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- LEVEL:** Middle School/High School
- NUMBER OF TEAMS:** One (1) team per school can participate at the MESA Day state competition. Three (3) teams can participate at MESA Regionals.
- TEAM MEMBERS:** Two (2) to Six (6) students
- OBJECTIVE:** Students will build a PVC pipe bridge that meets the criteria outlined in the design parameters and is designed to safely support a maximum vertical load of 100 pounds.

MISSION AND SUMMARY

Civil Engineering is challenged with various aspects of infrastructure every day. The MESA PVC Pipe Bridge Competition increases awareness of real-world engineering issues such as spatial constraints, material properties, strength, serviceability, fabrication, building processes, safety, esthetics, project management, and cost. Success in competition requires application of engineering principles and theory, and effective teamwork. Future engineers are stimulated to innovate, practice professionalism, and use materials efficiently. Students design and build a PVC pipe bridge by themselves, but may consult with teachers and other advisors. Students gain maximum benefit if they fabricate the entire bridge themselves. Safety is paramount. ASCE requests that competitors, advisors, hosts, and judges take all necessary precautions to prevent injury to competitors, judges, host personnel, and spectators. Risky procedures are prohibited. The Competition provides design and management experience, opportunity to learn fabrication processes, and the excitement of networking with and competing against teams from other schools.

The rules simulate a request for proposal with realistic challenges encountered in bridge design and construction. Competition judges take the role of the “owner” and have authority to accept and reject entries.

The rules accommodate a variety of designs and encourage innovation. Students must consider the comparative advantages of various alternatives. For example, a through bridge may be stiffer than a deck bridge but slower to construct. Successful teams compare alternatives prior to fabrication using value analysis based on scoring criteria. The rules are intended to be prescriptive but may require some interpretation. The procedure for requesting clarification is on the MESA website.

Members of the Student Steel Bridge Rules Committee are:

Jose A. Aguilar, E.I.T., Psomas, ASCE Southern Arizona Branch Younger Member Forum

PROBLEM STATEMENT

The MESA-DOT (Department of Transportation) provides funds to repave the state's highways and replace numerous bridges rendered deficient by age, increased traffic demand, overloading, and inadequate maintenance. MESA-DOT determined that design costs can be minimized for most bridges by using a generic superstructure needing only minor adaptations for each site. This strategy is viable only if the design accommodates the more challenging site conditions. Therefore, there are restrictions on transportation, site layout, and access over water. Serviceability, construction cost and duration, material cost, and esthetics are critical considerations. PVC is specified for ease of prefabrication, rapid construction, high strength to weight ratio, and high level of recycled content. Each competing firm (team) is requested to submit a bridge model to demonstrate its concept. Models will be constructed under simulated field conditions and will be tested for stability, strength, and serviceability using standardized vertical loads. MESA-DOT engineers will judge the models by multiple criteria including durability, constructability, usability, stiffness, construction speed, efficiency, economy, and aesthetics. The contract will be awarded to the firm whose model satisfies specified requirements and best achieves project objectives.

GLOSSARY

- *Bridge* – a structure constructed only of members and loose connections.
- *Member* – a rigid component. A member shall retain its shape, dimensions, and rigidity during timed construction and load testing.
- *Assembly* – two members that are joined together with a connection.
- *Footing* – a member of the bridge that makes contact with the ground. (*See layout for "footing area"*)
- *Builder* – a student member of a team who assembles the bridge.
- *Tool* – a device that is used to construct the bridge but is not part of the bridge.
- *Load* – a weight supported by the bridge

DESIGN PARAMETERS

1. Bridge members must be made of ½" **Schedule 40 PVC**.
2. Members shall not exceed overall dimensions of 2' x 6" x 6". That is, it shall fit into a right rectangular prism (i.e., box) of those dimensions.
3. Connections must be loose and can be made of PVC pipe connectors or other materials.
4. Dimensions of bridge (*See Diagrams in the Appendix for more info*)
 - a. The bridge's height shall not extend more than 5'0" above the ground or river.
 - b. The bridge shall not be less than 2'0" wide nor wider than 4'0" at any location along the span.
 - c. Except for the footings, the bridge shall not touch the ground. The river is 2' wide and the footings must be at least 2' and no more than 3' from the edge of the river.
 - d. A minimum vertical clearance of 1' 6" under the bridge shall be maintained at all points directly over the ground and river outside the footing area.

