
- C. To provide a level surface for connecting the column.
- D. To spread the column load so that the bearing pressure on the foundation is not excessive.

9. Which of the following are advantages of a conventional truss over a Vierendeel truss?

- I. Less deflection
- II. Less material
- III. Less conflict between truss members and doors or windows
- IV. Ability to have loads applied between panel points

- A. I and II
- B. I and IV
- C. II and III
- D. I, II, and IV

10. Which of the following is the best definition of live load?

- A. The load superimposed by the use and occupancy of a building, not including the wind, earthquake, or dead load.
- B. Any continuously-applied load, except the dead load.
- C. The load superimposed by the use and occupancy of a building, including the wind or earthquake load, but not including the dead load.
- D. The weight of a building's occupants and movable furniture.

11. In a structural steel rigid frame, moment resistance at the beam-column joints may be provided by which of the following?



- I. Two clip angles bolted to the beam web and the column flange.
- II. Groove welds between the top and bottom beam flanges and the column flange.
- III. Plates welded to the column flange and bolted to the top and bottom beam flanges.
- IV. A seat angle welded to the column flange and bolted to the bottom flange of the beam.

- A. I and II
- B. I and III
- C. I, II, III, and IV
- D. II and III

12. For which of the following building types does the structural cost represent the lowest percentage of the total cost of construction?

- A. Hospital
- B. Parking garage
- C. Warehouse
- D. Shopping mall

13. A wood column is used to support an axial load of 40 kips. The column is 16 feet long, and its ends are restrained against lateral movement. The allowable stress in compression parallel to the grain is  $0.30 E/(l/d)^2$ , where  $E = 1,600,000$  psi,  $l$  = unsupported length of column, and  $d$  = least lateral dimension of column, but such stress may not exceed 1150 psi. What is the smallest column that may be used?

- A. 6 x 6
- B. 6 x 8
- C. 8 x 8
- D. 8 x 10

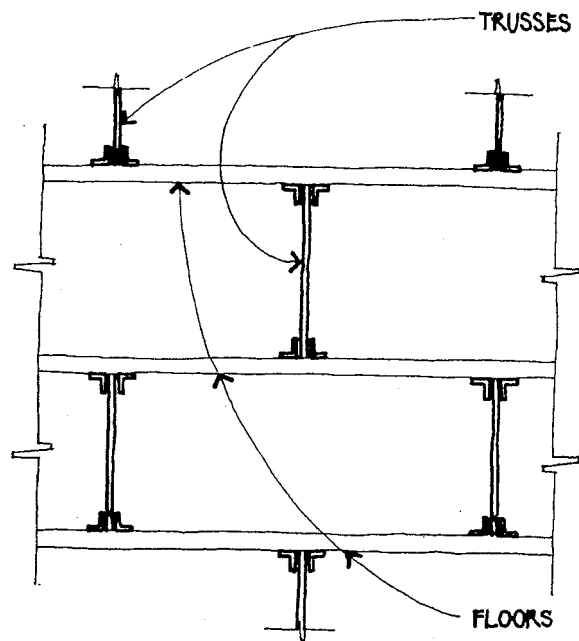
14. You are designing a parking garage with a span of 62 feet. Which of the follow-

ing systems would probably be practical and economical?

- I. One-way concrete joist and beam
- II. Prestressed concrete tees
- III. Flat slab
- IV. Posttensioned concrete girders with pretensioned concrete planking

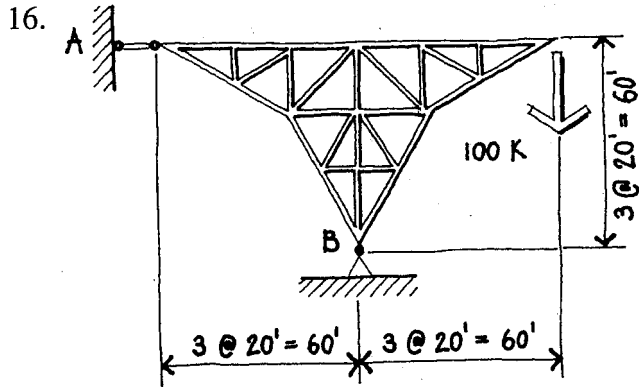
- A. I and III
- B. II and IV
- C. I and IV
- D. I, II, III, and IV

15. The structural system shown below is called a

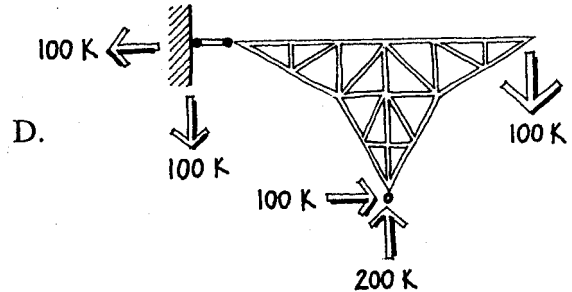
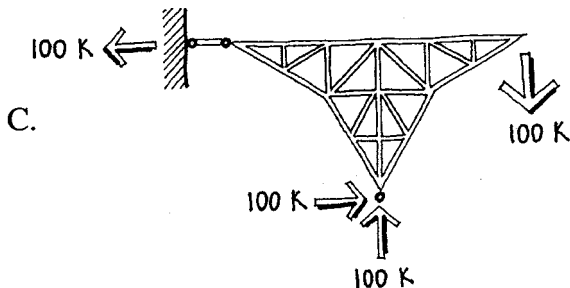
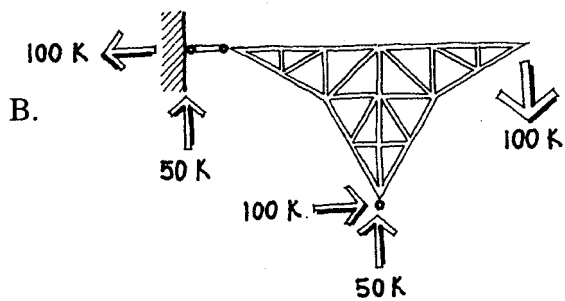
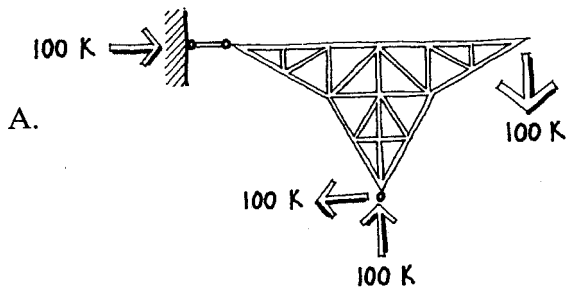


**LONGITUDINAL SECTION**

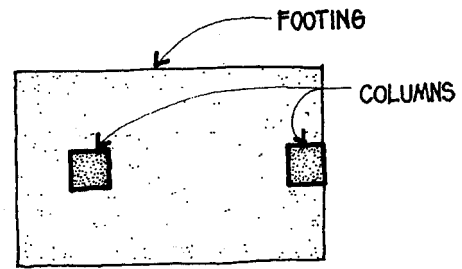
- A. Vierendeel truss system.
- B. staggered truss system.
- C. space frame.
- D. two-way truss system.



Which of the following correctly shows the reactions at A and B for the structure shown above?



17.



PLAN

What is the purpose of the footing shown above?

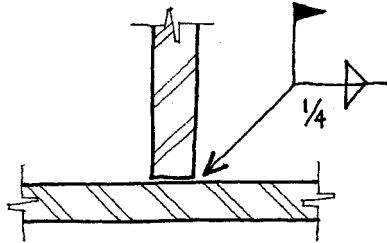
- A. To resist differential settlement.
- B. To fix the column bases against rotation.
- C. To distribute the column loads over a large area when soil conditions are poor.
- D. To support two columns where one of the columns is too close to the property line to have a symmetrical footing.

18. How can the calculated deflection of a steel beam be reduced?

- A. Use steel with a greater yield strength.
- B. Use a beam with a greater moment of inertia.
- C. Use a beam with a greater section modulus.
- D. Use steel with a greater modulus of elasticity.



19. The detail below indicates what type of weld?



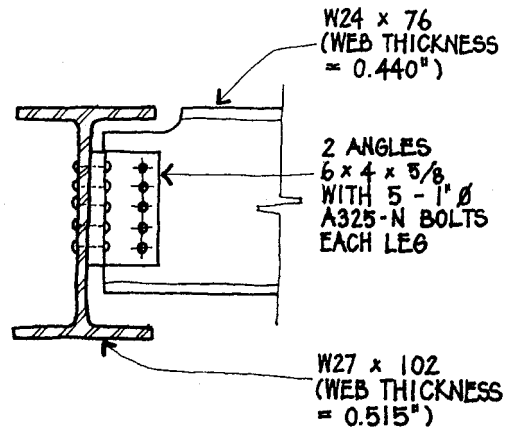
- A. 1/4 inch fillet weld both sides made in the field.
- B. 1/4 inch fillet weld both sides made in the shop.
- C. Full penetration groove weld made in the field.
- D. 1/4 inch plug weld made in the field.

20. Which of the following statements about cable structures is correct?

- I. When supporting loads which are uniformly distributed horizontally across its span, the shape of a cable is parabolic.
- II. When a cable is subject to changing loads, it changes its shape.
- III. The horizontal thrust at the ends of a cable is directly proportional to the sag of the cable.

- A. I and II
- B. II and III
- C. I and III
- D. I, II, and III

21. What is the capacity of the connection shown above right? All connected material is ASTM A36 ( $F_y = 36$  ksi,  $F_u = 58$  ksi). Assume that the beam and connection angles are adequate, and use the tables on pages 37 and 38.



- A. 82.5 kips
- B. 153 kips
- C. 165 kips
- D. 330 kips

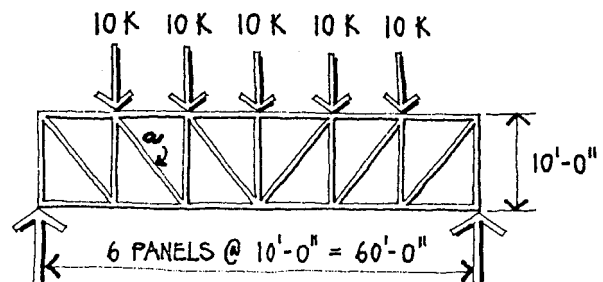
22. The ratio of unit stress to unit strain is called the

- A. moment of inertia.
- B. elastic limit.
- C. modulus of elasticity.
- D. yield point.

23. The workability of concrete is determined by the

- A. cylinder test.
- B. core test.
- C. impact hammer test.
- D. slump test.

24. For the truss shown below, what is the internal axial force in member a?





- A. 10.6 kips tension
- B. 14.1 kips tension
- C. 15.0 kips tension
- D. 21.2 kips tension

25. You are the architect for a gymnasium which is 120 feet by 120 feet in plan and has no interior columns. Two systems are being considered: a space frame and a system of one-way parallel trusses spaced 30 feet apart. Which of the following are advantages of the space frame over the parallel trusses?

- I. Economy through the use of many identical members and connections
- II. Greater stiffness
- III. Less depth
- IV. Simpler analysis

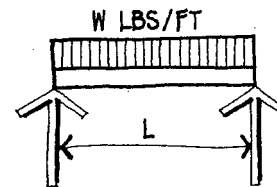
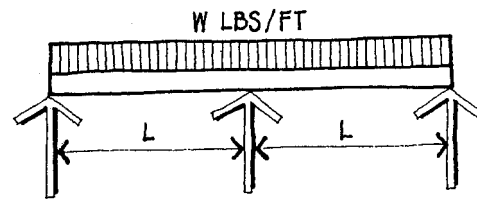
- |               |                   |
|---------------|-------------------|
| A. II and III | C. I, II, and IV  |
| B. I and III  | D. I, II, and III |

26. A 24-foot-long steel beam is installed when the temperature is 60°F. How much will it expand if the temperature rises to 90°F? The coefficient of expansion of steel is 0.0000065.

