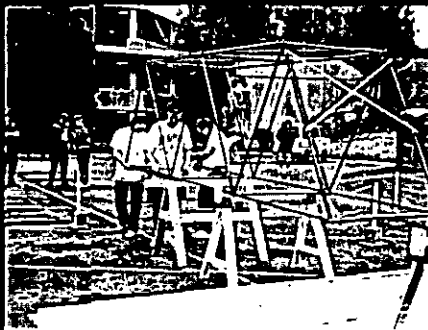
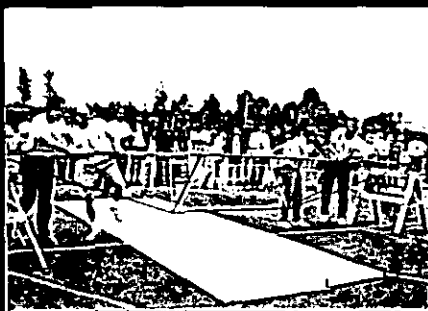




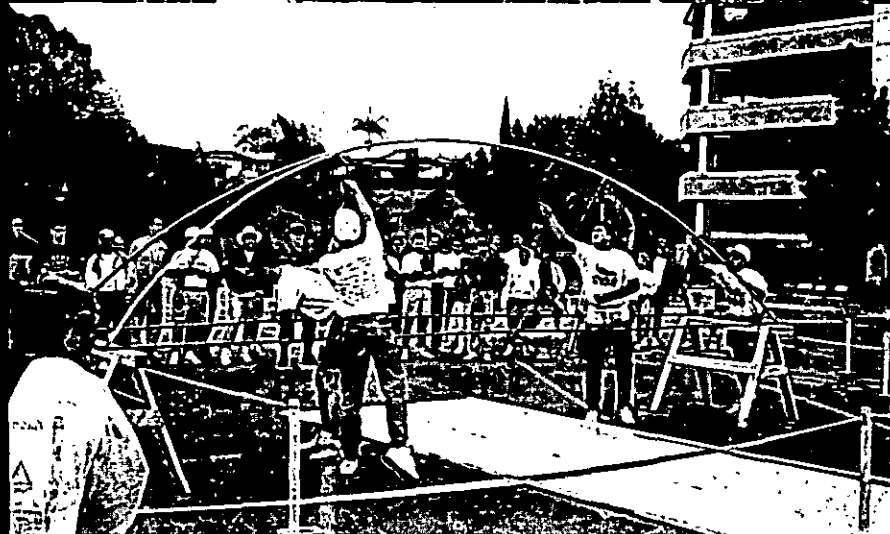
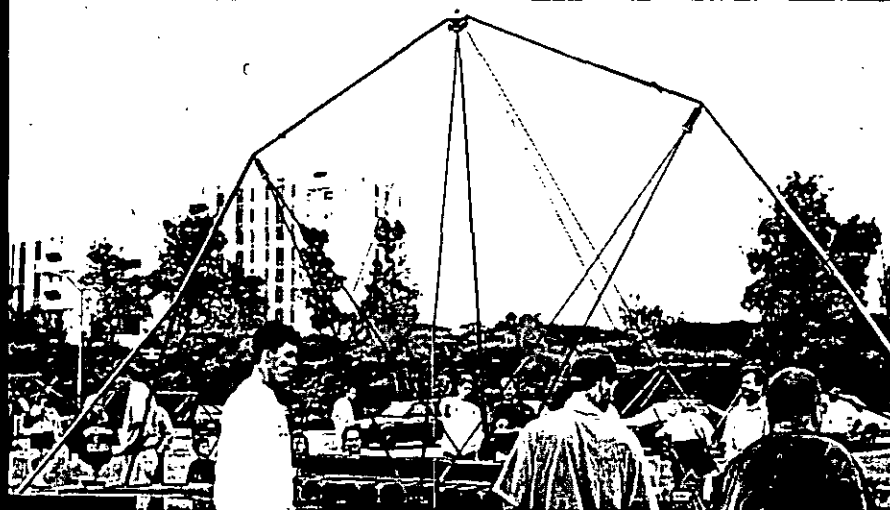
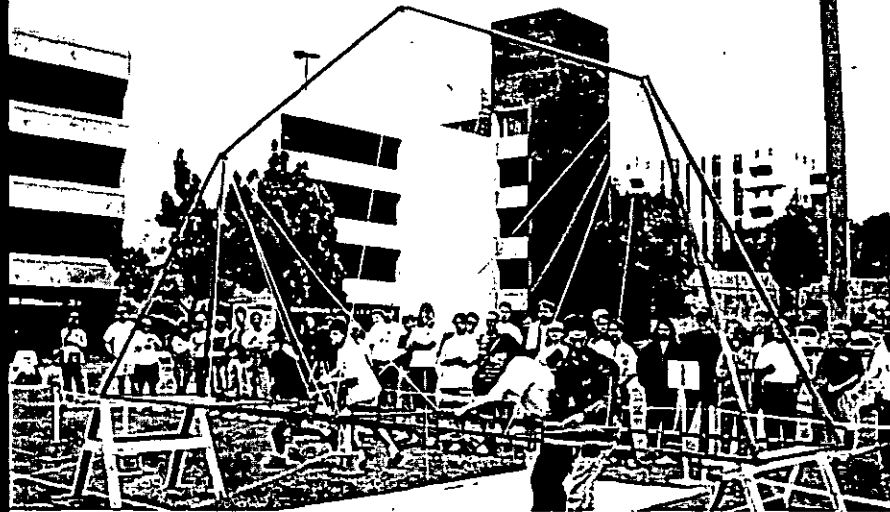
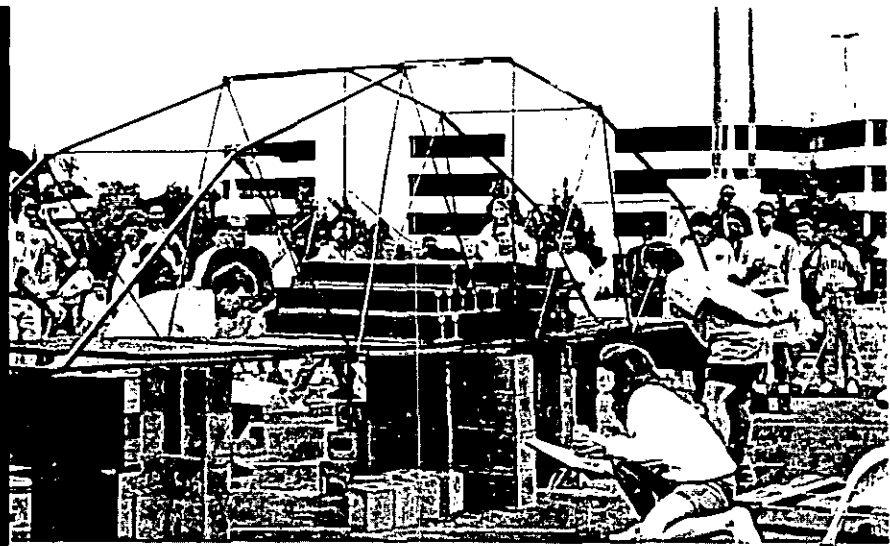
1995 STEEL BRIDGE BUILDING COMPETITION



