2021 APT PETC SPECIFICATIONS

The Masonry Arch

APT Preservation Engineering Technical Committee
Student Design-Build Competition

Engineering problems with unreinforced masonry arches require an understanding of masonry design and construction technologies, including present day techniques and those utilized at the time of construction. While these types of structures are common elements in the existing building stock, fewer and fewer practitioners have opportunities to get hands-on experience to gain an understanding into their behavior and repair methodologies. This year's competition will expose competitors to the multi-billion-dollar masonry conservation field.

In This Package

This package provides information about this year's Student Design-Build Competition hosted by APT's Preservation Engineering Technical Committee. In this document you will find background information, an overview of the competition phases, as well as the specifications and competition requirements. ***Take a look to see if you and your team are inspired to enter!***

Quick Dates Guide

The following schedule is preliminary and may be subject to change. PETC will notify teams should dates or deadlines change.

DATE	ITEM	DEADLINE/INFO
January 2021	Competition Information Announced	Info
Mid-January 2021	Specifications Package Released	Info
February 15, 2021	Team requests for PETC to clarify any questions regarding Phase 1	Last Day
February 28, 2021	**Teams submit Phase 1: Notice of Participation and Arch Selection**	**DEADLINE**
March 1 – 5, 2021	Teams can contact PETC to confirm receipt of Phase 1 submission	Info
March 8, 2021	PETC notifies teams that will move from Phase 1 to Phase 2	Info
April 13, 2021	**Phase 2 Teams submit Financial Plan**	**DEADLINE**
April 23, 2021	Team requests for PETC to clarify any questions regarding Phase 2	Last Day
May 15, 2021	**Teams submit Phase 2: Report, Design-Build, and Videos**	**DEADLINE**
May 17 – 21, 2021	Teams can contact PETC to confirm receipt of Phase 2 submission	Info
About June 7, 2021	PETC notifies the teams that are invited to the Phase 3 Finals	Info
September 1, 2021	Requests for clarification of Phase 3	Last Day
(Late September 2021)	(Phase 3 Digital Posters and potentially build/load videos due if conference is fully virtual)	**(DEADLINE TBD)** (PETC will provide more info and advance notice)
October 27 – November 2, 2021	**Phase 3 Competition**	**Finalists Compete at APT Conference**

Contents

APT PETC's Student Design-Build Competition began in 2016 with the Timber Bridge at the San Antonio conference, and two schools, Texas A&M University and Carleton University, competed in the finals. In 2017, teams at the Ottawa conference competed in the first Masonry Arch competition. From there, the competition has alternated between the Timber Bridge (Buffalo 2018 and Edmonton 2020) and the Masonry Arch (Miami 2019). This year, the competition returns to the Masonry Arch. PETC looks forward to your submissions!

2021
The Masonry Arch

APT Preservation Engineering Technical Committee Student Design-Build Competition

Introduction

Conservation of masonry structures is a multi-billion-dollar industry in North America, with an ever-growing demand for qualified and capable designers and trades people. Structural arches have been used in construction for centuries to span openings while adding significant heritage value to a masonry structure.

This year, the Association for Preservation Technology (APT) Preservation Engineering Technical Committee (PETC) Student Design-Build Competition will focus on masonry design and conservation by highlighting the intricacies of masonry arch construction and the technologies used for their preservation.

Team will be tasked to research, design, and build a masonry arch to understand their design and preservation principals which allow these structures to withstand the test of time.

Competition Objectives

The Design-Build competition challenges students from a range of backgrounds in a friendly competition atmosphere while providing the best "take-away" educational and team-building experience possible.

The key objectives of this competition include:

1. Expose students to the fundamentals of researching and analyzing a historic masonry arch.
2. Expose students to the materials common in masonry construction and preservation by providing a hands-on experience.
3. Introduce students to preservation engineering fundamentals, using a real structure as a case study.
4. Promote "out of the box" learning and problem solving.

5. Promote interaction between students and APT members though mentoring during the on-campus work and networking during conference finals.
6. Expose students to real project experience elements by understanding logistics, stakeholders' interactions, project budgeting, and constructability constraints.

