STRUCTURAL ENGINEERING

OVERVIEW

Teams apply the principles of structural design and engineering through basic research, design, construction, and destructive testing to determine the design efficiency of a structure. Details about the structure and information related to it will be posted on the TSA website under Competitions/Themes and Problems. The on-site semifinalist problem will be a variation of the pre-conference problem posted on the TSA website.

ELIGIBILITY

One (1) team of two (2) individuals per chapter may participate.

SAFETY EYEWEAR

Participants are required to wear safety-approved eyewear during the on-site phase of this event. Prescription eyewear will need to have side shields to be considered safety eyewear. Should a team member remove the eyewear and fail to replace it, he/she will be reminded once. If there is a second infraction, the team will be disqualified. Sunglasses are not suitable.

TIME LIMITS

1. On-site structures (semifinalist teams only) must be started, completed, and checked in during the three (3) hours allowed for design and construction.
2. Semifinalist participants with time conflicts must present a written explanation of the conflict to the event coordinator at least one (1) hour before the construction time noted in the conference program. Work must begin during the time scheduled for the event.

ATTIRE

TSA competition attire is required.

PROCEDURE

PRE-CONFERENCE

1. Teams review the details about the structure under Competitions/Themes and Problems on the TSA website.
2. Participants conduct research and apply principles of structural design and engineering to their current structure while considering the theme.
3. Pre-built structures must be started and completed during the current school year.
4. All work must be completed by the team members only, and verified by the team's chapter advisor using the Team Verification form.
5. Teams must provide a full-size, three (3)-view (front, top, and right end) drawing (hand or computer-generated) of their structure.

PRELIMINARY ROUND –
On-site Destructive Testing of Pre-Built Structures

1. Participants check in the following at the time and place stated in the conference program:
   a. Pre-built structure and any related required materials (including the Analysis and Assessment form)
   b. Portfolio documentation materials
   c. A hard copy of the LEAP Response with no report cover, separated from the portfolio
2. Participants are required to wear safety approved eyewear (refer to the Safety Eyewear section of this guide).
3. Structures will be assessed and will undergo destructive testing.
4. Destructive testing of pre-built structures is not open for public viewing.
5. Destructive testing will be completed using structural testing equipment, as designated by TSA.
6. When the destructive testing is completed, a list of twenty (20) semifinalist teams will be posted.

SEMIFINAL ROUND – On-site Construction

1. The twenty (20) semifinalist teams will take part in the on-site problem, which will feature the construction and destructive testing of a designated structure to determine the ten (10) finalist teams.
2. Twenty (20) semifinalist teams report to the event area at the time and place stated in the conference program.
3. Teams will be seated by a monitor.
4. The design problem will be explained and a list of directions for the construction problem will be provided.
5. Teams have a three (3) hour window when drawing begins and building stops, typically allotted as:
    a. Thirty (30) minutes to review the problem and create a sketch/drawing of their solution.
    b. Two and one-half (2 and ½) hours to review the problem and construct a solution.
6. During the building of the team's structure, construction regulations must be observed.
7. All work stops at the coordinator's signal. Teams that fail to comply with coordinator or monitor directions, after one (1) warning, will be issued a penalty of 20% of the team's total score.
8. Participants may leave early, but they must first complete check-out as directed.
9. Teams return all supplied items as directed, and clean and clear their work stations. Failure to do so will result in a 20% penalty deduction.
10. Teams must identify their structure with only their team ID number, using the label provided.
11. Structures are allowed to dry in a secure area until destructive testing time.

SEMIFINAL ROUND – Destructive Testing

1. Structures are checked for rules violations and weighed before testing.
2. Destructive testing is completed by evaluators and is open for spectator viewing.
3. When all testing is completed, the greatest failure weight of all tested structures is recorded on the rating form, the efficiency rating of individual structures is calculated, and ranking is determined.
4. Judges review the LEAP Response.
5. The top ten (10) finalist teams will be announced.