*For student chapters of
the American Society
of Civil Engineers*



In Cooperation With **ASCE**
American Society Of Civil Engineers



RULES
AISC STEEL BRIDGE-BUILDING
COMPETITION
1995

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INTRODUCTION

The Steel Bridge-Building Competition is sponsored by the American Institute of Steel Construction. This inter-collegiate challenge requires Civil Engineering students to design, fabricate and construct a steel bridge.

Safety is of primary importance. The AISC requests that competitors, hosts and judges take all necessary precautions to prevent injury.

The competition rules have been changed for 1995 in order to improve the contest and to assure that competitors design and build new bridges.

Ideally, students should fabricate the entire bridge themselves. However, appropriate shop facilities and supervision may not be available at every college and university. Therefore, the services of a commercial fabricator may be used provided that students observe the operations.

This booklet describes the contest and states the official rules for this year. It is distributed to universities throughout the country. A companion booklet is distributed to hosts and provides directions for conducting a competition.

EXECUTIVE SUMMARY

Civil Engineering students are challenged to an inter-collegiate competition that includes design, fabrication and construction. Participating students gain practical experience in structural design, fabrication processes, construction planning, organization and teamwork.

The Problem Statement describes challenges encountered in a representative structural engineering project. The competition is a scaled simulation of that project.

Standards for durability, constructability, usability, strength and serviceability reflect the volumes of regulations that govern the design and construction of full-scale bridges. Criteria for excellence are represented by the award categories of stiffness, lightness, construction speed, aesthetics, efficiency and economy. As with a real construction project, safety is the primary concern.

The rules of the competition accommodate a large variety of designs and allow innovation. Designers must carefully consider the comparative advantages of various alternatives. For example, a truss bridge may be stiffer than a girder bridge but slower to construct.

The Steel Bridge-Building Competition provides design and construction planning experience, an opportunity to learn fabrication procedures, and the excitement of competing against students from other colleges and universities.

PROBLEM STATEMENT

A century-old bridge that crosses a river valley in a mountainous region must be replaced. The bridge carries heavy truck traffic to and from mines which are the basis for the economy of this rural region, as well as providing access and emergency services to residences. A quick replacement is necessary because no other river crossing of adequate capacity is available for miles.

The State Department of Transportation has requested design/build proposals for replacing the existing bridge. Any appropriate type of bridge will be considered, but the State has specified steel as the material because of its durability and fast erection. The bridge must accommodate two lanes of traffic and be able to carry specified patterns of traffic and wind loads without exceeding deflection limits. In order to expedite environmental approvals, no piers may be erected in the river, nor may temporary scaffolding or causeways be used in the river. However, temporary shoring may be erected on the banks. Construction barges and marine cranes are not feasible due to fast currents and flash floods.