- |           |           |
|-----------|-----------|
| A. 0.047" | C. 0.112" |
| B. 0.056" | D. 0.168" |

27. Comparing the two beams shown above right, the two-span continuous beam and the simple beam, which of the following statements is INCORRECT?

- A. The maximum positive moment in the simple beam is greater than in the continuous beam.
- B. The maximum shear in the simple



beam is greater than in the continuous beam.

- C. The maximum deflection of the simple beam is greater than that of the continuous beam.
- D. The continuous beam has negative moment over the interior support, and the simple beam has no negative moment.

28. What is the purpose of bellling a caisson?

- A. To increase the caisson's frictional resistance.
- B. To stabilize the soil around the caisson.
- C. To increase the caisson's bearing capacity.
- D. To make the excavation watertight.

29. The load capacity of a structural steel column depends on the ratio  $Kl/r$ . In this regard, which of the following statements are correct?

- I.  $K$  is a constant determined by the end conditions of the columns.
- II.  $l$  is the effective length of the column.





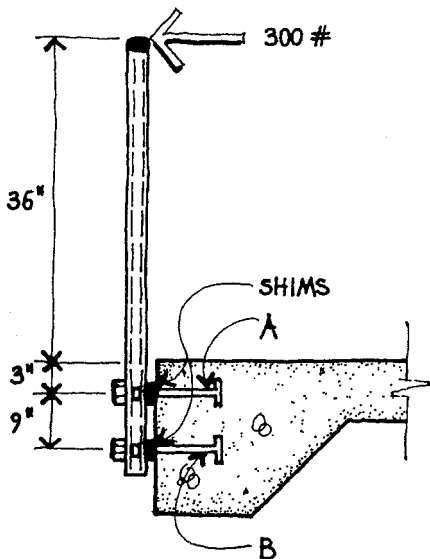
III.  $r$  is the radius of gyration, which depends on the yield strength of the steel.

- A. I only
- B. I and II
- C. I and III
- D. II and III

30. Which of the following factors affects the shear capacity of a reinforced concrete beam?

- A. The cross-sectional area of the longitudinal tension reinforcing
- B. The span of the beam
- C. The ultimate 28-day strength of the concrete
- D. The load on the beam

31.



What is the force in bolt A resulting from the handrail detail shown above?

- A. 1300 lbs. tension
- B. 1600 lbs. tension
- C. 300 lbs. tension
- D. 1300 lbs. compression

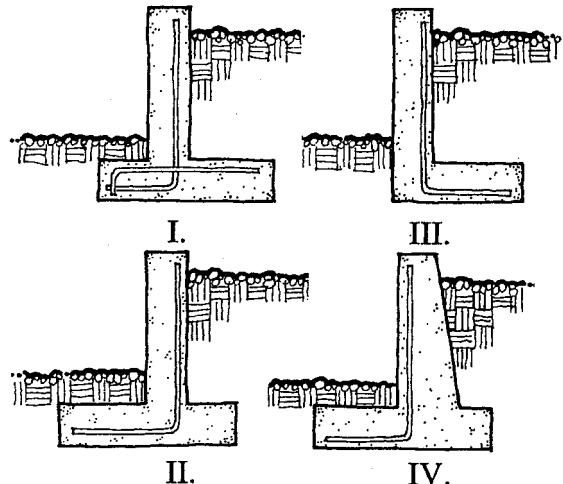
32. What is the maximum bending moment that can be resisted by a 6 x 12 wood beam, if  $F_b = 1600$  psi,  $A = 63.25$  in.<sup>2</sup>,  $S = 121.229$  in.<sup>3</sup>, and  $I = 697.068$  in.<sup>4</sup>?

- A. 10,120 ft.-lbs.
- B. 11,153 ft.-lbs.
- C. 16,164 ft.-lbs.
- D. 19,397 ft.-lbs.

33. A two-story library with stacks on both floors has 40-foot by 40-foot bays. Which of the following reinforced concrete floor framing systems would probably be the most economical?

- A. Waffle slab
- B. Flat slab
- C. Flat plate
- D. One-way slab and beam

34. Which of the retaining wall sections below show the correct placement of reinforcing steel?



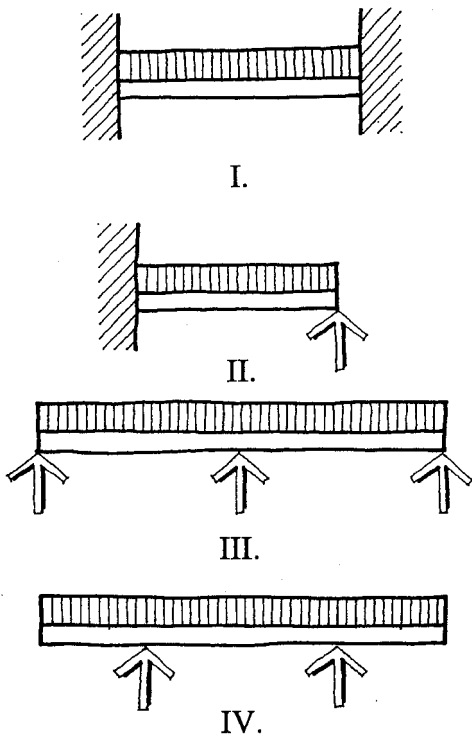
- A. I and II
- B. II and III
- C. III and IV
- D. I, II, and III

35. When a steel bar is subject to a tensile load, it increases in length. Up to a certain

unit stress, the bar will return to its original length when the load is removed. What is this unit stress called?

- A. Modulus of elasticity
- B. Ultimate strength
- C. Yield point
- D. Elastic limit

36. Which of the beams below are statically indeterminate?



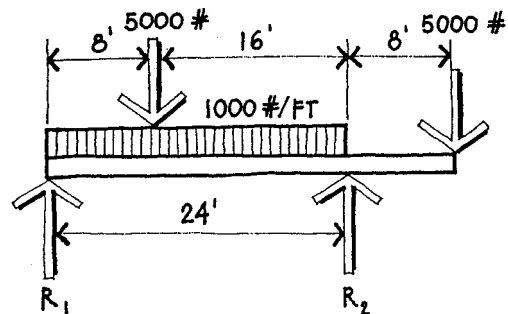
- A. I, II, and III
- B. I and III
- C. II and IV
- D. I and II

37. Which of the following statements about glued laminated beams is correct?

- A. A glued laminated beam tends to fail along the glue line, since the adhesive is weaker than the wood.

- B. The allowable stresses for a glued laminated beam are the same whether the beam is loaded parallel or perpendicular to the wide faces of the laminations.
- C. Since glued laminated beams are more dimensionally stable than sawn members, they tend to deflect less.
- D. Glued laminated beams often have better grade lumber in the outer laminations.

38.



A beam supports the loads shown above. What is the reaction at  $R_1$ , neglecting the weight of the beam?

- A. 20,333#
- B. 17,000#
- C. 15,333#
- D. 13,667#

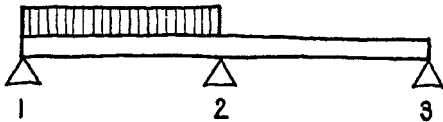
39. What is the maximum moment in the beam shown in the previous question?

- A. 77,559 ft.-lbs.
- B. 90,664 ft.-lbs.
- C. 93,386 ft.-lbs.
- D. 112,000 ft.-lbs.

40. A steel column supports a dead load of 120 kips and a live load of 150 kips. The allowable soil bearing value is 4000 pounds per square foot. What is the smallest pad footing that may be used?

- A. 5'-6" x 5'-6"
- B. 6'-2" x 6'-2"
- C. 6'-9" x 6'-9"
- D. 8'-3" x 8'-3"



41. Which of the following statements about steel columns is correct?
- A. The buckling tendency of a steel column depends on its yield point.
  - B. The maximum allowable slenderness ratio is 50.
  - C. Tubular sections have less tendency to buckle than wide flange sections.
  - D. If the value of  $r$  is different in each direction, the greater value is used to compute the  $Kl/r$  ratio.
42. Which of the following factors are more critical for long span buildings than for conventional buildings?
- I. Field inspection and testing
  - II. Snow drift loads and partial snow loads
  - III. The effects of temperature, creep, and shrinkage
  - IV. Secondary stresses caused by deflection and the interaction of building elements
- A. I and III
  - B. II and IV
  - C. I, II, and IV
  - D. I, II, III, and IV
43. Long span steel joists with a clear span of 80 feet are used to support a roof. The joists are six feet apart, the dead load is 20 pounds per square foot (including the joist weight), the live load is 30 pounds per square foot, and the live load deflection is limited to  $1/360$  of the span. What is the lightest joist that can be used? Use the table on page 39.
- A. 40LH12
  - B. 40LH13
  - C. 44LH13
  - D. 48LH12
44. The stiffness of a member refers to its resistance to
- A. deformation.
  - B. applied loads.
  - C. impact.
  - D. abrasion.
45. Which of the following statements concerning strength design of reinforced concrete is INCORRECT?
- A. The amount of reinforcing steel used assures that yielding of the steel will occur before failure of the concrete.
  - B. The reinforcing steel is generally assumed to resist all the tensile stresses, while the concrete is assumed to resist all the compressive stresses.
  - C. The amount of reinforcing steel used must be at least equal to that which would produce a balanced design.
  - D. The ultimate load factors are greater for live load than for dead load.
46. A bar two inches in diameter and 10 feet long stretches 0.159" when subject to a tensile load of 50 kips. What is the modulus of elasticity of the bar?
- A. 1,001,000 psi
  - B. 10,010,000 psi
  - C. 12,012,000 psi
  - D. 29,000,000 psi
47. 
- Which of the following statements about the continuous beam shown above is INCORRECT? Neglect the weight of the beam.



- A. The moment in span 1-2 is always negative.
- B. The moment over support 2 is negative.
- C. The reaction at 3 is downward.
- D. The moment in span 2-3 is always negative.

48. Which of the following connectors are NOT used in wood-to-steel joints?

- A. Shear plates      C. Machine bolts
- B. Split rings      D. Wood screws

49. A steel beam spans 30 feet and supports a load of 1800 pounds per foot including the weight of the beam. What is the lightest steel section which can support the load? Assume A36 steel and full lateral support. Use the table on page 40.

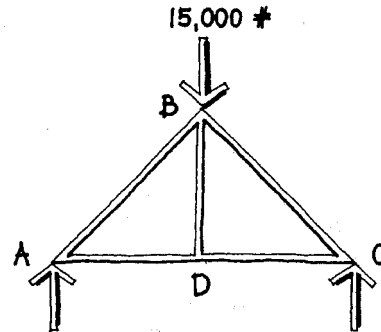
- A. W14 x 48      C. W21 x 44
- B. W14 x 68      D. W24 x 55

50. For the beam in the previous question, what would be the lightest steel section that could support the load, if the beam were laterally supported at 10-foot intervals? Use the chart on page 41.

- A. W14 x 68      C. W21 x 62
- B. W14 x 74      D. W12 x 79

51. What is the internal force in member BD of the truss shown above right?

- A. zero      C. 7.5 kips
- B. 5 kips      D. 15 kips



52. The roof of a circular building is supported by a series of radial cables, which connect to a ring at the center of the roof and to another ring at the perimeter. Which of the following statements is correct?

- A. The center ring is higher than the perimeter ring.
- B. Both rings are in tension.
- C. The center ring is in tension and the perimeter ring is in compression.
- D. Both rings are in compression.

53. How are the allowable stresses for wood adjusted for the duration of the load?

- A. The shorter the duration, the greater the allowable stresses.
- B. The shorter the duration, the lower the allowable stresses.
- C. The shorter the duration, the greater the allowable stresses for members, but not for mechanical fasteners.
- D. The duration does not affect the allowable stresses.