REGULATIONS AND REQUIREMENTS

PRE-CONFERENCE

A. Documentation materials (comprising a "portfolio") are required and must be secured in a clear front report cover (click here for a sample) including the following single-sided, 8½" x 11" pages, in this order:
    1. Title page that includes the event title, the conference city and state, the year, and the team/chapter ID number; one (1) page
    2. Team Verification form completed
    3. The Analysis and Assessment form completed.
    4. Completed LEAP Response
    5. Full size drawing of one-side view of your structure.
    6. A cut parts list of the materials used in the construction of your structure.

PRELIMINARY ROUND

A. Participants must provide and wear safety glasses for this portion of the event.
B. Drawing and pre-built structures must be completed prior to check-in.
C. The testing of pre-built structures is not open to spectators.

SEMIFINAL ROUND

A. Participants must provide and wear safety glasses for this portion of the event.

B. Participants are required to provide their own tool box (with identification [school name, address, and advisor cell phone number]), which should not exceed twenty (20) inches (508 mm) length x ten (10) inches (254 mm) width x ten (10) inches (254 mm) height. The box must contain all items needed to fabricate the solution.
   1. The following is a suggested list:
      a. Cutting devices; NONE may be electric
      b. Adhesives
         i. Aerosol and electric applicators are not allowed
         ii. A bottle of Uncure or Debonder is recommended
      c. Temporary fastening devices
         i. Straight pins
         ii. Clamps
         iii. Tape
      d. A cutting surface that prevents table-top marring (required)
      e. Rulers, straightedges, and/or measuring scales
      f. Abrasives sheets, sanding sponges, emery boards
      g. Marking devices (pens, pencils, etc.) and sharpener
      h. Sheet of wax paper, as large as is needed for the competition (required)
      i. Pliers, wrenches, nut drivers, as needed
      j. Safety glasses and side shields, as required

C. Planning and fabrication supplies are provided by TSA. Teams will be issued a packet of construction materials (necessary balsa wood) to use for fabrication of the on-site designed structure once the team's drawing of the on-site solution is complete.
   1. Planning and fabrication supplies (these materials may not be part of the structure submitted for testing):
      a. 11" x 17" paper with ¼" grids for sketching the structure
      b. Pin board
      c. A sheet of wax paper
      d. Structure label

D. Teams that fail to comply with coordinator or monitor directions, after one (1) warning, will be issued a penalty of 20% of the team's total score.

E. Filming and the taking of photographs is prohibited during the viewing of structure, judging, and testing.

F. LEAP Response:
   1. Teams document the leadership skills the team has developed and demonstrated while working on this event and on a non-competitive event leadership experience.
   2. Find the specific LEAP Response regulations in the LEAP Program section of this guide and on the TSA website.

EVALUATION

Evaluation is based on the compliance and design efficiency of a pre-built structure and an on-site structure (semifinalists only), both of which are destructively tested, and the content and quality of the LEAP Response (semifinalists only).

Please see the official rating form for more information.

STEM INTEGRATION

This event has connections to the STEM areas of Science, Technology, Engineering, and Mathematics.

TSA AND CAREERS

This competition has connections to one (1) or more of the careers below:

- Architect
- Civil engineer
- Engineering technician
- Mathematician
- Structural engineer
- Structural iron and steel work technician

Participant/Team ID# _____

STRUCTURAL ENGINEERING – MIDDLE SCHOOL ANALYSIS AND ASSESSMENT

PRE-BUILT STRUCTURE	
For TEAMS:	
How many structures were designed, built, and tested prior to competition?	
Record the weight of the structure designated for competition:	
Predict the ultimate load-carrying capacity of the structure:	
Predict where or how the structure will fail:	
What are the four major types of forces that act on a structure under stress?	
What is the static load of a structure?	
What part of a testing device should be considered live load?	
What effect would a shorter length test block have during stress testing?	
For JUDGES:	
Record the weight of the structure after check-in and prior to testing:	
Record the actual load-carrying capacity of the structure:	