- e. The bridge shall have exactly two decking support surfaces that are continuous along the full length of the bridge and provides a straight rectangular vehicle passageway that will allow a vehicle to pass without obstruction along the decking support surfaces for the full length of the bridge. A “vehicle” template, illustrated by in the site plan, will be used to check that support surfaces conform to this rule. The vehicle template will be 2’0” wide by 1’0” tall.
- f. The height of the bridge’s loading surface shall be no more than 2’ 7” above the surface of the river or ground at any point.
5. All connections and members shall be visible in the completed bridge so that compliance with specifications can be verified.
6. Bridge must withstand a maximum of 100 pounds loaded vertically.
7. Bridge must have permanent identification of the bridge consisting of the name of the school. The name shall be applied to PVC with paint or decals, and should be easily legible (lettering at least 1” high is recommended).

TESTING CONDITIONS:

CONSTRUCTION GUIDELINES

- Only builders and judges are permitted within the construction site boundary during timed construction. Team members who are not builders, coaches, faculty, advisers, other associates of the team, and spectators shall remain in designated areas at a distance from the construction site that assures they are not at risk and cannot interfere with the competition.
- There shall be no more than six (6) and a minimum of two (2) builders.
- A tool shall not weigh more than fifteen pounds. Tools requiring external power connections, batteries, or other internal energy supplies shall not be used during timed construction.
- The clock is stopped when the team captain informs the judge that construction is complete. After construction is finished the bridge shall not be modified except for correction of connections that may become loose in transport.

SAFETY PRACTICES

- If any rule in this section is violated during timed construction, the judge will explain the violation. The clock will continue to run during the explanation. Builders will continue to construct their bridge safely. However, if they are not able to construct the bridge completely using safe procedures, construction will cease and the bridge will not be approved for load testing and will not be eligible for awards.
- Builders, judges, host personnel, and spectators shall not be exposed to risk of personal injury. Only builders and judges may be in the construction site.
- At all times during timed construction every builder shall wear personal protective equipment in the proper manner. Minimum safety equipment will consist of safety glasses and closed toed shoes.
- Throwing anything from builder to builder is prohibited.

SAFETY PRACTICES (continued)

- A builder shall not cross from the ground on one side of the river to the ground on the other side.
- A bridge with damage that would reduce its strength or stability (such as a missing or broken member) will not be approved for load testing and is not eligible for awards. Repair and modifications are not permitted after timed construction.
- It is the responsibility of judges, host personnel, and competitors to employ effectively all precautions, which are summarized in this sub-section. Competitors should follow the same precautions when proof testing bridges in preparation for competition.
- An activity shall be halted if the judge considers it to be hazardous. If competitors cannot load their bridge safely, loading will cease.
- Competitors who are not participating in loading, faculty, advisers, and other spectators shall observe from a safe area designated by the judges.
- Damaged bridges (e.g., missing or broken member) shall not be tested.
- Bridges may collapse suddenly without warning, and a failure may involve only one side so that the load tips sideways. The intent of the provisions of this subsection is to prevent personal injury if a bridge collapses.
- The number of people near the bridge shall be minimized during vertical load tests. No more than one (1) competitor shall participate in the vertical load test.
- Safety supports shall be provided by MESA, and shall be of adequate strength, height, and number to arrest falling load if a bridge collapses. Safety supports shall be in place under the decking units before load is placed on the bridge. Safety supports shall be adjusted individually for each bridge so that load cannot drop more than 5". Safety supports may be steel, nested stacks of plastic buckets, timbers, or sand bags.
- No one shall reach, crawl, or step under a bridge while any portion of vertical load is in place. If safety supports must be adjusted during loading, the load shall first be removed without disturbing the bridge, adjustments made, and the load replaced as it was before being removed.
- Judges shall observe the behavior of the bridge. Loading shall cease and the load shall be removed carefully if, in the opinion of a judge, collapse is imminent.
- Teams shall accept imperfect field conditions such as bent decking, sloping floors, and unfavorable floor surfaces.