54. Which of the following statements concerning an object in equilibrium is INCORRECT?

- A. There is no unbalanced force acting on the object.



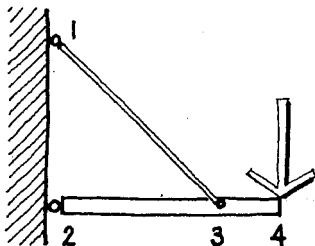
- B. The resultant force on the object passes through the centroid.
- C. There is no unbalanced moment acting on the object.
- D. The resultant force on the object is equal to zero.

55. Select the correct statements.

- I. The modulus of elasticity of concrete varies with the strength and weight of the concrete.
- II. The deflection of a reinforced concrete beam increases over time, even if the load is not increased.
- III. Adding compressive reinforcement has no effect on the deflection of a reinforced concrete beam.

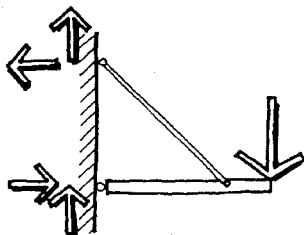
- A. I and II
- B. II and III
- C. I and III
- D. I, II, and III

56.

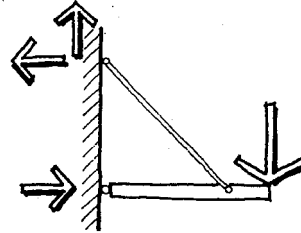


Which of the following diagrams correctly shows the reactions acting on the structure shown above?

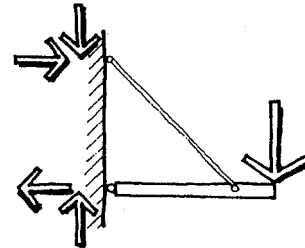
A.



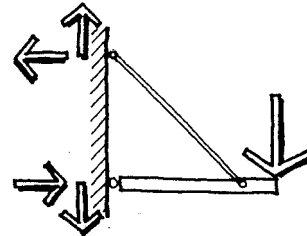
B.



C.



D.



57. A membrane inflated by air pressure encloses an occupied space and is anchored to a reinforced concrete ring at its perimeter. Which of the following statements is correct?

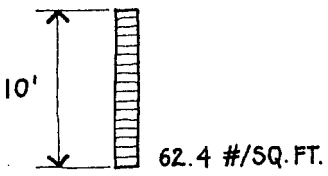
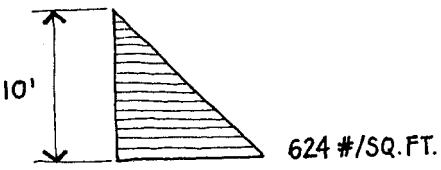
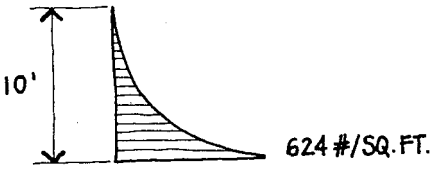
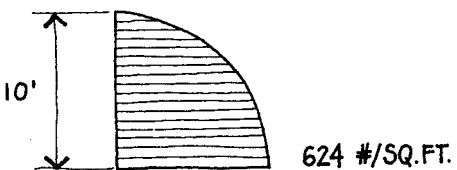
- I. The ring is in compression.
- II. The ring is in tension.
- III. The membrane tends to lift off the ring.
- IV. The membrane tends to push down on the ring.

- A. I and IV
- B. I and III
- C. II and IV
- D. II and III

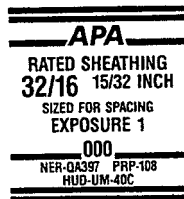
58. A tank is filled with water to a depth of ten feet. Which of the following diagrams correctly shows the pressure exerted on the



tank walls? The unit weight of water is 62.4 pounds per cubic foot.

- A.  62.4 #/SQ. FT.
- B.  624 #/SQ. FT.
- C.  624 #/SQ. FT.
- D.  624 #/SQ. FT.

59.



During the construction of a project, you observe plywood panels with the mark shown above. What does this mark signify?

- I. The panels can span 32 inches when used as roof sheathing.
- II. The panels can span 16 inches when used as subflooring.

III. The plies are all Douglas Fir.

IV. The panels are manufactured with exterior glue.

- A. I and II
- B. I, III, and IV
- C. I, II, and IV
- D. II and IV

60. What is a stub girder system?

- A. A steel beam-and-girder system in which floor beams pass over the main girders and stub girders are welded over the main girders along the same axis.
- B. Short lengths of steel girders shop welded to steel columns to simplify field erection.
- C. Wood or steel girders designed and detailed for simulated continuity.
- D. Steel girders used at the base of a steel column to spread the column load.

61. The change of length which a member undergoes when loaded axially depends on which of the following?

- I. The magnitude of the load
- II. The length of the member
- III. The moment of inertia of the member
- IV. The cross-sectional area of the member
- V. The modulus of elasticity of the material

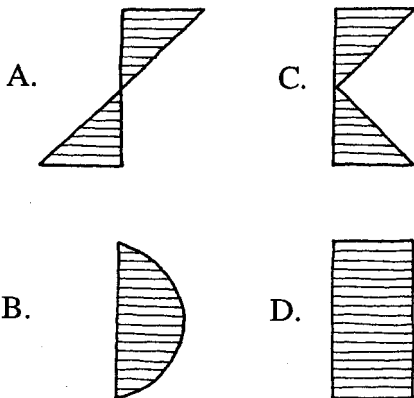
- A. II, III, and IV
- B. I, II, IV, and V
- C. I, III, and V
- D. I, II, III, IV, and V

62. A steel bar two inches in diameter and 20 feet long resists a tensile load of 50,000 pounds. What is the unit tensile stress in the bar?



- A. 7958 psi      C. 15,915 psi  
B. 12,500 psi    D. 25,000 psi

63. Which of the following correctly shows the variation of shear stress within the depth of a rectangular beam?



64. Your design calculations for a retaining wall show that the dead load resisting moment is equal to 1.5 times the overturning moment from earth pressure. Which of the following statements is correct?

- A. The design is satisfactory.  
B. The footing should be made wider.  
C. The footing should be made deeper.  
D. The amount of reinforcing steel in the wall and footing should be increased.

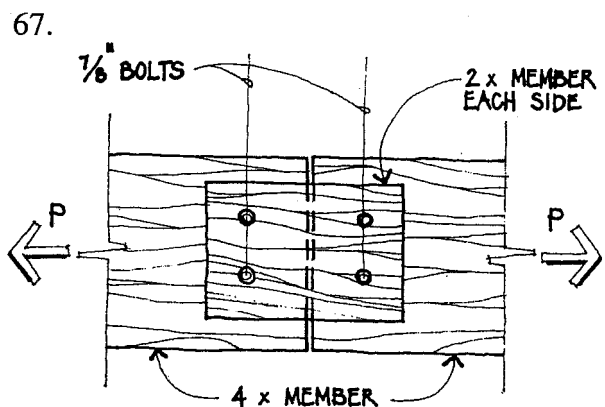
65. Select the correct statement about composite design.

- A. Connectors welded to the steel beam and embedded in the concrete resist flexural stresses.  
B. Composite design is most efficient with light loads and short spans.

- C. The concrete slab resists compressive bending stresses.  
D. Since a composite beam is stiffer than a non-composite beam, it is usually unnecessary to check deflections.

66. Which of the following statements is INCORRECT?

- A. The greatest drying shrinkage in wood members occurs across the grain.  
B. Expansion and contraction of wood members caused by temperature change is not an important design consideration.  
C. Glued laminated members generally shrink less than sawn timber members.  
D. Shrinkage of wood is usually greater in lighter pieces than in heavier pieces of the same species.



67.

What is the maximum load P that can be transferred by the splice detail shown above? The members are Douglas Fir-Larch. Use the table on page 42.

- A. 2520#      C. 5600#  
B. 2780#      D. 7160#



68. Why are stirrups used in reinforced concrete construction?
- A. To provide compressive reinforcement.
  - B. To provide web reinforcement where the concrete is overstressed in shear.
  - C. To anchor the tensile reinforcement.
  - D. To prevent lateral buckling of compressive reinforcement.

69. What property is practically constant for all structural steels?

- A. Yield point
- B. Ultimate strength
- C. Weldability
- D. Modulus of elasticity

70. Which of the following statements are correct concerning an air-supported fabric structure which encloses an occupied space?

- I. Fans are required to pressurize the space.
- II. People and equipment must pass through airlocks or special doors to get into and out of the facility.
- III. Long spans require steel cable reinforcement.
- IV. Loss of pressure can cause the roof to deflate and possibly fail.

- A. I and III
- B. II and IV
- C. I, II, and IV
- D. I, II, III, and IV

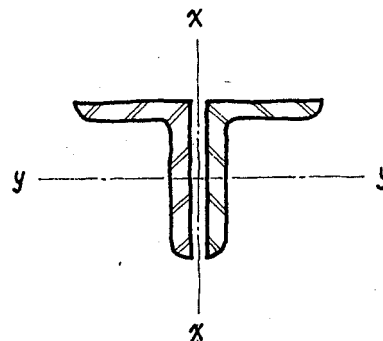
71. Which of the following statements about a three-hinged gabled frame is INCORRECT?

- A. It is statically determinate.
- B. Its supports permit rotation.
- C. The moment at the center is zero.
- D. The maximum moment occurs at the intersection of the column and the sloping beam and is generally greater than in a rectangular rigid frame.

72. In general, the internal forces in the web members of a parallel chord truss

- A. decrease toward the center of the span.
- B. increase toward the center of the span.
- C. remain relatively constant across the span.
- D. may increase or decrease toward the center of the span.

73.



Two angles placed as shown above are to be used for the top chord of a truss whose panel points are 10 feet apart. To determine the required size of the angles, the value of the radius of gyration  $r$  should be with respect to which axis?

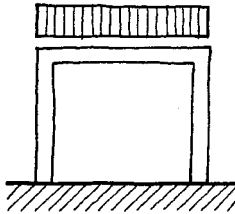
- A. x-x
- B. y-y
- C. x-x or y-y, whichever results in the lower value of  $r$
- D. x-x or y-y, whichever results in the higher value of  $r$



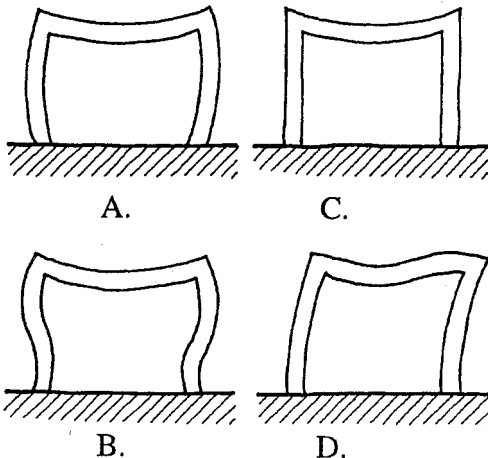
74. Which of the following statements is INCORRECT?

- A. The cost of connections is a significant factor in selecting structural steel systems.
- B. Fillet welds are usually more economical than full penetration welds.
- C. Shop connections are usually more economical than field connections.
- D. Welded connections are usually more economical than bolted connections.

75.



A one-story steel rigid frame with fixed bases supports a uniformly distributed vertical load as shown above. Which of the following correctly shows the shape of the deflected frame?

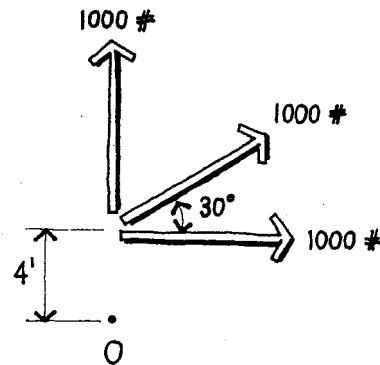


76. You have specified an ultimate 28-day compressive strength of 4000 psi for the

concrete on a project. Cylinders tested at 7 days indicate a strength of 3000 psi. What action should you take?