The stone abutments of the existing bridge are in good condition and will serve for the new bridge, provided that no lateral thrust nor uplift is applied to the abutments. The State DOT will not permit modification of the existing abutments. The new bridge, when complete, must be supported only by the existing abutments; for example, stays and anchorages to the river banks are prohibited.

The new bridge must accommodate modular decking, which the State DOT salvaged from another bridge. Decking units may not be modified.

Access to the construction site is limited by narrow, winding roads. This imposes restrictions on the size of components, and on the movements of construction equipment. Soil conditions restrict the weight that may be lifted by cranes.

Your company's design/build proposal is among those that the State DOT has deemed responsive. The DOT has asked each competing firm to submit a 1:10 scale model to demonstrate its concept. Models will be erected under simulated field conditions and then load tested. The DOT will evaluate the models by multiple criteria including durability, constructability, usability, stiffness, construction speed, efficiency, economy and aesthetics. The contract will be awarded to the company that submits the best model. This is an opportunity to become leaders in the bridge replacement market.

QUALIFICATION

In order to compete for awards, a bridge must qualify by satisfying the following minimum standards for durability, constructability, usability, strength and serviceability.

Durability

The bridge must be constructed entirely of steel.

Constructability

The bridge may be constructed only of components conforming to the restrictions on size and weight specified in "Components." The bridge must be constructable according to regulations given in "Construction" and without violating requirements listed in "Safety Regulations."

Usability

The bridge must conform to the specifications described in "Dimensions and Support."

Strength and Serviceability

The bridge must pass load tests 1 and 2 described in "Load Tests."

AWARD COMPETITION

Only qualified bridges are eligible to compete for awards. Categories of competition are stiffness, lightness, construction speed, efficiency, economy and aesthetics. In addition, overall performance is rated.

Stiffness

The bridge with the lowest incremental vertical deflection will win in the stiffness category. Incremental vertical deflection is determined from load test 3. A bridge that fails load test 3 will be eliminated from the stiffness and efficiency categories of competition.

Lightness

The bridge with the least total weight will win in the lightness category. Decking and temporary shoring are not included in total weight.

Construction Speed

The bridge with the lowest construction time will win in this category. Construction time is the product of the size of the construction team and the duration of construction. The construction team includes everyone who handles the bridge or any of its components during timed construction. A bridge that accumulates \$150,000 or more in penalties will be eliminated from competition in the construction speed and economy categories (see "Accidents.")

Efficiency

The bridge with the smallest sum of normalized weight and deflection ratios (SNWD) will win in the efficiency category. The sum of normalized weight and deflection ratios is computed as

$$\text{SNWD} = \frac{\text{Incremental vertical deflection (in)}}{0.20 \text{ (in)}} + \frac{\text{Total weight (lb)}}{100 \text{ (lb)}}$$

Economy

The bridge with the lowest cost (C) will win in the economy category. Cost is computed as

$$\begin{aligned} C = & \text{Total weight (lb)} \times 1000 \text{ (\$/lb)} \\ & + \text{Construction time (person-min)} \times 5000 \text{ (\$/person-minute)} \\ & + \$10,000 \text{ if temporary shoring is used} \\ & + \text{Penalty costs (listed in "Accidents")} \end{aligned}$$

Aesthetics

Factors that may be considered include general appearance, balance and proportion of the design, elegance of connections, finish, construction organization and teamwork. Quality of fabrication should not be considered because some bridges may be fabricated professionally while other are student work.

Overall Performance

The overall performance rating of a bridge is determined by adding the rank of the bridge in the efficiency category to its rank in the economy category. The bridge with the lowest sum will win the overall competition. A bridge that was eliminated from the efficiency and/or economy categories is not eligible for the overall performance competition. In the case of a tie, judges will use aesthetics as the tie breaker.

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COMPONENTS

A bridge may be constructed only of components made entirely of steel and conforming to the following descriptions of members, cables with fittings, assemblies, and fasteners.

A member may not weigh more than 40 pounds nor exceed overall dimensions of 5'6" x 7.5" x 7.5". A member may consist of parts connected together before timed construction begins but those parts must remain connected throughout the construction process. A member may be hinged, jointed, articulated or telescoping.

A cable together with its fittings may weigh no more than 40 pounds and must be capable of being coiled to a diameter not exceeding two feet. Fittings are eyes, hooks, plates, clamps, clevises, turnbuckles and similar parts connected to cables, and not exceeding 7.5" in any dimension. A cable with fittings may consist of parts connected together before timed construction begins but those parts must remain connected throughout the construction process. A cable with fittings may have any number of ends.

An assembly is no more than 3 members and/or cables with fittings that are connected together in the staging yards during timed construction.

Fasteners are bolts and nuts, pins, plates, shims and similar parts used for connecting members, cables and assemblies, and not exceeding 7.5" in any dimension.

CONSTRUCTION

Tools

Competitors provide their own tools. Only hand tools are permitted. Field welding and power tools are prohibited. Ropes are permitted but gin poles, jacks, winches, come-alongs, counterweights and other hoisting devices are prohibited. Stools, ladders and similar objects for elevating builders are prohibited.

Construction Site

See the figure titled "Site Plan" for layout of river, banks, and other features that affect construction.