Participant/Team ID# _____

STRUCTURAL ENGINEERING

2020 & 2021 OFFICIAL RATING FORM

MIDDLE SCHOOL

Judges: Using minimal (1-3 points), adequate (4-7 points), or exemplary (8-10 points) performance levels as a guideline, record the scores earned for the event criteria in the column spaces to the right. The X1 or X2 notation in the criteria column is a multiplier factor for determining the points earned. (Example: an "adequate" score of 7 for an X1 criterion = 7 points; an "adequate" score of 7 for an X2 criterion = 14 points.) A score of zero (0) is acceptable if the minimal performance for any criterion is not met.

Go/No Go Specifications

- Before judging the entry, ensure that the items below are present; indicate presence with a check mark in the box.
- If an item is missing, leave the box next to the item blank and place a check mark in the box labeled ENTRY NOT EVALUATED.
- If a check mark is placed in the ENTRY NOT EVALUATED box, the entry is not to be judged.

- ☐ Team of two is present.
- ☐ The structure is present, identified, and in its storage box.
- ☐ The Team Portfolio is present and includes:
  - ☐ The Team Verification form completed
  - ☐ The Analysis and Assessment form completed
  - ☐ Full size drawing of one-side view of your structure
  - ☐ A complete cut parts list for your structure
- ☐ Completed LEAP Response is present.
- ☐ ENTRY NOT EVALUATED

PRE-BUILT STRUCTURE (Construction) – (40 points)				
Indicate N for non-compliant or C for compliant, for each regulation in the Construction section. One non-compliant mark will result in the entry not being evaluated. Dimensional criteria will have a tolerance of + or -⅛" for height.				
Regulation	**Noncompliant**		**Compliant**	
Outside width of structure	The outside width of the structure is greater than the designated construction width; the structure does not fit inside the PVC testing tube.		The outside width of the structure is within the designated tolerance of the assigned construction width.	
Outside height of structure	The height of the structure is greater or less than the designated tolerance of the assigned construction height.		The height of the structure is within the designated tolerance of the assigned construction height.	
Inside structure width	The inside structure space is less than the required construction space; the PVC test pipe does not fit inside of the structure.		The inside structure space is greater than the required construction space; the PVC test pipe fits inside of the structure.	
Construction materials	Material other than ⅛" by ⅛" balsa was used in the construction of the tower.		Only ⅛" by ⅛" balsa was used in the construction of the tower.	
Substructure*	A substructure is present.		No substructure is present	
Laminations	Laminations were used in the construction of the tower.		No laminations were used in the construction of the the tower.	
Coating of materials*	Coating of the construction materials with glue is present.		No coating of the construction materials with glue is present.	
Testing rod and block clearance*	The testing block and rod cannot be placed and passed through the center of the structure to allow for testing.		The testing block and rod pass freely through the center of the structure to allow for testing.	

PRE-BUILT STRUCTURE (Construction) – continued	
DISQUALIFIED	
PRE-BUILT STRUCTURE APPROVED FOR TESTING	
Record the mass (weight) of the structure (in grams to the nearest tenth of a gram) prior to testing.	
Record the failure weight in pounds to the nearest tenth of a pound.	
Determine the efficiency (shown to three decimal places) by multiplying the failure weight (or adjusted failure weight, as applicable) by 4.54 and then dividing by the mass (weight) of the structure.	