- A. Redesign the concrete mix.
- B. No action.
- C. Order core tests of the concrete.
- D. Order load tests of the concrete.

77.



What is the moment about point O of the three forces shown above?

- A. zero
- B. 4000 ft.-lbs.
- C. 7464 ft.-lbs.
- D. 12,000 ft.-lbs.

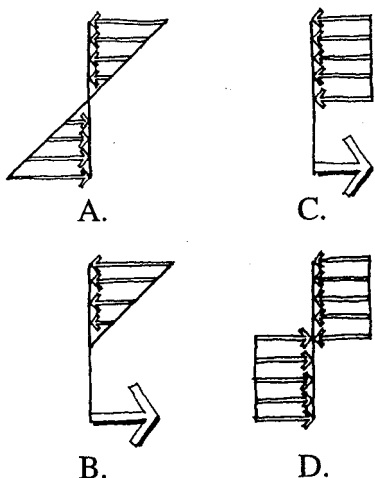
78. Prior to the placing of concrete for footings, you observe that the footing excavation is frozen. What is the best procedure to follow?

- A. Place the concrete on the frozen ground.
- B. Provide a temporary heated enclosure for the excavation and then place the concrete.
- C. Thaw the frozen ground by steaming.
- D. Excavate the frozen ground and place the concrete against earth which is not frozen.

79. What is a lamella roof?

- A. A series of parallel arches, skewed with respect to the axes of a building, which intersect another series of skewed arches.
- B. A two-way truss system in which the trusses are inclined, rather than in a vertical plane.
- C. A series of radial cables which are stabilized by another series of cables.
- D. A system consisting of two intersecting arches placed along the diagonals of a building.

80. Which of the diagrams below represents the flexural stresses in a reinforced concrete beam at failure?



81. The soil boring log for a building site shows that the upper 15 feet of subsurface material is a loose fill, below which is a thick layer of dense sand. Which of the following foundation systems might be appropriate on this site?

- I. Footings placed after the fill is removed and recompacted.

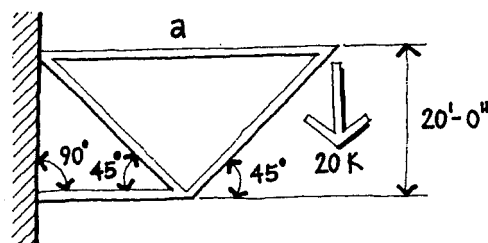
II. Footings extending through the fill into the dense sand.

III. Belled caissons bearing on the dense sand.

IV. Piles extending through the fill into the dense sand.

- A. I and II
- B. III and IV
- C. II, III, and IV
- D. I, II, III, and IV

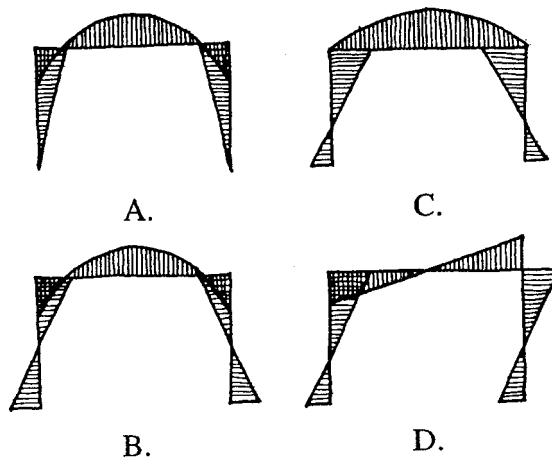
82.



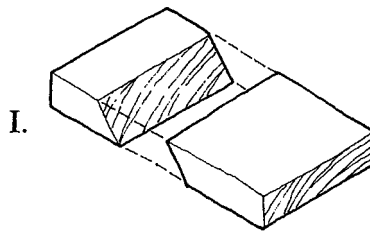
What is the internal force in member a of the cantilever truss shown above?

- A. 20 kips tension
- B. 20 kips compression
- C. 40 kips tension
- D. 40 kips compression

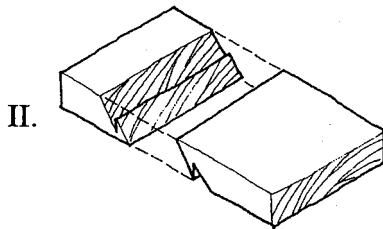
83. Which of the following diagrams correctly shows the moment diagram for the frame in Question 75?



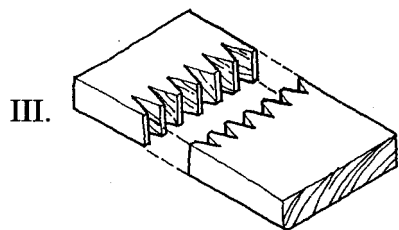
84. In glued laminated construction, it is often necessary to join pieces of lumber end to end to produce laminations of sufficient length. Which of the following joints are acceptable for this purpose?



PLAIN SCARF JOINT



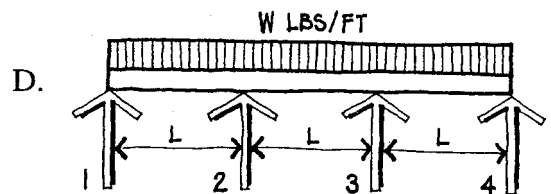
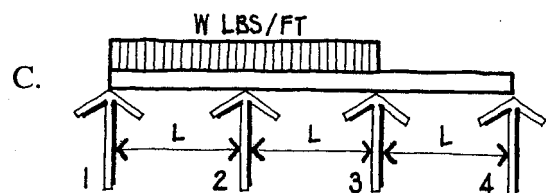
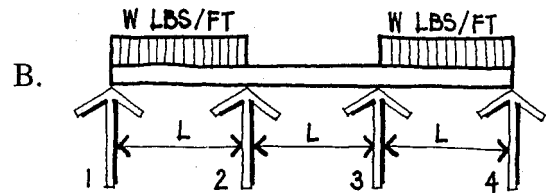
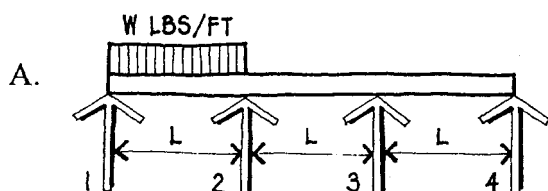
HOOKED SCARF JOINT



FINGER JOINT

- A. I and II      C. II and III  
B. I and III      D. I, II, and III

85. Which of the live load arrangements shown below will result in the greatest positive moment in span 1-2?



86. Which of the following are advantages of prestressed concrete over conventional reinforced concrete?

- I. Elimination of tension cracks  
II. Economy in repetitive applications  
III. Lower material and labor costs  
IV. Less need for close quality control

- A. I and II      C. I and III  
B. II and III      D. I, II, III, and IV

87. The ponding of water on a flat roof supported by long span open web joists can be a problem. In this regard, which of the following statements are correct?

- I. The most economical way to prevent ponding is to build pitch into the joist top chords.  
II. An effective way to minimize ponding

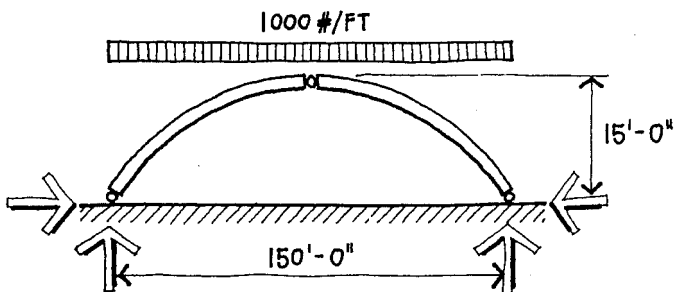


is to provide sufficient camber for the joists.

- III. A slope of 1/8 inch per foot will prevent ponding.
- IV. Using parallel chord joists with end supports at different elevations is an economical way to provide slope.

- A. I and II
- B. II and III
- C. II and IV
- D. I and III

88. What is the horizontal thrust at each end of the three-hinged arch shown below?



- A. Not determinable from the information given
- B. 75 kips
- C. 187.5 kips
- D. 375 kips

89. What is a composite deck?

- A. Steel decking and a concrete slab which act together to span between beams.
- B. Decking made of two different grades of steel.
- C. A steel beam and a formed concrete slab which act together as a single flexural member.
- D. A steel beam with steel decking and a concrete slab over, which act together

as a single flexural member.

90. A saddle-shaped surface formed by moving a vertical parabola with downward curvature along and perpendicular to another parabola with upward curvature is known as a

- A. hyperbolic paraboloid.
- B. parabolic dome.
- C. membrane.
- D. folded plate.

91. Which type of arch is statically determinate when subject to a uniformly distributed load across the entire span?

- A. A two-hinged arch
- B. A three-hinged arch
- C. A fixed arch
- D. Any arch

- 92.



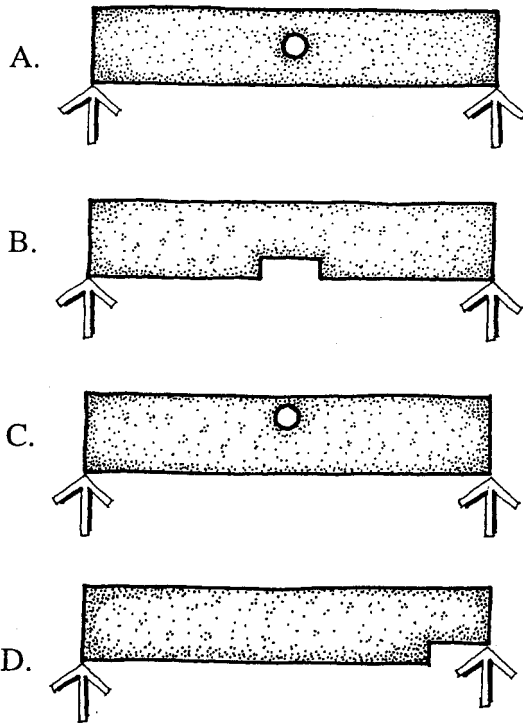
The nominal diameter and yield strength of the reinforcing bar shown above are as follows:

- A. Diameter = 5/8 inch, yield strength = 60 ksi
- B. Diameter = 1 inch, yield strength = 60 ksi



- C. Diameter = 0.60 inch,  
yield strength = 100 ksi
- D. Diameter = 1-1/4 inch,  
yield strength = 60 ksi

93. A hole or notch for a pipe must be provided in a reinforced concrete beam. Which of the diagrams below shows the hole or notch which will LEAST affect the beam's load-carrying capacity?



94. What is the most common type of structural weld?

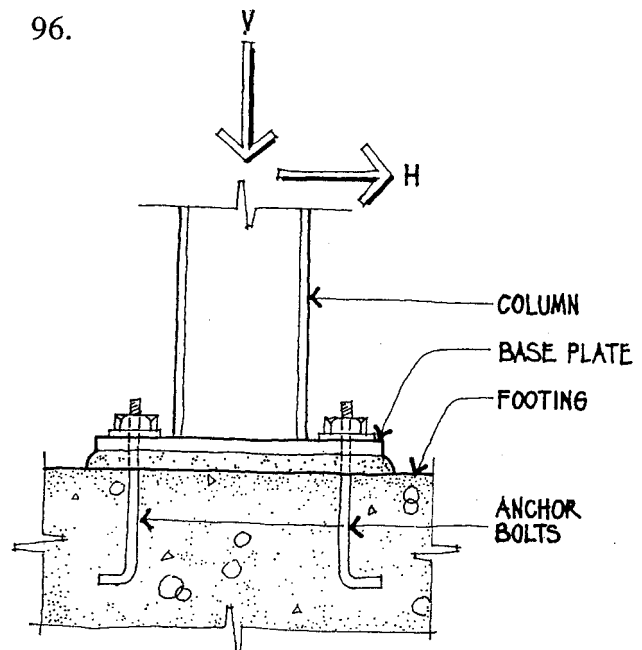
- A. Full penetration weld
- B. Plug weld
- C. Fillet weld
- D. Groove weld

95. A 16-foot-long steel column supports

an axial load of 300 kips and is welded to a 20" x 20" base plate. What is the bearing pressure under the base plate?