Temporary Shoring

Shoring is temporary support on the river banks, and is provided by the competitors. There are no restrictions on the materials and design for temporary shoring other than it must provide sufficient strength and stability to

support the bridge and builders. There is a cost assigned to temporary shoring; its advantage is that builders may be supported by the bridge only if temporary shoring is in place. If temporary shoring is used, it must be used on both banks.

Safety Support

During construction the top of the safety support must be in place at the midspan of the bridge with its top surface no more than 8 inches from the bottom of the bridge.

Start

Before construction begins, all members, cables with fittings, fasteners, tools and builders are in the staging yards. Temporary shoring, if used, has been constructed and is in place on both river banks. The safety support is in place. Timing and construction begin when the builders signify that they are ready and the judge declares the start.

Time

Time is kept from the start to finish of construction. The clock will be stopped:

1. if a builder or judge sees a condition that could cause personal injury;
2. when a safety regulation has been violated, and
3. if the safety support must be adjusted.

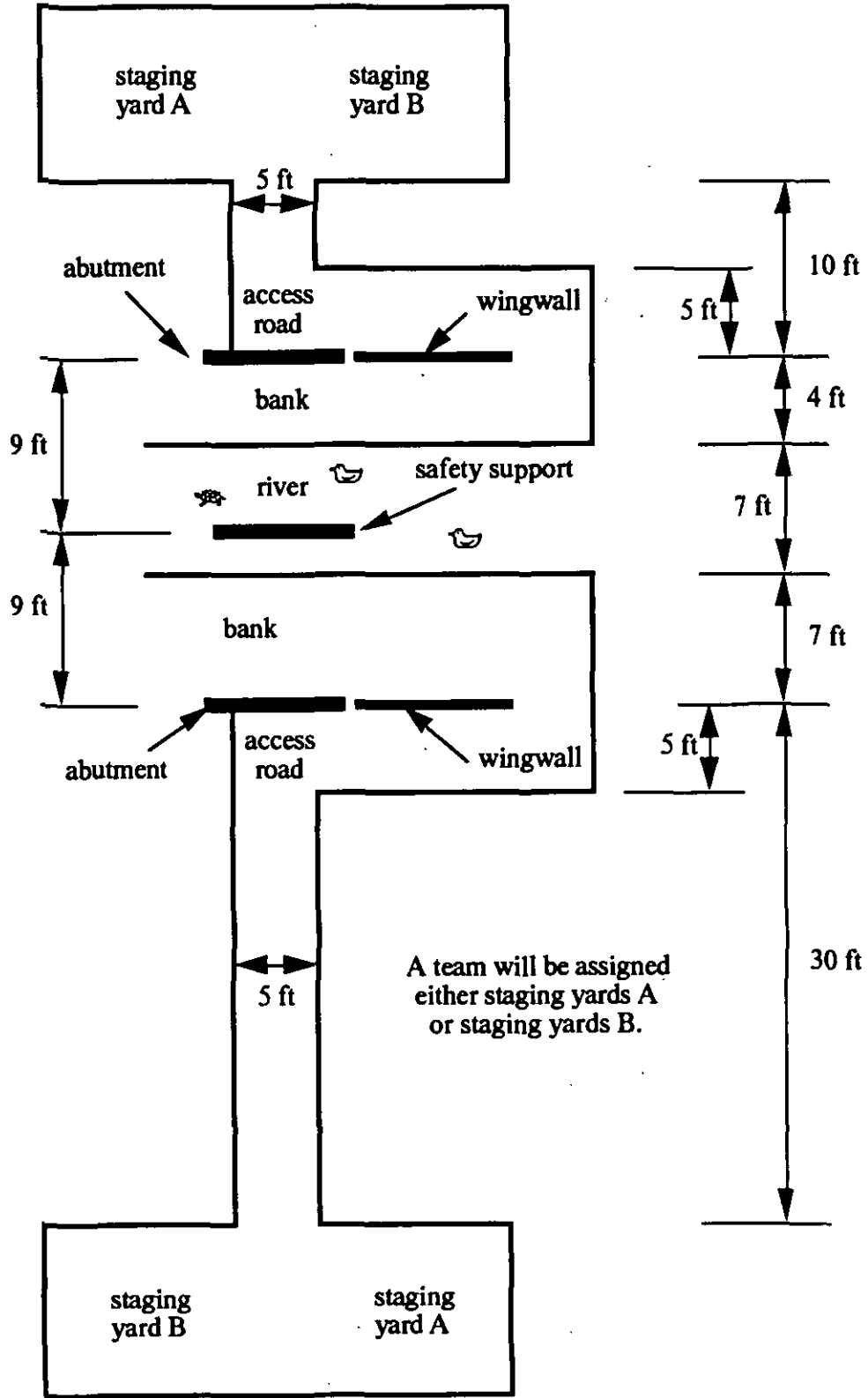
Construction ceases while the clock is stopped. The clock is restarted after the situation has been corrected.