PRE-BUILT STRUCTURE TOTAL POINTS (40 points)	

DRAWING (10 points)

CRITERIA	Minimal performance	Adequate performance	Exemplary performance	Record scores in the column spaces below.
	1-3 points	4-7 points	8-10 points	
Drawing (X1)	The submitted drawing was incomplete, not accurate, of proper quality, or was not to scale; a complete parts list was not included.	The submitted drawing was complete but lacked clarity, accuracy, or was of poor quality; the parts diagram was not complete or was incorrect.	The submitted drawing was complete, accurate, and to scale; the parts list was complete and accurate.	
			DRAWING SUBTOTAL (10 points)	

PRELIMINARY SUBTOTAL (50 points)	

ON-SITE STRUCTURE (Qualification) – (40 points)

For the ON-SITE STRUCTURE: Indicate N for non-compliant or C for compliant, in the Qualification and Construction sections below. In the Qualification section, one non-compliant mark will result in disqualification. In the Construction section, one non-compliant mark will result in the structure not being evaluated. Dimensional height criteria will have a tolerance of + or -⅛"

Regulation	**Noncompliant**		**Compliant**	
Team of two	Only one (1) team member is present.		Both team members are present	
Safety eyeware	Warnings about eyewear are issued.		No warnings about eyewear are issued.	
Structure identification	The identification sticker is not attached.		The identification sticker is attached.	
Tools and fabrication supplies	Inappropriate tools or supplies are brought to the event.		Appropriate tools and supplies are brought to the event.	

ON-SITE STRUCTURE (Construction)				
Outside width of structure	The outside width of the structure is greater than the designated construction width; the structure does not fit inside the PVC testing tube.		The outside width of the structure is within the designated tolerance of the assigned construction width.	
Outside height of structure	The height of the structure is greater or less than the designated tolerance of the assigned construction height.		The height of the structure is within the designated tolerance of the assigned construction height.	
Inside structure width	The inside structure space is less than the required construction space; the PVC test pipe does not fit inside of the structure.		The inside structure space is greater than the required construction space; the PVC test pipe fits inside of the structure.	
Construction materials	Material other than ⅛" by ⅛" balsa was used in the construction of the tower.		Only ⅛" by ⅛" balsa was used in the construction of the tower.	
Substructure*	A substructure is present.		No substructure is present	
Laminations	Laminations were used in the construction of the tower.		No laminations were used in the construction of the tower.	
Coating of materials*	Coating of the construction materials with glue is present.		No coating of the construction materials with glue is present.	
Testing rod and block clearance*	The testing block and rod cannot be placed and passed through the center of the structure to allow for testing.		The testing block and rod pass freely through the center of the structure to allow for testing.	
			DISQUALIFIED	
			On-site structure approved for testing	
			Record the mass (weight) of the structure (in grams to the nearest tenth of a gram) prior to testing.	
			Record the failure weight in pounds to the nearest tenth of a pound.	
			Determine the efficiency (shown to three decimal places) by multiplying the failure weight (or adjusted failure weight, as applicable) by 4.54 and then dividing by the mass (weight) of the structure.	

ON-SITE STRUCTURE TOTAL POINTS (40 points)	

SEMIFINAL LEAP RESPONSE (10 points)				Record scores in the column spaces below.
CRITERIA	Minimal performance	Adequate performance	Exemplary performance	
	1-4 points	5-8 points	9-10 points	
LEAP Response (X1)	The team's efforts are not clearly communicated, lack detail, and are unconvincing; few, if any, attempts are made to identify and incorporate the SLC Practices.	The team's efforts are adequately communicated, include some detail, are clear, and are generally convincing; identification and incorporation of the SLC Practices are satisfactory.	The team's efforts are clearly communicated, fully-detailed, and convincing; identification and incorporation of the SLC Practices are excellent.	
			SEMIFINAL LEAP RESPONSE SUBTOTAL (10 points)	

Rules violations must be initialed by the judge, coordinator, and manager of the event. Record the deduction in the space to the right. Indicate the rule violated: _____	
SEMIFINAL SUBTOTAL (50 points)	
To arrive at the TOTAL score, add any subtotals and subtract rules violation points, as necessary. **TOTAL** (100 points)	

Comments:

_____

I certify these results to be true and accurate to the best of my knowledge.