- A. 1500 psi
- B. 1200 psi
- C. 750 psi
- D. 469 psi

96.



A steel column supports a vertical load  $V$  and resists a horizontal shear  $H$  as shown above. How is the horizontal shear transferred from the column to the footing?

- A. Bearing of the base plate on the footing
- B. Friction between the base plate and the footing
- C. Tension in the anchor bolts
- D. Shear in the anchor bolts

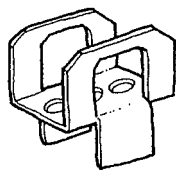
97. Which of the following statements is INCORRECT? The flat slab floor system

- A. spans simultaneously in two directions.

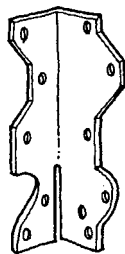
- B. is economical in reinforcing steel.
- C. is appropriate for heavy live loads.
- D. generally has no beams or girders.

98. A parabolic arch supports a uniformly distributed vertical load. What is the nature of the stress in the arch at any point along its length?
- A. Pure compression, no bending moment
  - B. Pure bending moment, no compression
  - C. Combined compression and bending moment
  - D. Pure tension, no bending moment
99. I-shaped wood joists consist of lumber flanges and a strand board web inserted and glued into a groove in each flange. What type of stress does the glue resist?
- A. Flexural tension or compression
  - B. Axial tension or compression
  - C. Bending moment
  - D. Horizontal shear

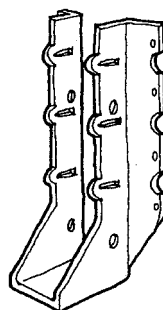
100. Four types of wood connectors are shown below (not to scale). Which of the four choices correctly identifies them?



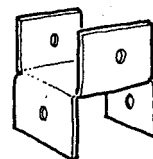
1



2



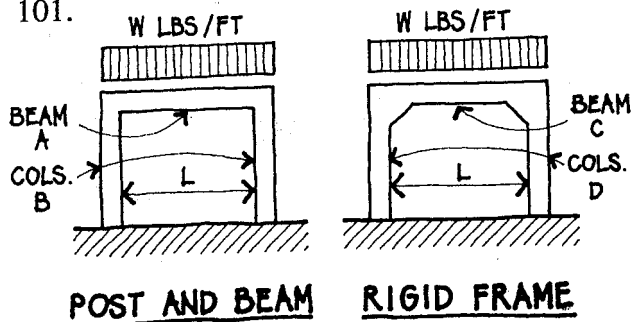
3



4

- A. 1-framing anchor, 2-plywood clip, 3-joist hanger, 4-post cap
- B. 1-plywood clip, 2-framing anchor, 3-joist hanger, 4-post cap
- C. 1-post cap, 2-joist hanger, 3-framing anchor, 4-plywood clip
- D. 1-plywood clip, 2-joist hanger, 3-framing anchor, 4-post cap

101.



Comparing the post-and-beam and the rigid frame shown above, which of the following statements are correct?

- I. The maximum moment in columns D is greater than in columns B.
- II. The maximum moment in beam C is less than in beam A.
- III. The axial force in columns D is the same as in columns B.
- IV. The horizontal reaction at the base of columns D is greater than at columns B.



- A. I and II                      C. I and III  
B. III and IV                  D. I, II, III, and IV

102. A nominal 4 x 8 wood post supports a vertical load of 2000 pounds applied 6 inches from its center line. The post is 10 feet long. What is the horizontal reaction at the top and bottom of the post? The properties of the post are:  $A = 25.375 \text{ in.}^2$ ,  $S = 30.661 \text{ in.}^3$ ,  $I = 111.148 \text{ in.}^4$ .

- A. 1200 pounds      C. 100 pounds  
B. 1000 pounds     D. 10 pounds

103. If the post in the previous question is oriented so that the bending is about its strong axis, what is the maximum unit stress in the post?

- A. 187 psi                      C. 391 psi  
B. 281 psi                      D. 470 psi

104. Which of the following statements about prestressed concrete construction is NOT true?

- A. Precast, prestressed members usually require end anchorages.  
B. Pretensioned members require no end anchorages.  
C. Prestressing a beam results in a smaller section.  
D. Posttensioned members usually require end anchorages.

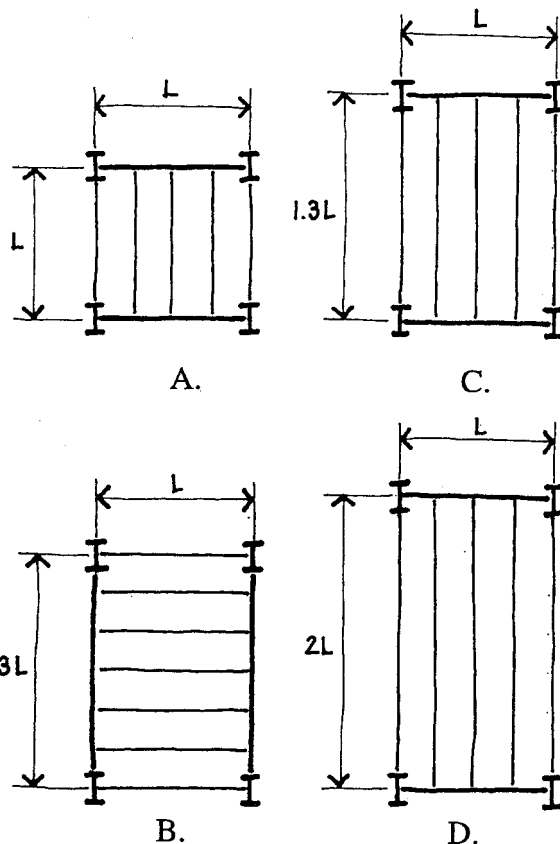
105. Which of the following statements concerning the economy of structural steel framing are correct?

- I. Moment connections should be used in preference to simple connections.

- II. Built-up sections should be used instead of rolled sections, to save weight.  
III. High-strength low-alloy steel should be used instead of ASTM A36 steel, because of its greater strength.  
IV. Composite steel deck should be used, rather than non-composite steel deck.

- A. III and IV                      C. II and III  
B. I and III                      D. IV only

106. Which of the structural steel framing plans below is usually the most economical?

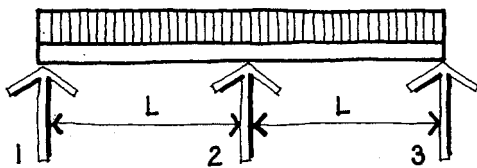


107. What happens to a reinforced concrete dome when the exterior temperature rises?

- A. The top of the dome moves up.

- B. The top of the dome moves down.
- C. The dome develops internal compressive stresses.
- D. The dome develops internal tensile stresses.

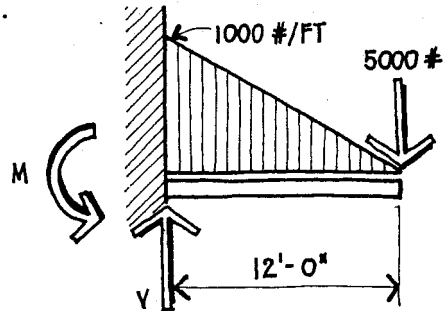
108.



Support 2 of the two-span continuous beam shown above settles one inch. How does this affect the reactions at 1, 2, and 3?

- A. There is no change in the reactions.
  - B. The reactions at 1 and 3 increase, and the reaction at 2 decreases.
  - C. The reactions at 1 and 3 decrease, and the reaction at 2 increases.
  - D. The reactions at 1, 2, and 3 increase.
109. A steel wire lengthens 0.10 inch under a tensile load. Approximately how much will an aluminum wire having the same length and diameter lengthen under the same load?
- A. 0.034 inch
  - B. 0.10 inch
  - C. 0.29 inch
  - D. 1.0 inch
110. Which of the following methods of splicing reinforcing bars is generally the most economical?
- A. Lap splice
  - B. Mechanical splice
  - C. Lap welded splice
  - D. Butt welded splice

111.



A cantilever beam is loaded as shown above. What is the magnitude of the reaction  $V$  and the moment  $M$  at the fixed end, neglecting the weight of the beam?

- A.  $V = 11,000\#$ ,  $M = 84,000$  ft.-lbs.
  - B.  $V = 11,000\#$ ,  $M = 96,000$  ft.-lbs.
  - C.  $V = 17,000\#$ ,  $M = 108,000$  ft.-lbs.
  - D.  $V = 17,000\#$ ,  $M = 132,000$  ft.-lbs.
112. The load-carrying capacity of a wood column is determined by all of the following, EXCEPT
- A. the species and grade of lumber.
  - B. the dimensions of the column section.
  - C. the unbraced height of the column.
  - D. the applied load.
113. Where is a wood beam most likely to fail in shear?
- I. At midspan
  - II. Near the supports
  - III. Close to mid-depth of the beam
  - IV. Close to the top of the beam
- A. I and IV
  - B. II and III
  - C. I and III
  - D. II and IV





114. The strength of a complete penetration groove weld in tension or compression is

- A. based on the shear strength through the throat of the weld.
- B. equal to that of a fillet weld.
- C. the same as that of the connected material.
- D. less than that of the connected material.

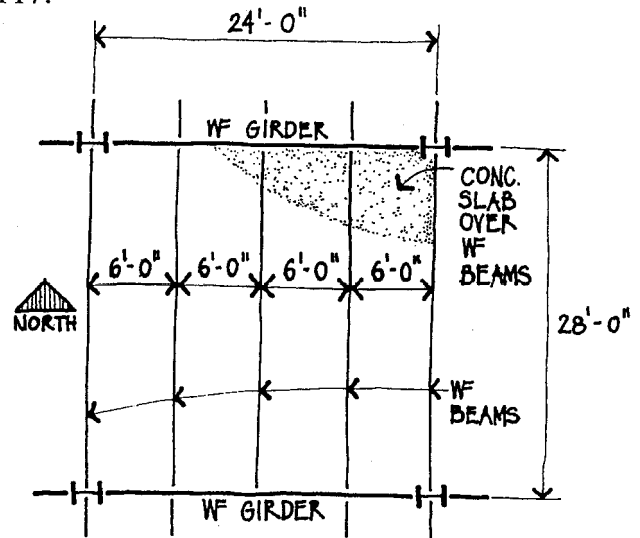
115. Which of the following statements concerning the maximum size of coarse aggregate in a concrete mixture is **INCORRECT**?

- A. The maximum size of coarse aggregate is limited by the narrowest dimension between forms.
- B. The maximum size of coarse aggregate is less than the minimum clear spacing between reinforcing bars.
- C. The smaller the maximum size of coarse aggregate, the greater the amount of water required.
- D. For economy, the maximum size of coarse aggregate should be as small as possible.

116. What is a rigid frame?

- A. A frame with diagonal braces.
- B. A three-dimensional frame which supports a building's dead and live loads.
- C. A steel or concrete frame which has bases fixed against rotation.
- D. A frame with rigid joints capable of resisting moment.

117.



**PLAN**

A typical interior bay of a building is 24 feet by 28 feet and is framed with steel beams and girders as shown above. The floor live load is 100 psf and the dead load is 70 psf. What is the maximum moment in a typical north-south beam, neglecting live load reduction?