Desired Learning Outcomes

1. Understand the value of multi-disciplinary teams
2. Learn to manage a team
3. Build networks to engage external professionals
4. Understand the basics of traditional masonry design and construction
5. Transfer design to physical construction
6. Design and execute a laboratory testing procedure
7. Learn from conference presentations and other activities

Competition Framework

The competition is structured into three phases. Phases 1 and 2 have teams working at their home campuses to identify an existing masonry arch, analyze that arch, and build a model of an arch according to their own design. Phase 3 (the finals) will culminate at the 2021 APT Conference in Washington, DC, and will include team presentations of research, an on-site build competition, and answering preservation challenges in front of the APT community live (in-person or virtually) at the conference. *Refer to the Technical Specifications and Appendix for details.*

- **Phase 1**
  - Notice of Participation
  - Masonry Structure (Arch) Selection and Reporting
- **Phase 2 – On-Campus Report, Design-Build, and Videos**
  - Home-campus Masonry Arch Build and Videos
  - Report (Background Research, Structural Analysis, Conservation Plan, Etc.)
- **Phase 3 – Finals**
  - Present and Display Posters at APT Conference
  - Conference "Dry Stack" Arch Build
  - Answer Preservation Problems

COVID-19 Disclaimer

The APT PETC Student Design-Build Competition Committee aims to host a successful and safe competition. The APT conference is currently scheduled to be in-person. Should the APT Conference Committee determine the conference will be changed to a virtual environment (as was done in 2020), revised Phase 3 requirements will be issued to all finalist teams.

Teams reaching Phase 3 may choose to compete in the conference remotely ("virtually"), regardless of the conference platform. PETC will strive to provide a fair and equal opportunity to for those teams to participate virtually.

Conference Schedule

APT's Annual Conference is scheduled to be held in Washington, DC, from **October 27-November 2, 2021**. Phase 3 of the Student Design-Build Competition will occur during the conference, and PETC

will communicate the specific dates and schedule in mid-2021 once the full conference agenda is established. The Phase 3 Finals activities will generally include:

- Presentation of Poster and Phase 2 on-campus build videos to the conference audience
- Teams attend a student workshop, with presentations by industry professionals
- Preservation Problems are assigned and worked on by teams during the conference to provide further learning and networking opportunities
- Team dinner and/or other social events
- Teams attend conference paper sessions
- Teams build and test their dry stack masonry arch structures during the conference
- Announcement of winners at the APT Annual Awards Ceremony

Team Requirements

Team Members

Teams are to be formed from post-secondary students from a single university (undergraduate or graduate program), college, or trade school. Teams are recommended to include engineering, architectural, and conservation/preservation students. Teams are to have a minimum of 4 people and a maximum of 6 people. Each team must name a Team Captain to liaise with PETC. An institution can have more than one team enter the competition.

If a team member must drop out of the competition after the Phase 1 team roster is submitted, the team is to notify PETC with a student substitution, if desired.

Faculty Advisors

Each team must have at least one Faculty Advisor, with more as desired. Their role is to advise students on technical and design issues, and to support and monitor the on-campus arch construction. Faculty Advisors also serve as a formal link to the institution for educational, construction, and/or safety matters.

Mentors

During Phase 2, PETC will assign teams to an APT-provided mentor who is typically a preservation practitioner in a related field. Out of respect for the mentors' time, PETC provides the following direction regarding team interactions with mentors:

- Teams will be student driven, and mentors will serve as sounding boards for ideas.
- Teams are expected to touch base with their mentor every week or two for discussion.
- Teams will be responsible for scheduling meetings and to be prepared for meetings with their mentors.

Each student team is encouraged to interact with their team mentor and other professionals throughout the competition. The goal of these interactions should be, in part, to provide opportunities for the students to gain constructive feedback on their methodology and craft at critical steps throughout Phases 1 and 2. The teams are encouraged to self-assess their practice area strengths; determine where additional professional mentoring and guidance could be best served.

Contacts

The Team Captains should contact the PETC Competition Committee via email for any questions or support. Answers will be issued to all Team Captains, to ensure all teams receive the same information.

- Team contact for PETC competition communications: **aptpetc@gmail.com**

Media

The PETC Student Design-Build Competition has no restrictions on talking to the media, and teams are encouraged to promote their work. PETC asks that articles, photographs, quotes, etc. are professional and in good taste. PETC asks to be sent a copy of any published (written or digital) articles in which the competition is discussed.

Be sure to include **#APTPETC** on social media posts.

The PETC Conference Committee will provide updates to APT members and the greater preservation community about the competition and teams. Please share photos and updates of the Phase 2 process throughout your team's work for inclusion in APT's social media platforms, APT's email Communique, and in PETC's e-blasts!

Technical Specifications

1 Phase 1 – Notice of Participation and Arch Selection

1.1 Notice of Participation

Each team is to provide a written Notice of Participation which shall be a 1-page submission with the following information:

- Name of the institution wishing to participate in the competition
  Note: If multiple teams from a single institution are submitting proposals, please provide an individual identifier (for example, specific campus location, name of arch, team number, Team Captain's surname, etc.) so as to distinguish them from other teams within the same institution.
- Name, email, and phone number of each team member
- Year and program of study of each team member
- Identification of Team Captain
- Name, email, and phone number of the team's Faculty Advisor(s)
- Desire to compete in Phase 3 **at the conference** or **virtually** *(PETC understands that circumstances may change leading up to the competition*).