JUDGE

Printed name: _____ Signature: _____

STRUCTURAL ENGINEERING
EVENT COORDINATOR INSTRUCTIONS

PERSONNEL

A. Event coordinator

B. Judges

1. Preliminary round to evaluate pre-built structures, two (2) or more
2. Semifinal round, to qualify structures after construction, two (2) or more
3. Semifinal round, destructive test judges, two (2) or more
    a. One (1) to weigh the structure, record structure weight, and record failure weight
    b. One (1) to bring the structure to the testing location, position the structure on the testing device, operate the tester, and then remove and store the structure following testing

C. Construction monitor, one (1) per twenty teams

D. Timekeeper, one (1)

MATERIALS

A. Coordinator's packet, containing:

1. Event guidelines, one (1) copy for the coordinator and each judge
2. TSA Event Coordinator Report
3. List of judges/assistants
4. Stick on labels for identifying entries
5. Results envelope with coordinator forms

B. Testing equipment, provided by TSA

C. Sample structures for both testing sessions that can be used to demonstrate the testing procedure and to determine that the testing equipment is working properly.

D. Evaluation and recording equipment

1. Gram scale (3-decimal place calculation)
2. Tape measure or 2' rule
3. Evaluation gauges (rulers)

E. Site requirements

1. Construction session
    a. Tables and chairs suitable for cutting and gluing
    b. Work area, at least 2' x 3' for each team (suggested space is two (2) teams per 6' x 2' or 8' x 2' area)
    c. One (1) chair per participant
    d. Tables for equipment check-out and check-in
    e. Tables and chairs for evaluators
    f. Secured area for drying entries and storing supplies
2. Testing session
    a. Tables for storage of structures
    b. Table for weighing
    c. Table for testing
    d. Table for recording
    e. Tables for storage of failed structures
    f. Chairs for spectators
    g. Barricade to separate testing area from spectators
3. Semifinalist team packets provided by TSA containing construction materials and instructions.
    a. Construction tools per team, to be used and returned to the event coordinator or helpers after construction:
        i. Pin board as supplied, but generally a one-foot by two-foot (1' x 2') piece of fiber or foam board
        ii. Grid paper, ¼" x ¼" grid on 11" x 17" paper for structure sketch (to remain with the completed structure when turned in)
        iii. Wax paper to cover the pin board (to remain with the completed structure when turned in)
        iv. Label for structure
    b. Construction materials – Balsa as needed for each team
    c. Instructions

RESPONSIBILITIES

A. Prepare the structure problem statement (including any necessary related information) for posting on the TSA website.

AT THE CONFERENCE

1. Attend the mandatory coordinator's meeting at the designated time and location.
2. Report to the CRC room and check the contents of the coordinator's packet.
3. Review the event guidelines and check to see that enough personnel have been scheduled.
4. Check to see that all event equipment and materials have been secured.
5. One (1) hour before the event is scheduled to begin, meet with judges/assistants to review time limits, procedures, and regulations. If questions arise that cannot be answered, speak to the event manager before the event begins.

PRELIMINARY ROUND

1. Oversee participant check-in of the following entries:
   a. Pre-built structure and any related required materials (including the Analysis and Assessment form)
   b. Portfolio documentation materials
   c. A hard copy of the LEAP Response with no report cover, separated from the portfolio
2. Coordinate and manage the on-site testing of pre-built structures.
3. Coordinate the recording and tabulation of results with judges (refer to the Evaluation section of this event).
4. Determine the twenty (20) semifinalist teams.
5. Submit semifinalist results to the CRC for posting.
6. Assemble semifinalist packets of construction materials and directions for the twenty (20) on-site semifinalist teams.

SEMIFINAL ROUND
Team Check-in for On-site Construction

1. Check-in will begin at the time noted in the conference program and will continue until all teams arriving on time have been checked in and seated. The event will begin at the posted time.
2. Both members of a team must be present during check-in.
3. No team is allowed to begin late unless its members have complied with the following: Participants with time conflicts must present a written explanation of the conflict to the event coordinator at least one (1) hour before the construction time noted in the conference program.
4. Work must begin during the time frame scheduled for this portion of the event.