EQUIPMENT PROVIDED BY MESA

- Safety supports of sufficient height, strength, number, and extent shall be provided.
- A piece of decking will be placed on bridges before loading. Decking will be a 2' x 2' piece of half-inch plywood. Decking is not included as part of the 100 pound load.
- A total load of 100 pounds should be supplied in pieces of uniform size and weight that can be handled safely. The recommended load consists of books, sacks of material, containers of liquid, concrete blocks, jacking systems or steel pieces.
- Vehicle template will be supplied to assure the bridge meets the usability requirements, which dimensions are provided in the Diagrams.

SPECIFICATION CHECK:

1. During specification check, teams will check in to the competition area and will receive an assigned building area. All bridge materials and tools will be submitted for impounding.
2. Immediately upon submission for competition, bridge members and tools will receive a specification check to determine whether it conforms to dimensions, materials, and construction rules. Any bridge which fails the initial specification check will be given a performance score of zero. No modifications will be allowed for competition during or after judging.
3. All materials that will constitute the finished bridge will be weighed. Weight will be recorded in pounds (lb) and this will be used as the final weight of the bridge. All these materials will be placed in the "bridge members".
4. Judges **may disqualify** any entry if, in their opinion, the testing of the device might create a safety hazard for spectators, team members, or property (i.e. sharp edges).
5. After construction is completed, bridge will receive a second specification check to determine whether it conforms to remaining dimension, material, and construction rules. Judges will check to ensure that all parts that were weighed have been used and no additional parts have been added. Any bridge which fails the secondary specification check will be given a performance score of zero.
6. Repairs are allowed, replacement parts and materials only, and all repairs must be done under supervision of a judge.
7. All repair materials to be used during the competition must be impounded with the other materials and labeled as "spare parts".

JUDGING:

1. Teams (including materials and tools) must be ready for competition when called. Teams not ready will not be allowed additional construction time to complete their bridge.
2. Judges will inform teams when their construction time starts. Teams will have 45 minutes to complete construction. If construction time exceeds 45 minutes, the team may finish building the bridge. Consequently, the bridge will receive a time of 60 minutes for the time score, but will still be load tested.
3. All team members participating in the build shall wear at least the minimum safety equipment prior to starting until building is complete. See Safety Practices section for more information.
4. When teams are close to completing their bridge, they must inform the judges so that they are prepared to check the completion time.
5. When building is completed, teams will inform judges they are done and judges will note the time and record it in minutes on the score sheet.
6. Judges will then provide teams instructions for load testing. See Safety Practices for load testing information.
7. Bridges will be tested to ensure that they hold a maximum of 100 pounds of vertical load. Judges may refuse to add load based on their observations of the bridge. The last load safely held will be used for scoring.

SCORING

- The overall performance rating of a bridge will be determined by the following formula:

$$(\text{Builders} \times \text{Construction Speed} \times \text{Weight of Bridge}) / \text{Load Held}$$

Scoring Example:

Team A had 3 builders participate. It took them 40 minutes to complete their bridge, and their bridge weighed 12 lb. The bridge held the maximum 100 pound load. Their score would be:

$$(3 \times 40 \times 12) / 100 = 1140 / 100 = 11.4$$

- The team with the lowest score wins.