Time Limit

In order to expedite the competition the host may limit the clock time for constructing a bridge to 30 minutes. A higher limit may be imposed. A bridge that exceeds the limit will be eliminated from all categories of competition. If the host opts to impose a time limit, all competitors must be notified at least a month before the competition.

Finish

Construction ends when the bridge is complete, and all tools and builders are in the staging yards, and the builders signify that they are finished. Temporary shoring may remain on the banks. Installation of decking is not included in timed construction.



Site Plan

SAFETY REGULATIONS

If any of the following safety regulations are violated the judge will stop the clock and explain the violation. Before restarting the clock, builders, tools and bridge components will be returned to the positions they occupied before the violation. Construction that necessitates violation of safety regulations is not permitted.

1. If temporary shoring is not used, a builder may not stand on the bridge nor occupy it in any other way such that the bridge supports the builder's body weight. However, a builder may lean on the bridge if both feet remain on the river bank.

2. Temporary shoring may not be placed in the river.

3. A builder may lift or carry only one member or one cable with fittings at a time.

4. An assembly may not be lifted nor carried by one builder alone.

5. Two or more builders may lift or carry only one assembly at a time.

6. Nothing may be thrown.

7. A builder may not stand, sit or kneel in the river, nor use the river for support in any way.

8. A builder must stay within the limits of the access roads and river banks.

9. A builder may not cross the wingwalls.

10. The safety support as well as temporary shoring on both banks must be in place and properly adjusted before a builder climbs onto the bridge.

11. A builder may not cross the abutments except to climb onto the bridge with temporary shoring and safety support in place.

12. No member, cable with fittings nor assembly may be carried while climbing onto the bridge.

13. A builder may not cross the river by jumping, by temporary scaffolding, by crossing the bridge, nor by any other means.

14. A member, cable with fittings, assembly, fastener or tool may not be laid down except in the staging yards, on the abutments, on the temporary shoring and on the bridge. A member, cable with fittings, assembly, fastener or tool may not be leaned against an abutment, temporary shoring or safety support.

15. A constructed portion of the bridge may be slid horizontally, provided that it is supported by both abutments, or by temporary shoring on both banks, or by one abutment and one unit of temporary shoring.

16. One side or end of a constructed portion of the bridge may be moved a few inches in any direction in order to align a connection.

ACCIDENTS

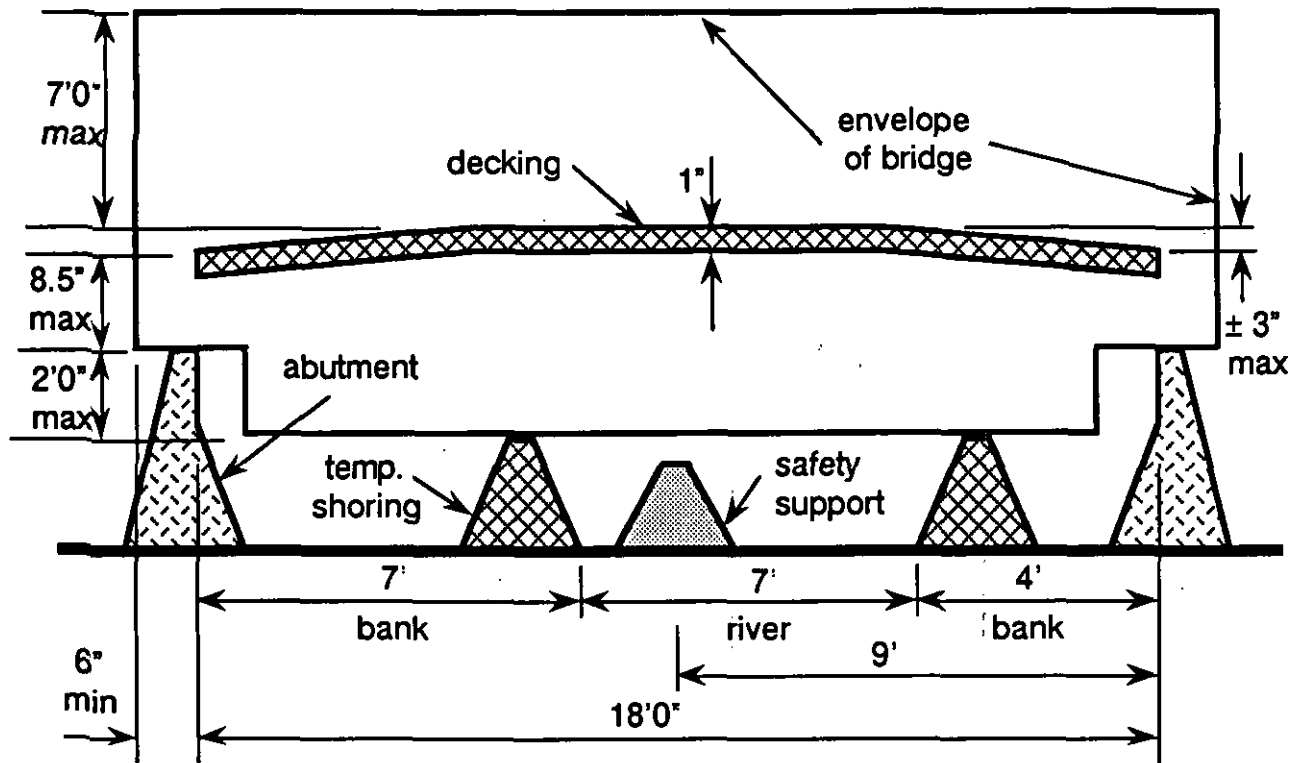
In general, the clock is not stopped when an "accident" occurs. Builders involved in accidents may continue to build, and components involved in accidents may be recovered and used. Types of accidents and the corresponding cost penalties are:

1. A builder touches the river or the safety support. \$50,000 for each occurrence.
2. A member, cable with fittings, assembly, or the bridge touches the river, a bank, an access road or the safety support. \$20,000 for each occurrence.
3. A tool or fastener touches the river, a bank or an access road. \$1000 for each occurrence.

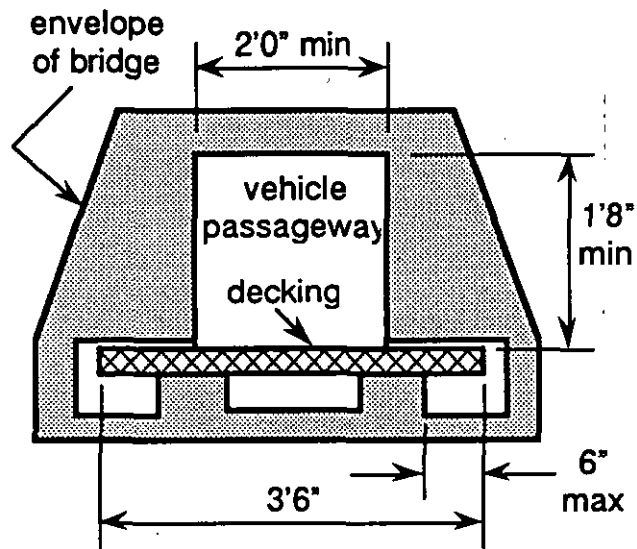
DIMENSIONS AND SUPPORT

The figures titled "Side Elevation" and "Clearance and Deck Support" illustrate some of the following specifications.

1. The bridge must span the abutments, which are fixed in place so that the distance between faces is 18 feet.
2. The bridge must provide bearing area extending at least 6 inches behind the face of each abutment so that the bridge will remain supported by the abutments in the event that it is displaced 6 inches in the direction of span.
3. A 2'0" wide by 1'8" high rectangular vehicle passageway must be provided along the full length of the bridge.
4. No part of the bridge may extend more than 2 feet below the top of the abutments at any point on the span.
5. No part of the bridge may extend more than 7 feet above the top of the deck at any point on the span.



Side Elevation



Clearance and Deck Support

6. The surface of the deck must be no more than 8.5" above the top of the abutments, measured at the abutments.
7. The absolute value of camber must not exceed 3 inches.
8. The bridge must provide support for the decking on both of the edges that run in the longitudinal direction of the bridge. The support must be continuous for the full span of the bridge.
9. The edges of the decking that run in the longitudinal direction of the bridge may be cantilevered over their supports no more than 6 inches.
10. The continuous supports for the deck must be capable of accommodating decking anywhere on the span, without gaps, overlaps or abrupt elevation differences between decking units. However, small elevation differences, such as those caused by decking resting on bolt heads, are acceptable.
11. The decking may not be attached nor anchored to the bridge.
12. The bridge may not be attached nor anchored to the abutments, and it may bear only on the top surface of the abutments.
13. The bridge may not be anchored, tied nor braced to the ground.

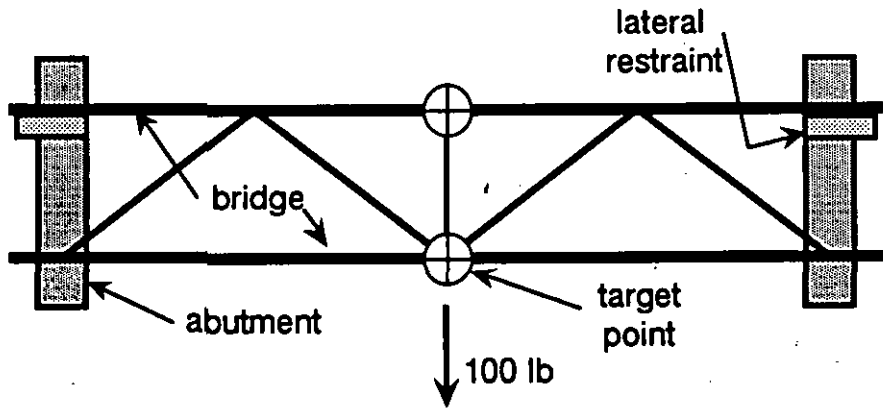
LOAD TESTS

CAUTION: A bridge could collapse or sway suddenly during load tests. Therefore, minimize the number of people near the bridge while it is being tested. During testing the bridge must be supported so that its lowest point is no more than 8 inches above ground or above the top of the safety support.