SEMIFINAL ROUND
On-site Construction

1. Assign team construction locations.
2. When all teams are seated, distribute instructions and review these, as well as any details for the assigned structure.
3. Teams will be allowed a maximum of three (3) hours to complete their structure:
   a. Thirty (30) minutes of this time is allotted for completing the design drawing.
   b. Two and one-half (2 ½) hours, is allotted for actual construction.
4. When a team notifies a monitor that the required sketch is complete, and the monitor confirms this, the team will receive a materials packet and may begin the on-site construction phase of the event.
5. No additional supplies are provided during the event.
6. Call time at the end of the allotted three (3) hour time-frame. All teams must stop working at this point.
7. All work stops at the coordinator's signal. Note any teams that fail to comply with coordinator or monitor directions after one (1) warning and issue a penalty of 20% to the team's total score.

SEMIFINAL ROUND
Team Check-out

1. Establish the procedure for check-in and recording of finished structures.
2. Designate an area for storage, and allow for the return of construction materials.
3. Coordinate the return and removal of all supplied items and ensure that teams clean and clear their work stations. Deduct a 20% penalty for teams that do not comply.

4. Teams check-in excess supplies as directed by the monitors.
5. Ensure that teams identify their structure with only their team ID number, using the label provided.
6. Teams place their structures in the storage area with the sketch as directed by the monitor. The structure must be identified with the team number only (using the label provided in the materials packet).
7. Once check-out is complete, all participants leave the competition area. Participants may leave early, but they must complete check-out as directed.
8. The structures are secured by the monitor and allowed to dry for a minimum of twelve (12) hours.

SEMIFINAL ROUND

Destructive Testing

1. After the structures have dried, judges report to the event area at the time and place stated in the conference program.
2. Judges test each structure and spectators are permitted during the testing period.
3. Judges evaluate the LEAP Response.

EVALUATION

1. Check (with assistance from judges) all structures for regulations compliance. Structures that are in compliance will be tested without penalty.
   a. Weigh all structures before testing and record the weight on the evaluation rubric.
   b. Use the testing device, designated by TSA, to test each structure. (A specific testing block or attachment for the structure may be necessary for the on-site problem.)
   c. Apply an increasing load to the structure, via the test block or attachment, until the structure fails.
   d. Record the greatest failure weight on the rubric. This weight is the greatest weight recorded (of all the tested structures) during testing before they fail.
   e. Determine each structure's efficiency by the greatest failure weight x 4.54, divided by the weight of the structure in grams; round off the efficiency to three (3) decimal places and record it on the rubric.
   f. The highest numeric efficiency determines the winner. In the case of an efficiency tie, the greatest weight held by the tied entries will determine the winner.
2. Structures will not be tested if:
   a. A non-compliance construction regulation violation was determined before testing.
   b. The structure cannot be placed on the tester.
   c. The testing attachment cannot be properly placed within or on the structure.
   d. Straight pins are left in the structure.
   e. There is a failure of a participant to wear safety eyewear and/or to follow safe practices.
   f. Laminations fail to comply with the guidelines as specified in the current year's challenge.
   g. Failure to use each of the materials specified in the current year's challenge.
3. Structures with one (1) construction regulation non-compliance mark will be tested, but a 20% penalty will be noted on the rating form. (The penalty, a 20% reduction of the greatest weight held in the competition, is subtracted from the team's failure weight. This penalty factor will not be determined until all structures have been tested).
4. Manage, with assistance from judges, the destructive testing of all structures that were not officially tested due to non-compliance.
5. Decisions about rules violations must be discussed and verified with the judges, event coordinator, and the CRC manager to determine either:
   - To deduct twenty percent (20%) of the total possible points in this round
   - To disqualify the entry

   The event coordinator, judges and CRC manager must all initial either of the violations on the rating form.
6. Submit the finalist results and all other related forms in the results envelope to the CRC room.
7. Semifinalist teams may pick up their structures at a time determined by the event coordinator.