School: _____

Student Names: _____

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Specification Check Pre-Build (circle one):	Pass	Fail
Bridge only uses 1/2" Schedule 40 PVC for structural members?	Yes	No
Members are within the allowed dimensions (2'0" x 6" x 6")	Yes	No
Connections are loose	Yes	No

Specification Check Post-Build (circle one):	Pass	Fail
Bridge does not touch the ground or water, except for footings?	Yes	No
Footings are between 2' and 3' from edge of river?	Yes	No
Bridge does not extend more than 5'0" above the ground/river?	Yes	No
Bridge is not wider than 4'0" anywhere along the span?	Yes	No
Bridge has a Vertical clearance under the bridge of at least 1'6"?	Yes	No
Has two decking support surfaces and does not obstruct Vehicle Clearance Template	Yes	No
Decking support surfaces that are no more than 2'7" above the ground/river	Yes	No
All connections and members are visible	Yes	No
Bridge has permanent identification (name of school)	Yes	No

Design Testing:

Builders: _____ (people)

Construction Speed: _____ (minutes)

Weight of Bridge: _____ (pounds)

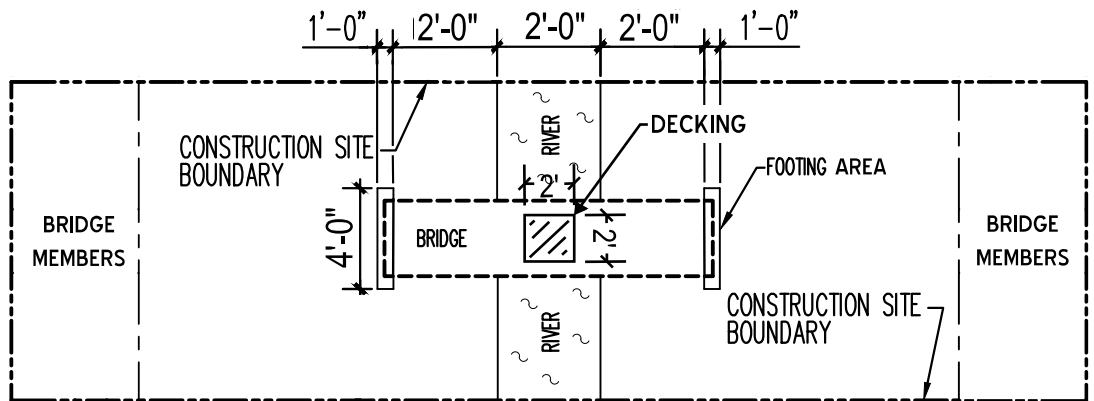
Load: _____ (pounds)

Overall Performance = (Builders x Construction Speed x Weight of Bridge)/Load:

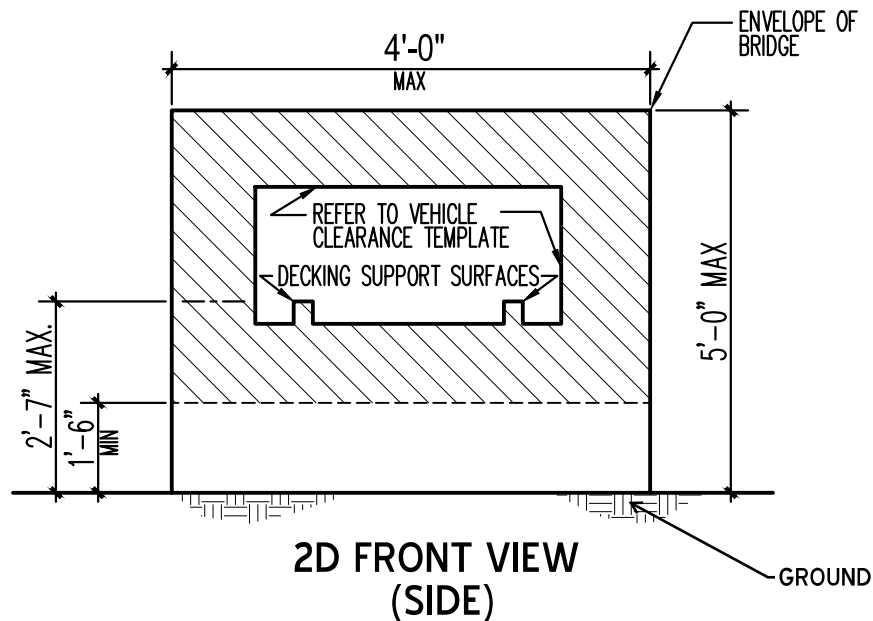
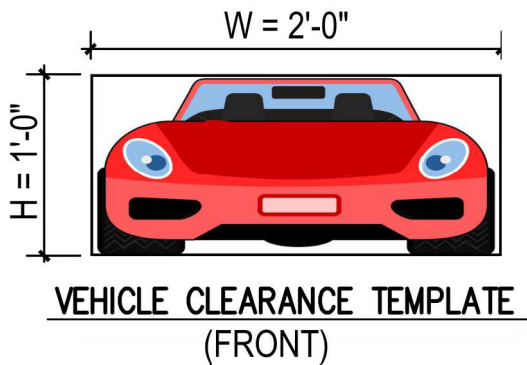
Lead Judge Signature: _____ Student Signature: _____