- A. 42.8 ft.-kips      C. 166.6 ft.-kips
- B. 100.0 ft.-kips    D. 342.7 ft.-kips

118. A stub girder system is analogous to

- A. a triangulated truss.
- B. a rigid frame.
- C. a Vierendeel truss.
- D. an open web joist.

119. Which of the following systems provides maximum flexibility for a hospital without interruption of service?

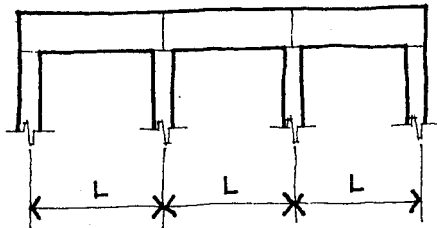
- A. Interstitial trusses

- B. Staggered trusses
- C. Space frame
- D. Flat slab

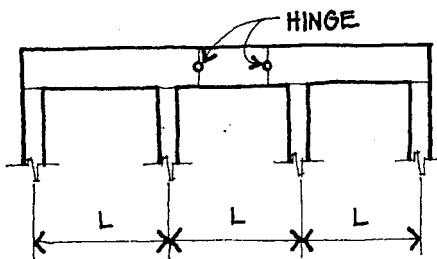
120. A column of ASTM A36 steel is 16 feet long and supports a load of 200 kips. What is the most economical W10 column section which can support the load? Use the chart on page 43.

- A. W10 x 39
- B. W10 x 45
- C. W10 x 49
- D. W10 x 54

121.



**SCHEME A**



**SCHEME B**

Two different framing schemes are being considered, as shown above. Scheme A consists of three simple beams of equal span. In scheme B, the middle beam is hung from the outer beams. What are the advantages of scheme B?

- I. Reduced positive moment in the end spans
- II. Reduced positive moment in the center

span  
III. Reduced column loads

- A. I only
- B. I and II
- C. II only
- D. I, II, and III

122. Which of the following statements about Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD) are correct?

- I. ASD uses unfactored working loads and a single factor of safety.
- II. LRFD uses separate factors for each load and for the resistance.
- III. ASD provides uniform reliability for all steel structures under various loading conditions.

- A. I and II
- B. II and III
- C. I and III
- D. I, II, and III

123. A stress of 20,000 pounds per square inch (psi) is equivalent to how many kilopascals (kPa)? Use the conversion factor 1 pound per square inch (lbf/in<sup>2</sup>) = 6.895 kilopascals (kPa).

- A. 137.9 kPa
- B. 2900 kPa
- C. 137,900 kPa
- D. 137,900,000 kPa

124. The radius of gyration  $r$  of a steel section is a function of the

- I. modulus of elasticity.
- II. moment of inertia of the section.
- III. cross-sectional area of the section.
- IV. section modulus of the section.

- A. I and II
- B. II and III
- C. III and IV
- D. I, II, and III

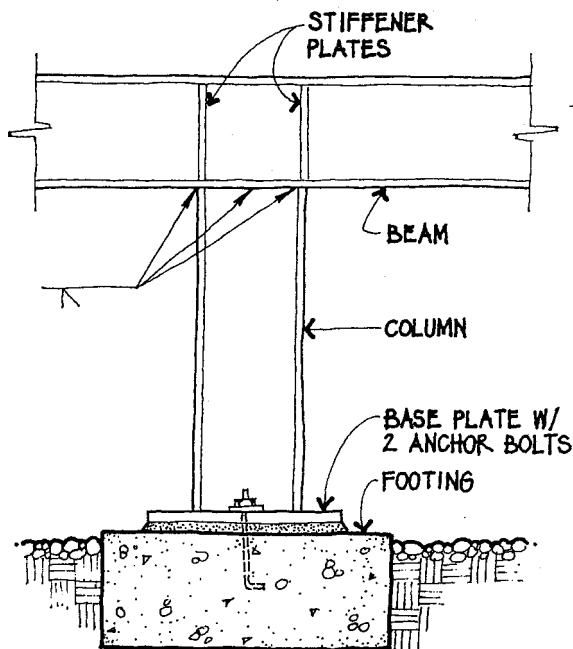


125. Which of the following are likely to result in economical concrete construction?
- I. Vary column and beam sizes to minimize the amount of concrete.
  - II. Use a greater number of smaller bars in preference to a smaller number of larger bars.
  - III. Use tied columns in preference to spiral columns.
  - IV. Use straight bars in preference to bent bars.
- A. I and II                      C. II and IV  
B. III and IV                  D. I and IV
126. Which of the following 19th century buildings is considered to be the first true skyscraper?
- A. Monadnock Building
  - B. Home Insurance Building
  - C. Carson Pirie Scott Store
  - D. Marshall Field Warehouse
127. Which of the following historic structures contains a dome built without any temporary centering?
- A. The Pantheon
  - B. Hagia Sophia
  - C. Santa Maria del Fiore in Florence
  - D. The Parthenon
128. The work of Pier Luigi Nervi is associated with which of the following?
- I. Ferrocement
  - II. Prefabricated concrete domes
  - III. Prefabricated concrete lamella roofs
  - IV. Suspension bridge roof
- A. II and III                      C. III and IV  
B. I and IV                      D. I, II, III, and IV
129. All of the following are tubular steel buildings, EXCEPT the
- A. Water Tower Building in Chicago.
  - B. World Trade Center in New York.
  - C. Sears Tower in Chicago.
  - D. John Hancock Building in Chicago.
130. In Saarinen's design for the Dulles Airport terminal, why are the buttresses inclined?
- A. To counteract the pull of the cables which support the roof.
  - B. To simulate the sensation of flying.
  - C. To counteract the push of the arches which support the roof.
  - D. To provide greater resistance to wind.
131. All of the following are examples of Roman architecture, EXCEPT
- A. Pont du Gard.
  - B. Baths of Caracalla.
  - C. Maison Carrée.
  - D. Treasury of Atreus.
132. The shape which a cable assumes when the only load acting on it is its own weight is called a
- A. parabola.                      C. hyperbola.
  - B. catenary.                      D. paraboloid.
133. A thin shell structure is able to resist which of the following?



- I. Shear
- II. Tension
- A. II only
- B. III only
- III. Compression
- IV. Bending moment
- C. I, II, and III
- D. II, III, and IV

134. A steel column in a moment-resisting steel frame is to be constructed as shown below.



135. Section modulus is a measure of a beam's

- A. resistance to deflection.
- B. stiffness.
- C. elasticity.
- D. bending strength.

To determine the value of K for the column, the top of the column is assumed to be

- A. fixed against rotation and free to translate.
- B. free to rotate and fixed against translation.
- C. free to rotate and free to translate.
- D. fixed against rotation and fixed against translation.



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## Reference Material

The Architect Registration Examination (ARE) is closed book; no reference material is permitted for any part of the exam. Any reference material required for the structural test will be provided when you take the exam.

We suggest that, prior to the exam, you obtain some of the reference books which may be excerpted, in order to become familiar with them and thereby save valuable time at the exam.

The reference books which have often had sections reproduced for reference during the test include the *AISC Manual*, the *Uniform Building Code*, and the *Standard Specifications for Steel Joists*.

Many architectural and engineering offices have these references in their library, which you may be able to borrow during your exam preparation. The *AISC Manual* and the *UBC* are also available from ALS.

Once you have the reference books, you should try to become generally familiar with the scope and format of each book, how its charts and tables are organized, and so forth, rather than trying to memorize anything.

On the following pages, we have reproduced the charts and tables needed to answer several of the questions in this *Structures Mock Exam*.





# **BOLTS, THREADED PARTS AND RIVETS** **Shear** **Allowable load in kips**

TABLE I-D. SHEAR													
ASTM Designation		Connection Type <sup>a</sup>	Hole Type <sup>b</sup>	F <sub>u</sub> ksi	Load-ing <sup>c</sup>	Nominal Diameter d, in.							
						5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
						Area (Based on Nominal Diameter) in. <sup>2</sup>							
						.3068	.4418	.6013	.7854	.9940	1.227	1.485	1.767
Bolts	A307	—	STD	10.0	S	3.1	4.4	6.0	7.9	9.9	12.3	14.8	17.7
			NSL		D	6.1	8.8	12.0	15.7	19.9	24.5	29.7	35.3
	A325	SC <sup>a</sup> Class A	STD	17.0	S	5.22	7.51	10.2	13.4	16.9	20.9	25.2	30.0
					D	10.4	15.0	20.4	26.7	33.8	41.7	50.5	60.1
			OVS, SSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
		LSL	12.0	S	3.68	5.30	7.22	9.42	11.9	14.7	17.8	21.2	
				D	7.36	10.6	14.4	18.8	23.9	29.4	35.6	42.4	
		N	STD, NSL	21.0	S	6.4	9.3	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
		X	STD, NSL	30.0	S	9.2	13.3	18.0	23.6	29.8	36.8	44.5	53.0
					D	18.4	26.5	36.1	47.1	59.6	73.6	89.1	106.0
	A490	SC <sup>a</sup> Class A	STD	21.0	S	6.44	9.28	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
			OVS, SSL	18.0	S	5.52	7.95	10.8	14.1	17.9	22.1	26.7	31.8
					D	11.0	15.9	21.6	28.3	35.8	44.2	53.5	63.6
		LSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5	
				D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0	
		N	STD, NSL	28.0	S	8.6	12.4	16.8	22.0	27.8	34.4	41.6	49.5
					D	17.2	24.7	33.7	44.0	55.7	68.7	83.2	99.0
		X	STD, NSL	40.0	S	12.3	17.7	24.1	31.4	39.8	49.1	59.4	70.7
					D	24.5	35.3	48.1	62.8	79.5	98.2	119.0	141.0
Rivets	A502-1	—	STD	17.5	S	5.4	7.7	10.5	13.7	17.4	21.5	26.0	30.9
					D	10.7	15.5	21.0	27.5	34.8	42.9	52.0	61.8
	A502-2 A502-3	—	STD	22.0	S	6.7	9.7	13.2	17.3	21.9	27.0	32.7	38.9
				D	13.5	19.4	26.5	34.6	43.7	54.0	65.3	77.7	
Threaded Parts	A36 (F <sub>u</sub> =58 ksi)	N	STD	9.9	S	3.0	4.4	6.0	7.8	9.8	12.1	14.7	17.5
				D	6.1	8.7	11.9	15.6	19.7	24.3	29.4	35.0	
	X	STD	12.8	S	3.9	5.7	7.7	10.1	12.7	15.7	19.0	22.6	
				D	7.9	11.3	15.4	20.1	25.4	31.4	38.0	45.2	
	A572, Gr. 50 (F <sub>u</sub> =65 ksi)	N	STD	11.1	S	3.4	4.9	6.7	8.7	11.0	13.6	16.5	19.6
				D	6.8	9.8	13.3	17.4	22.1	27.2	33.0	39.2	
	X	STD	14.3	S	4.4	6.3	8.6	11.2	14.2	17.5	21.2	25.3	
				D	8.8	12.6	17.2	22.5	28.4	35.1	42.5	50.5	
A588 (F <sub>u</sub> =70 ksi)	N	STD	11.9	S	3.7	5.3	7.2	9.3	11.8	14.6	17.7	21.0	
			D	7.3	10.5	14.3	18.7	23.7	29.2	35.3	42.1		
X	STD	15.4	S	4.7	6.8	9.3	12.1	15.3	18.9	22.9	27.2		
			D	9.4	13.6	18.5	24.2	30.6	37.8	45.7	54.4		

<sup>a</sup>SC = Slip critical connection.

N: Bearing-type connection with threads *included* in shear plane.

X: Bearing-type connection with threads *excluded* from shear plane.

<sup>b</sup>STD: Standard round holes ( $d + 1/16$  in.)

LSL: Long-slotted holes

NSL: Long-or short-slotted hole normal to load direction (required in bearing-type connection).