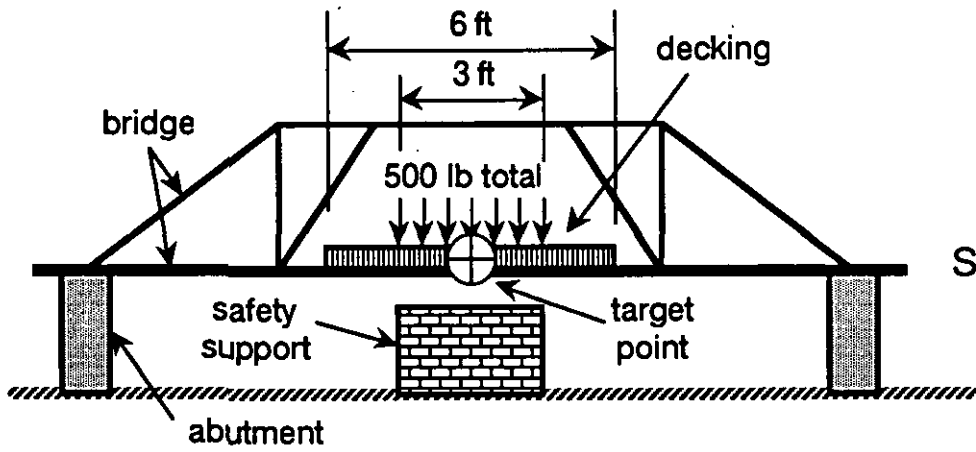
The figure titled "Load Tests" illustrates some of the following procedures.

Load tests are conducted without temporary shoring. Load test 1 is conducted without decking; load tests 2 and 3 are conducted with two decking units installed to accommodate the load.

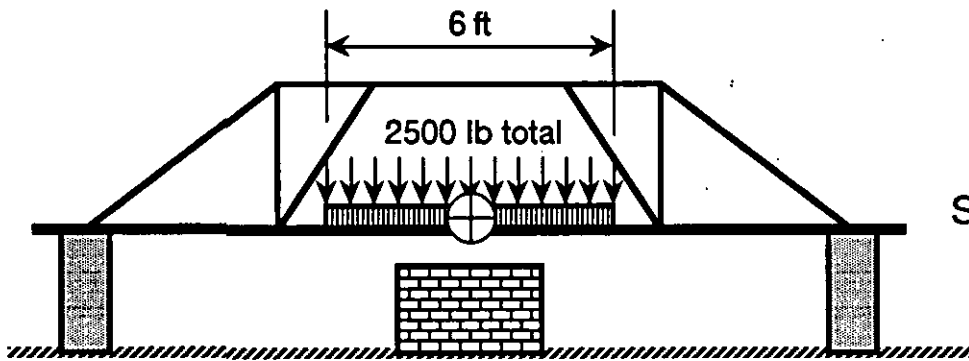
The judge designates two target points on the bridge, both located at midspan, one on each side. The target points should be close to the level of the deck, and may be on the decking itself. Lateral deflection measurements are made to the target point on one side of the bridge, designated by the judge. Vertical deflection measurements are made to both target points; vertical deflection is the maximum absolute value of the two measurements.



Load Test 1
Plan



Load Test 2
Side Elevation



Load Test 3
Side Elevation

Load Tests

Total lateral deflection is the absolute value of the horizontal distance of the target point from its position at the beginning of load test 2. Incremental vertical deflection is the maximum absolute value of the vertical distances of the target points from their positions at the beginning of load test 3.

Load tests are conducted in numerical order.

Load Test 1 - Qualifying, Lateral

Load test 1 is conducted with lateral restraint installed on the abutments to prevent the ends of the bridge from sliding. As close as practical to midspan apply a 100 pound force in the lateral direction. To pass load test 1, the lateral deflection of the bridge must not exceed 1.0". If the bridge does not pass load test 1, do not conduct any other load test. Remove the lateral load; it is not part of the remaining load tests.

Load Test 2 - Qualifying, Vertical

Uniformly distribute load over an area symmetric about the middle of the deck and extending 3 feet in the span direction. Terminate load test 2 when lateral deflection reaches 1.0" or vertical deflection reaches 2.0" or 500 pounds of load has been placed. A bridge passes load test 2 if 500 pounds of load was placed without a deflection limit being exceeded. If the bridge does not pass load test 2, do not conduct any other load test.

Load Test 3 - Competition, Vertical

With the load from test 2 remaining in place, uniformly distribute additional load over an area symmetric about the middle of the deck and extending 6 feet in the span direction. Terminate load test 3 when total lateral deflection reaches 2.0" or incremental vertical deflection reaches 2.0" or 2000 pounds of additional load has been placed. A bridge passes load test 3 if 2000 pounds of additional load was placed without a deflection limit being exceeded. If the bridge passes load test 3, record the incremental vertical deflection.

EQUIPMENT PROVIDED BY HOST CHAPTER

The following equipment will be provided at the contest site by the host. Competitors may wish to acquire similar equipment for use in practice and testing before the competition.