Comments/Suggestions:

SITE PLAN



2D PLAN VIEW
(TOP)



2D FRONT VIEW
(SIDE)

REV.	BY	DATE	APP.	REC. NO.	EXPIRES	SEAL HOLDER

2017 PVC BRIDGE RULES
DESCRIPTION

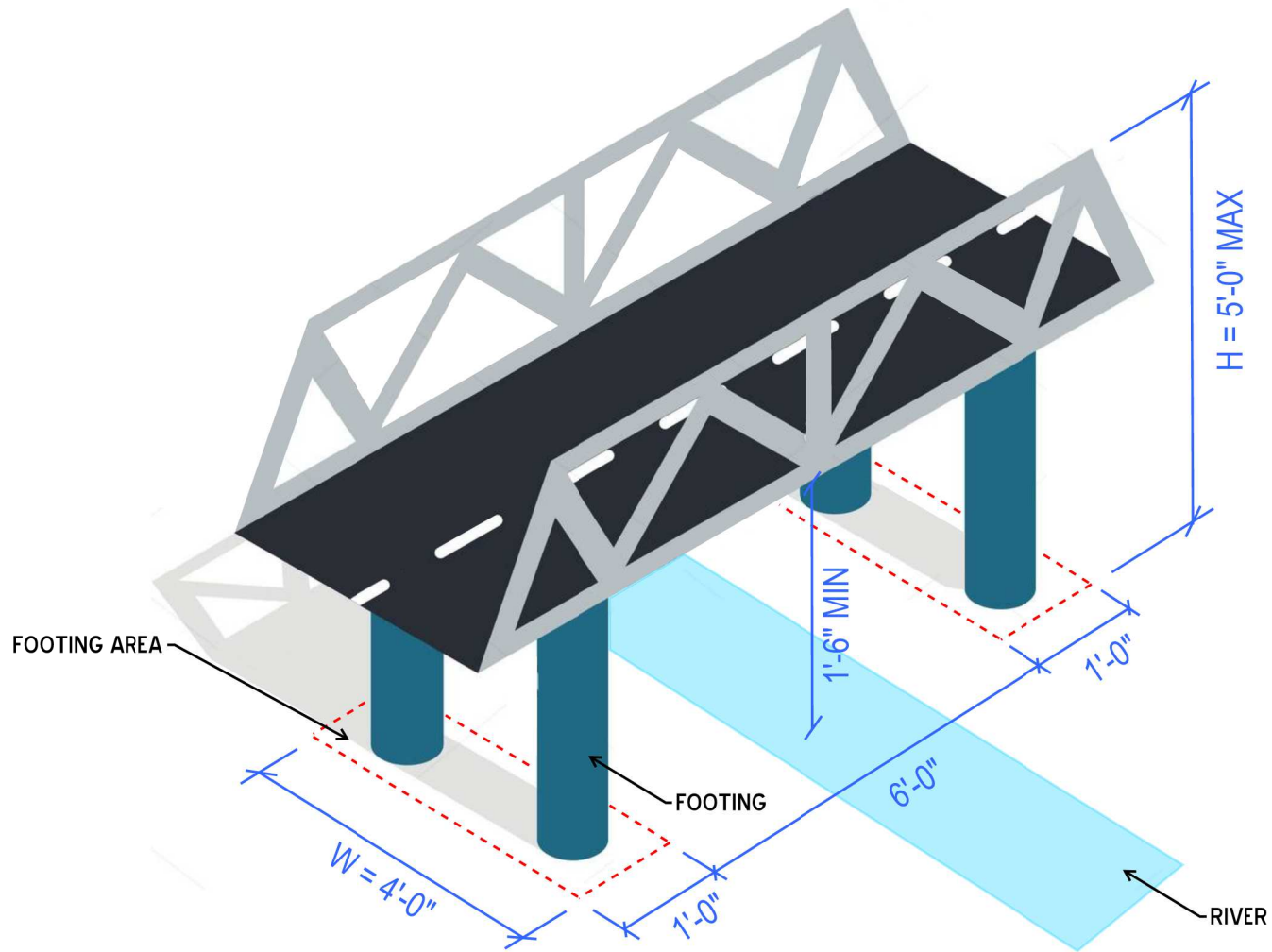
DESIGNED BY J. AGUILAR
 DRAWN BY J. AGUILAR
 CHECKED BY B. PIKE
 IN CHARGE M. LEON
 DATE 09/16