<sup>c</sup>S: Single shear

D: Double shear.

For threaded parts of materials not listed, use  $F_u = 0.17F_u$  when threads are included in a shear plane, and  $F_u = 0.22F_u$  when threads are excluded from a shear plane.

To fully pretension bolts 1 1/8-in. dia. and greater, special impact wrenches may be required.

When bearing-type connections used to splice tension members have a fastener pattern whose length, measured parallel to the line of force, exceeds 50 in., tabulated values shall be reduced by 20%. See AISC ASD Commentary Sect. J3.4.



**BOLTS AND THREADED PARTS**  
**Bearing**  
**Allowable loads in kips**

**TABLE I-E. BEARING**  
**Slip-critical and Bearing-type Connections**

Material Thick- ness	$F_u = 58$ ksi Bolt dia.			$F_u = 65$ ksi Bolt dia.			$F_u = 70$ ksi Bolt dia.			$F_u = 100$ ksi Bolt dia.		
	3/4	7/8	1	3/4	7/8	1	3/4	7/8	1	3/4	7/8	1
1/8	6.5	7.6	8.7	7.3	8.5	9.8	7.9	9.2	10.5	11.3	13.1	15.0
3/16	9.8	11.4	13.1	11.0	12.8	14.6	11.8	13.8	15.8	16.9	19.7	22.5
1/4	13.1	15.2	17.4	14.6	17.1	19.5	15.8	18.4	21.0	22.5	26.3	30.0
5/16	16.3	19.0	21.8	18.3	21.3	24.4	19.7	23.0	26.3	28.1	32.8	37.5
3/8	19.6	22.8	26.1	21.9	25.6	29.3	23.6	27.6	31.5	33.8	39.4	45.0
7/16	22.8	26.6	30.5	25.6	29.9	34.1	27.6	32.2	36.8		45.9	52.5
1/2	26.1	30.5	34.8	29.3	34.1	39.0	31.5	36.8	42.0			60.0
9/16	29.4	34.3	39.2	32.9	38.4	43.9		41.3	47.3			
5/8	32.6	38.1	43.5		42.7	48.8		45.9	52.5			
11/16		41.9	47.9		46.9	53.6			57.8			
3/4		45.7	52.2			58.5						
13/16			56.6									
7/8			60.9									
15/16												
1	52.2	60.9	69.6	58.5	68.3	78.0	63.0	73.5	84.0	90.0	105.0	120.0

**Notes:**

This table is applicable to all mechanical fasteners in both slip-critical and bearing-type connections utilizing standard holes. Standard holes shall have a diameter nominally 1/16-in. larger than the nominal bolt diameter ( $d + 1/16$  in.).

Tabulated bearing values are based on  $F_p = 1.2 F_u$ .

$F_u$  = specified minimum tensile strength of the connected part.

In connections transmitting axial force whose length between extreme fasteners measured parallel to the line of force exceeds 50 in., tabulated values shall be reduced 20%.

Connections using high-strength bolts in slotted holes with the load applied in a direction other than approximately normal (between 80 and 100 degrees) to the axis of the hole and connections with bolts in oversize holes shall be designed for resistance against slip at working load in accordance with AISC ASD Specification Sect. J3.8.

Tabulated values apply when the distance  $l$  parallel to the line of force from the center of the bolt to the edge of the connected part is not less than  $1\frac{1}{2}d$  and the distance from the center of a bolt to the center of an adjacent bolt is not less than  $3d$ . See AISC ASD Commentary J3.8.

Under certain conditions, values greater than the tabulated values may be justified under Specification Sect. J3.7.

Values are limited to the double-shear bearing capacity of A490-X bolts.

Values for decimal thicknesses may be obtained by multiplying the decimal value of the unlisted thickness by the value given for a 1-in. thickness.





**STANDARD LOAD TABLE/LONGSPAN STEEL JOISTS, LH-SERIES**  
Based on a Maximum Allowable Tensile Stress of 30 ksi

Joist Designation	Approx. Wt. in Lbs. per Linear Ft. (Joists Only)	Depth in Inches	SAFE LOAD* in Lbs. Between		CLEAR SPAN IN FEET																	
			47-59	60-64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80		
40LH08	16	40	16600	16600	254	247	241	234	228	222	217	211	206	201	196	192	187	183	178	174		
40LH09	21	40	21800	21800	332	323	315	306	298	291	283	276	269	263	256	250	244	239	233	228		
40LH10	21	40	24000	24000	367	357	347	338	329	321	313	305	297	290	283	276	269	262	255	249		
40LH11	22	40	26200	26200	399	388	378	368	358	349	340	332	323	315	308	300	293	286	279	273		
40LH12	25	40	31900	31900	486	472	459	447	435	424	413	402	392	382	373	364	355	346	338	330		
40LH13	30	40	37600	37600	573	557	542	528	514	500	487	475	463	451	440	429	419	409	399	390		
40LH14	35	40	43000	43000	656	638	620	603	587	571	556	542	528	515	502	490	478	466	455	444		
40LH15	36	40	48100	48100	734	712	691	671	652	633	616	599	583	567	552	538	524	511	498	486		
40LH16	42	40	53000	53000	808	796	784	772	761	751	730	710	691	673	655	638	622	606	591	576		
					469	455	441	428	416	404	387	371	356	342	329	316	304	292	282	271		
			52-59	60-72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88		
44LH09	19	44	20000	20000	272	265	259	253	247	242	236	231	226	221	216	211	207	202	198	194		
44LH10	21	44	22100	22100	300	293	286	279	272	266	260	254	249	243	238	233	228	223	218	214		
44LH11	22	44	23900	23900	325	317	310	302	295	289	282	276	269	264	258	252	247	242	236	232		
44LH12	25	44	29600	29600	402	393	383	374	365	356	347	339	331	323	315	308	300	293	287	280		
44LH13	30	44	35100	35100	477	466	454	444	433	423	413	404	395	386	377	369	361	353	346	338		
44LH14	31	44	40400	40400	549	534	520	506	493	481	469	457	446	436	425	415	406	396	387	379		
44LH15	36	44	47000	47000	639	623	608	593	579	565	551	537	524	512	500	488	476	466	455	445		
44LH16	42	44	54200	54200	737	719	701	684	668	652	637	622	608	594	580	568	555	543	531	520		
44LH17	47	44	58200	58200	821	803	785	767	750	732	715	699	683	667	652	638	624	610	597	584		
					450	438	426	415	405	390	376	363	351	338	327	316	305	295	285	276		
			56-59	60-80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96		
48LH10	21	48	20000	20000	246	241	236	231	226	221	217	212	208	204	200	196	192	188	185	181		
48LH11	22	48	21700	21700	266	260	255	249	244	239	234	229	225	220	216	212	208	204	200	196		
48LH12	25	48	27400	27400	336	329	322	315	308	301	295	289	283	277	272	266	261	256	251	246		
48LH13	29	48	32800	32800	402	393	384	376	368	360	353	345	338	332	325	318	312	306	300	294		
48LH14	32	48	38700	38700	475	464	454	444	434	425	416	407	399	390	383	375	367	360	353	346		
48LH15	36	48	44500	44500	545	533	521	510	499	488	478	468	458	448	439	430	422	413	405	397		
48LH16	42	48	51300	51300	629	615	601	588	576	563	551	540	528	518	507	497	487	477	468	459		
48LH17	47	48	57600	57600	706	690	675	660	646	632	619	606	593	581	569	558	547	536	525	515		
					397	383	371	358	346	335	324	314	304	294	285	276	268	260	252	245		



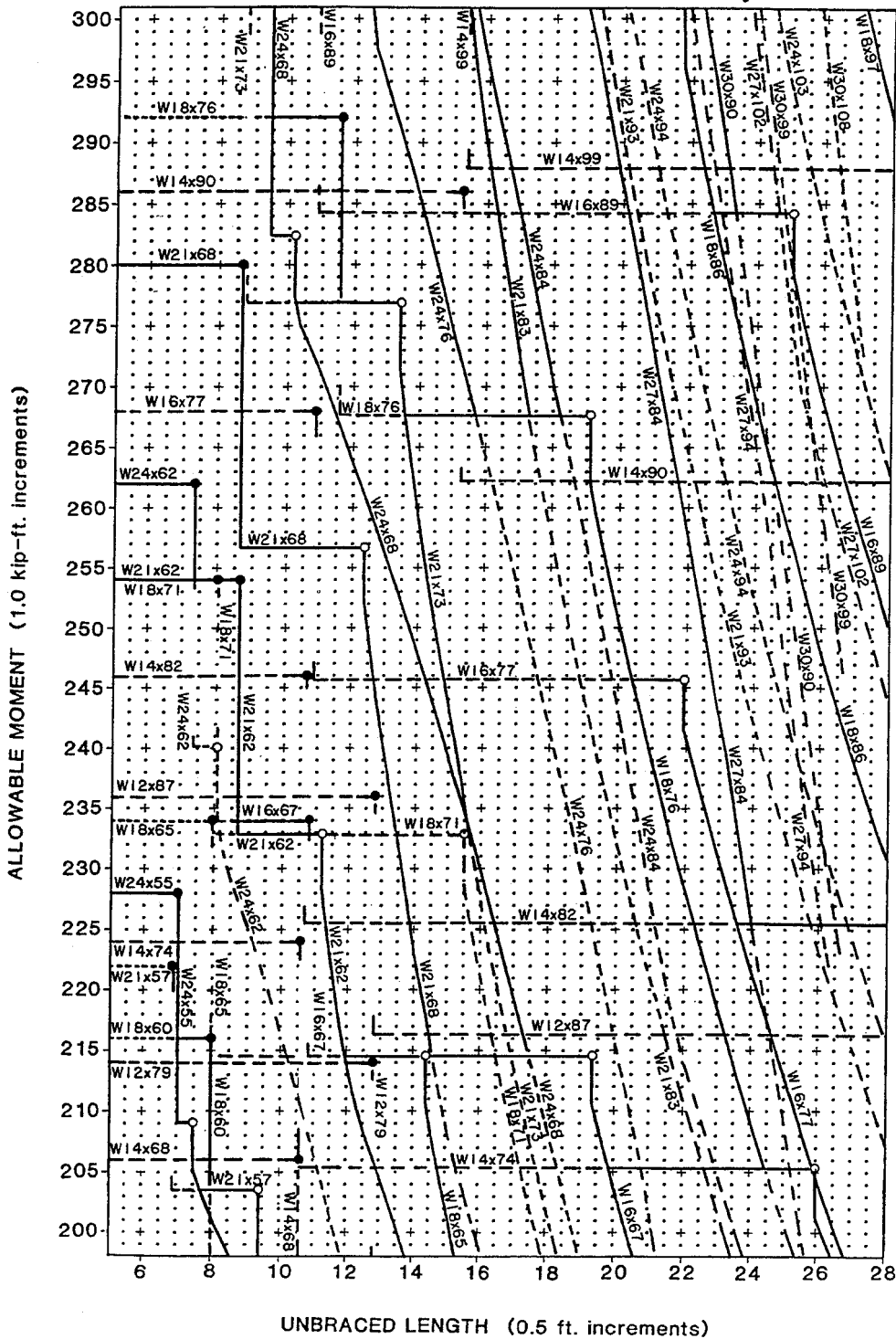
**ALLOWABLE STRESS DESIGN SELECTION TABLE**  
For shapes used as beams