Lateral Load Device

Capable of applying 100 lb force in the horizontal direction.

Measuring Scales and/or Instruments

Load

2500 pounds total. The load should be supplied in uniform increments of size and weight that may be handled safely. When in place, the load should not provide significant stiffness in the longitudinal direction of the bridge. Sections of steel angle of uniform size and length are recommended for load. Sacks of material, containers of liquid, concrete blocks or jacking systems could be used.

Decking

The decking is steel bar grating identified as W-19-4 (1 x 1/8). The dimensions of a piece of grating are 3'6" x 2'11-3/4" x 1". Grating has bending strength only in the direction of the main bars, which are 3'6" long. The grating will be installed with the main bars perpendicular to the length of the bridge, creating a roadway that is 3'6" wide. Therefore, support for the grating must be provided along the edges that are parallel to the length of the bridge. No support is needed for the edges of the grating that are perpendicular to the length of the bridge.

When loading, do not exceed 400 psf uniform load nor 500 pounds concentrated load. Do not load on a cantilevered portion of the grating.

Abutments

The top surface of each abutment should be at least 5 feet long, 3 inches wide, level, smooth, and approximately 3 feet above the ground. Temporary lateral restraints are needed during load test 1.

Safety Support

The safety support is intended to limit the consequences of a bridge collapsing during construction or load tests, but should not come in contact with the bridge unless there is a collapse or excessive deflection. The safety support is placed at the middle of the span and adjusted so that the top of the support is no more than 8 inches from the bottom of the bridge.

The safety support should be placed and adjusted to the proper height before the start of timed construction. At all times during construction the top of the safety support should be within 8 inches of the bottom of the bridge. If the safety support must be adjusted when the bridge is partially constructed, the clock will be stopped while the safety support is positioned. Builders are prohibited from being on the bridge unless the safety support is in place, as well as temporary shoring on both banks.

The safety support must be at least 6 feet wide in the lateral direction of the bridge.

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JUDGING

The host will recruit judges. Judges have full authority over conduct of the competition and interpretation of ambiguities in the rules. Judges are empowered to halt any activity that they deem to be hazardous. Decisions, scoring and rating are the sole responsibility of the judges and will be final.

TIPS FOR COMPETITORS

1. Strive for challenging but realistic goals for design and construction. The following statistics from the 1994 National Steel Bridge-Building Competition suggest the levels of performance that are possible. However, when reviewing these statistics keep in mind that the rules and scoring for 1995 differ from those for 1994.

	Winning bridge in category	Winning bridge, overall
Weight (lb)	84.5	117
Construction time (person-minutes)	10.28	28.60
Incremental vertical deflection (inches)	0.195	0.227

2. Start work on the design early, leaving adequate time to procure materials, fabricate the bridge, load test it and practice construction.
3. Design a bridge that may be fabricated, erected and load tested safely.
4. Design a bridge that may be fabricated with available materials, tools and facilities.
5. Allow tolerances for the decking to be slightly larger or smaller than specified. Provide adequate clearances so that the decking may be installed anywhere on the span.
6. When fabricating your bridge, use safe tools, operate them carefully and with adequate supervision.
7. When load testing your bridge before the competition keep it as low to the ground as possible and place safety supports a few inches below the bridge at intervals along the span. This will prevent injury and limit damage to the bridge if it collapses. Keep hands and feet out from under the bridge.
8. Make sure that abutments, safety supports and temporary shoring are strong enough (with a generous factor of safety) and will not tip during construction practice or if the bridge collapses during load testing.

9. Follow all safety regulations and guidelines during construction practice.
10. Don't stand, sit or lie on your bridge unless a safety support and temporary shoring are in place.
11. To expedite the competition have a preset plan for unloading and staging components of your bridge. Before the competition adjust your temporary shoring to conform to the height of the host's abutments. Know in advance the required elevation of the safety support.

SCORE SHEET

Penalties for Accidents

Builder touches river or safety support (\$50,000 each)	\$ _____
Part touches river, bank, road or safety support (\$20,000 each)	\$ _____
Tool or fastener dropped in river, on bank or road (\$1000 each)	\$ _____
TOTAL PENALTIES	\$ _____

Construction Time

_____ builders x _____ min = _____ person-min

Total Weight _____ pounds

Aesthetics

Items that may be considered:

General appearance	Balance and proportion
Finish	Elegance of connections
Construction organization	Teamwork

AESTHETICS SCORE _____

Deflection (incremental vertical, test 3) _____ inches

Efficiency

Total weight (lb) _____ / 100 = _____

Incremental vert. deflect. (in) _____ / 0.20 = + _____

SNWD (add) _____

Cost

Temporary Shoring: \$10,000 if used \$ _____

Const. Time _____ x \$5000 = +\$ _____

Weight _____ x \$1000 = +\$ _____

Total Penalties +\$ _____

TOTAL COST (add) \$ _____

Rank

Construction Speed _____ Efficiency _____

Lightness _____ Economy _____

Stiffness _____ Aesthetics _____

Overall Performance (Efficiency + Economy) = _____

Use aesthetics as tie breaker

REVISED

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