SUBMITTED _____
 APPROVED _____

SITE AND BRIDGE
 DIAGRAM

CONTACT NUMBER
 DRAWING NO. DWG 1
 SCALE NTS
 SHEET NO.



3D BRIDGE VIEW
(SIDE)

REV.	BY	DATE	APP.	REC. NO.	EXPIRES	SCALE	HOLDER	DESCRIPTION

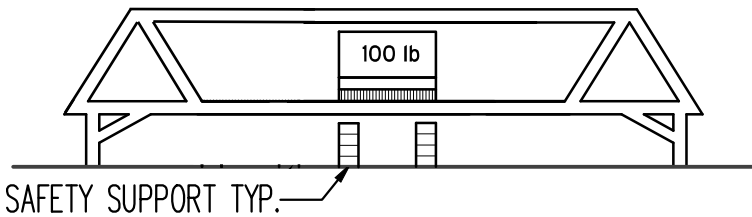
DESIGNED BY J. AGUILAR
 DRAWN BY J. AGUILAR
 CHECKED BY B. PIKE
 IN CHARGE M. LEON
 DATE 09/16



SUBMITTED _____
 APPROVED _____

3D VIEW

CONTACT NUMBER _____
 DRAWING NO. DWG 2
 SCALE NTS
 SHEET NO. _____



SAFETY SUPPORT TYP.

VERTICAL LOAD TEST

NOTES:

1. SAFETY SUPPORTS TO BE IN PLACE UNDER THE LOAD AND TO REMAIN AT ALL TIMES DURING LOADING.
2. ALL LOADING SAFETY PROCEDURES TO BE FOLLOWED.

							DESIGNED BY J. AGUILAR	 	 Mathematics Engineering Science Achievement	SUBMITTED _____ APPROVED _____	LOADING DIAGRAMS	CONTACT NUMBER
							DRAWN BY J. AGUILAR					DRAWING NO. DWG 2
							CHECKED BY B. PIKE					SCALE NTS
							IN CHARGE M. LEON					SHEET NO.
REV.	BY	DATE	APP.	REC. NO.	EXPIRES	SEAL HOLDER	2017 PVC BRIDGE RULES	DATE	09/16			
							DESCRIPTION					