**S<sub>x</sub>**

$F_y = 50 \text{ ksi}$			$S_x$	Shape	Depth $d$	$F_y$	$F_y = 36 \text{ ksi}$		
$L_c$	$L_u$	$M_R$					$L_c$	$L_u$	$M_R$
ft	ft	kip-ft	in. <sup>3</sup>		in.	ksi	ft	ft	kip-ft
8.1	8.6	484	176	W 24× 76	23 <sup>3</sup> / <sub>8</sub>	—	9.5	11.8	348
9.3	20.2	481	175	W 16×100	17	—	11.0	28.1	347
13.1	29.2	476	173	W 14×109	14 <sup>3</sup> / <sub>8</sub>	58.6	15.4	40.6	343
7.5	10.9	470	171	W 21× 83	21 <sup>3</sup> / <sub>8</sub>	—	8.8	15.1	339
9.9	15.5	457	166	W 18× 86	18 <sup>3</sup> / <sub>8</sub>	—	11.7	21.5	329
13.0	26.7	432	157	W 14× 99	14 <sup>1</sup> / <sub>8</sub>	48.5	15.4	37.0	311
9.3	18.0	426	155	W 16× 89	16 <sup>3</sup> / <sub>8</sub>	—	10.9	25.0	307
7.4	8.5	424	154	W 24× 68	23 <sup>3</sup> / <sub>8</sub>	—	9.5	10.2	305
7.4	9.6	415	151	W 21× 73	21 <sup>1</sup> / <sub>4</sub>	—	8.8	13.4	299
9.9	13.7	402	146	W 18× 76	18 <sup>1</sup> / <sub>4</sub>	64.2	11.6	19.1	289
13.0	24.5	385	143	W 14× 90	14	40.4	15.3	34.0	283
7.4	8.9	385	140	W 21× 68	21 <sup>1</sup> / <sub>8</sub>	—	8.7	12.4	277
9.2	15.8	369	134	W 16× 77	16 <sup>1</sup> / <sub>2</sub>	—	10.9	21.9	265
5.8	6.4	360	131	W 24× 62	23 <sup>3</sup> / <sub>8</sub>	—	7.4	8.1	259
7.4	8.1	349	127	W 21× 62	21	—	8.7	11.2	251
6.8	11.1	349	127	W 18× 71	18 <sup>1</sup> / <sub>2</sub>	—	8.1	15.5	251
9.1	20.2	338	123	W 14× 82	14 <sup>1</sup> / <sub>4</sub>	—	10.7	28.1	244
10.9	26.0	325	118	W 12× 87	12 <sup>1</sup> / <sub>2</sub>	—	12.8	36.2	234
6.8	10.4	322	117	W 18× 65	18 <sup>3</sup> / <sub>8</sub>	—	8.0	14.4	232
9.2	13.9	322	117	W 16× 67	16 <sup>3</sup> / <sub>8</sub>	—	10.8	19.3	232
5.0	6.3	314	114	W 24× 55	23 <sup>5</sup> / <sub>8</sub>	—	7.0	7.5	226
9.0	18.6	308	112	W 14× 74	14 <sup>1</sup> / <sub>8</sub>	—	10.6	25.9	222
5.9	6.7	305	111	W 21× 57	21	—	6.9	9.4	220
6.8	9.6	297	108	W 18× 60	18 <sup>1</sup> / <sub>4</sub>	—	8.0	13.3	214
10.8	24.0	294	107	W 12× 79	12 <sup>3</sup> / <sub>8</sub>	62.6	12.8	33.3	212
9.0	17.2	283	103	W 14× 68	14	—	10.6	23.9	204
6.7	8.7	270	98.3	W 18× 55	18 <sup>1</sup> / <sub>8</sub>	—	7.9	12.1	195
10.8	21.9	268	97.4	W 12× 72	12 <sup>1</sup> / <sub>4</sub>	52.3	12.7	30.5	193
5.6	6.0	260	94.5	W 21× 50	20 <sup>7</sup> / <sub>8</sub>	—	6.9	7.8	187
6.4	10.3	254	92.2	W 16× 57	16 <sup>3</sup> / <sub>8</sub>	—	7.5	14.3	183
9.0	15.5	254	92.2	W 14× 61	13 <sup>7</sup> / <sub>8</sub>	—	10.6	21.5	183
6.7	7.9	244	88.9	W 18× 50	18	—	7.9	11.0	176
10.7	20.0	238	87.9	W 12× 65	12 <sup>1</sup> / <sub>8</sub>	43.0	12.7	27.7	174
4.7	5.9	224	81.6	W 21× 44	20 <sup>5</sup> / <sub>8</sub>	—	6.6	7.0	162
6.3	9.1	223	81.0	W 16× 50	16 <sup>1</sup> / <sub>4</sub>	—	7.5	12.7	160
5.4	6.8	217	78.8	W 18× 46	18	—	6.4	9.4	156
9.0	17.5	215	78.0	W 12× 58	12 <sup>1</sup> / <sub>4</sub>	—	10.6	24.4	154
7.2	12.7	214	77.8	W 14× 53	13 <sup>7</sup> / <sub>8</sub>	—	8.5	17.7	154
6.3	8.2	200	72.7	W 16× 45	16 <sup>1</sup> / <sub>8</sub>	—	7.4	11.4	144
9.0	15.9	194	70.6	W 12× 53	12	55.9	10.6	22.0	140
7.2	11.5	193	70.3	W 14× 48	13 <sup>3</sup> / <sub>4</sub>	—	8.5	16.0	139



ALLOWABLE MOMENTS IN BEAMS ( $C_b=1$ ,  $F_y=36$  ksi)





**TABLE 23-I-F—HOLDING POWER OF BOLTS<sup>1,2,3</sup> FOR DOUGLAS FIR-LARCH,  
CALIFORNIA REDWOOD (CLOSE GRAIN) AND SOUTHERN PINE**  
(See U.B.C. Standard 23-17 where members are not  
of equal size and for values in other species.)

$p$ = safe loads parallel to grain, in pounds. $q$ = safe loads perpendicular to grain, in pounds.							
× 4.45 for N							
LENGTH OF BOLT IN MAIN WOOD MEMBER <sup>4</sup> (inches)		DIAMETER OF BOLT (inches)					
		$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
× 25.4 for mm							
$1\frac{1}{2}$	Single $p$	325	470	590	710	830	945
	Shear $q$	185	215	245	270	300	325
	Double $p$	650	940	1,180	1,420	1,660	1,890
	Shear $q$	370	430	490	540	600	650
$2\frac{1}{2}$	Single $p$		630	910	1,155	1,370	1,575
	Shear $q$		360	405	450	495	540
	Double $p$	710	1,260	1,820	2,310	2,740	3,150
	Shear $q$	620	720	810	900	990	1,080
$3\frac{1}{2}$	Single $p$			990	1,400	1,790	2,135
	Shear $q$			565	630	695	760
	Double $p$	710	1,270	1,980	2,800	3,580	4,270
	Shear $q$	640	980	1,130	1,260	1,390	1,520
$5\frac{1}{2}$	Single $p$					1,950	2,535
	Shear $q$					1,090	1,190
	Double $p$		1,270	1,990	2,860	3,900	5,070
	Shear $q$		930	1,410	1,880	2,180	2,380
$7\frac{1}{2}$	Single $p$						
	Shear $q$						
	Double $p$			1,990	2,860	3,890	5,080
	Shear $q$			1,260	1,820	2,430	3,030
$9\frac{1}{2}$	Single $p$						
	Shear $q$						
	Double $p$				2,860	3,900	5,080
	Shear $q$				1,640	2,270	2,960
$11\frac{1}{2}$	Single $p$						
	Shear $q$						
	Double $p$					3,900	5,080
	Shear $q$					2,050	2,770
$13\frac{1}{2}$	Single $p$						
	Shear $q$						
	Double $p$						5,100
	Shear $q$						2,530

<sup>1</sup>Tabulated values are on a normal load-duration basis and apply to joints made of seasoned lumber used in dry locations. See Division III for other service conditions.

<sup>2</sup>Double shear values are for joints consisting of three wood members in which the side members are one half the thickness of the main member. Single shear values are for joints consisting of two wood members having a minimum thickness not less than that specified.

<sup>3</sup>See Division III for wood-to-metal bolted joints.

<sup>4</sup>The length specified is the length of the bolt in the main member of double shear joints or the length of the bolt in the thinner member of single shear joints.



$F_y = 36 \text{ ksi}$		<div style="text-align: center;"><b>COLUMNS</b> <b>W shapes</b> Allowable axial loads in kips</div> <div style="text-align: right;"></div>											
$F_y = 50 \text{ ksi}$													
Designation		W10											
Wt./ft		60		54		49		45		39		33	
$F_y$		36	50	36	50	36	50	36	50	36	50	36	50
Effective length in ft KL with respect to least radius of gyration $r_y$	0	380	528	341	474	311	432	287	399	248	345	210	291
	6	353	482	317	433	289	394	260	351	224	303	189	255
	7	348	472	312	423	284	385	253	340	218	293	184	246
	8	341	461	306	414	279	376	247	328	213	283	179	237
	9	335	450	300	403	273	367	240	316	206	272	173	228
	10	328	437	294	392	268	357	232	303	200	260	167	217
	11	321	425	288	381	262	346	224	289	193	248	161	207
	12	313	412	281	369	256	335	216	274	186	235	155	196
	13	306	398	274	356	249	324	208	259	178	221	149	184
	14	297	383	267	343	242	312	199	243	170	207	142	171
	15	289	368	259	330	235	299	190	227	162	193	135	159
	16	280	353	251	316	228	286	180	209	154	177	127	145
	17	271	337	243	301	221	273	170	191	145	161	120	131
	18	262	320	235	286	213	259	160	172	136	144	112	117
	19	253	303	226	271	205	245	149	154	126	130	103	105
	20	243	285	217	255	197	230	138	139	116	117	95	95
	22	222	248	199	221	180	198	115	115	97	97	78	78
	24	201	209	179	186	161	167	97	97	81	81	66	66
	26	177	178	158	159	142	143	82	82	69	69	56	56
	28	154	154	137	137	123	123	71	71	60	60	48	48
	30	134	134	119	119	107	107	62	62	52	52	42	42
	32	118	118	105	105	94	94	54	54	46	46	37	37
	33	111	111	99	99	88	88	51	51	43	43		
	34	104	104	93	93	83	83						
	36	93	93	83	83	74	74						
Properties													
$U$		2.55	2.55	2.56	2.56	2.57	2.57	3.25	3.25	3.28	3.28	3.35	3.35
$P_{wo}$ (kips)		99	138	83	116	73	101	79	109	64	89	55	77
$P_{wl}$ (kips/in.)		15	21	13	19	12	17	13	18	11	16	10	15
$P_{wb}$ (kips)		239	282	163	193	127	149	138	163	101	119	79	93
$P_{lb}$ (kips)		104	145	85	118	71	98	86	120	63	88	43	59
$L_c$ (ft)		10.6	9.0	10.6	9.0	10.6	9.0	8.5	7.2	8.4	7.2	8.4	7.1
$L_u$ (ft)		31.1	22.4	28.2	20.3	26.0	18.7	22.8	16.4	19.8	14.2	16.5	11.9
$A$ (in. <sup>2</sup> )		17.6		15.8		14.4		13.3		11.5		9.71	
$I_x$ (in. <sup>4</sup> )		341		303		272		248		209		170	
$I_y$ (in. <sup>4</sup> )		116		103		93.4		53.4		45.0		36.6	
$r_y$ (in.)		2.57		2.56		2.54		2.01		1.98		1.94	
Ratio $r_x/r_y$		1.71		1.71		1.71		2.15		2.16		2.16	
$B_x$ } Bending		0.264		0.263		0.264		0.271		0.273		0.277	
$B_y$ } factors		0.765		0.767		0.770		1.000		1.018		1.055	
$a_x/10^6$		50.5		45.0		40.6		37.2		31.2		25.4	
$a_y/10^6$		17.3		15.4		13.8		8.0		6.7		5.4	
$F'_{ex} (K_x L_x)^2/10^2$ (kips)		200		198		196		194		189		182	
$F'_{ey} (K_y L_y)^2/10^2$ (kips)		68.5		68.0		66.9		41.9		40.7		39.0	
Note: Heavy line indicates $Kl/r$ of 200.													