1.2 Masonry Arch Selection

Each team is to select an in-situ (real world) unreinforced masonry arch structure that the team can access for the required field inspection work. The arch may be an interior or exterior element of the existing structure. The selection of this arch is the keystone of the team's Phase 1 research on historic construction practices and will serve as the base model for the Phase 2 arch analysis, design, and build.

The Masonry Arch Selection submission is a 1-2-page report (double-spaced). The report is to include the following:

- Name and location of the selected structure
- Date of construction (approximate if not possible to find the exact date)
- General information on the arch's history and construction, including its historical significance or designations
- Original materials used in its construction
- References for the literature used to understand the history and construction of the structure
- References for the historic codes that will be used to analyze the structure
- Three to five images of the arch and surrounding structure (Note: The images are not included in the page length.)

If a team is unable to locate a masonry arch that meets the given criteria outlined above, a non-local arch may be selected, or the team can contact the PETC Competition Committee for alternatives.

Teams are to notify the PETC Competition Committee if they have not received notification on receipt of Phase 1 documents by the committee ***within one week*** of their submission to ensure transmittal of the information to PETC was successful.

Once the team submissions are received, the PETC Competition Committee will provide feedback and/or approval of each team's submittal. Teams should prepare to respond promptly to any feedback provided by the Competition Committee's questions during the review period. PETC will notify the teams that will move to Phase 2.

2 Phase 2 – On-Campus Report, Design-Build, and Videos

Phase 2 includes submitting a report on the team's arch selected in Phase 1, designing and constructing a masonry arch at their home campus, loading the arch, and providing videos of the on-campus build and testing.

2.1 Report

The report consists of four components and are described below (see Appendix A for specific report format requirements):

- Background research
- Structural analysis
- Preservation (conservation) plan
- Appendix

2.1.1 Background and Historic Significance

In the first part of the report, teams will build upon the information presented in their Phase 1 Arch Selection narrative and prepare a more detailed report including:

- Date of construction and architect (if known)
- The significance of the selected structure, including the architectural, cultural/technological significance. Historic literature and reference materials should be used as a guide.
- The materials used in construction, identification of the original material source and their composition, etc.
- Archival or current photos/drawings.

2.1.2 Structural Analysis

The second part of the report demonstrates an understanding the structural behavior of the selected arch. Teams will assess the structural arch by utilizing methods and principles likely used in its original design and construction. The following are to be included in the report:

- Describe assumptions made for their analysis (material properties, boundary conditions, analysis methods, limitations, etc.)
- Identify the load-carrying capacity for each method of analysis used; and,
- Provide commentary and comparisons on how the existing arch design compares to design standards used today.

2.1.2.1 Define Relevant Loads

Teams are to identify the relevant loads or conditions used in the evaluation, as well as any load combinations (if applicable). Discuss: What loads have been selected and why? Were any loads intentionally not evaluated? Is any specialized load evaluation required?

2.1.2.2 Evaluate Performance

Teams will evaluate the arch's performance and failure mechanisms of the existing structure. Teams shall undertake their evaluation using any **two** of the following approaches:

- Empirical Design (Classical Approaches)
- Nineteenth Century Analytical Models (Graphic Statics or Similar)
- Contemporary Structural Engineering Analytical Software

Teams must justify why at least one of the selected approaches would provide a safe analysis and comment why the two approaches were selected. Provide the ultimate performance of the arch and a brief overview of the analysis undertaken. Provide commentary regarding the limitations related to selected approaches.

2.1.2.3 Discussion

Teams are to discuss the results of their analysis and the real-world relevance within their report. Develop discussion from the team's research and experience completing the analysis. Consider including thoughts on theories applied and effectiveness of various analysis approaches.

Some guiding questions or starting points:

- *What are the general failure mechanisms of arches?*
- *What are the visible signs that an arch has become over-stressed? Are there any signs that your team's selected "real world" arch is over-stressed?*
- *Are there existing structural interventions visible on your team's "real world" arch, or could one be introduced to address failure mechanisms? Consider the intervention's compatibility with the existing building materials and heritage characteristics, reversibility, cost-effectiveness and durability or resilience.*

2.1.3 Preservation (Conservation) Plan

The final part of the report is to provide a preservation (conservation) plan for the masonry structure over the next 25+ years.

The built environment is subject to external forces that often wreak havoc on the condition, materials, and structural integrity of historic structures. As preservationists, it is our responsibility to assess the condition and provide guidelines for owners on how to best conserve and maintain their assets.

Building Pathology refers to the study of decay, deterioration, and defects of a building material or assembly. Deterioration can be caused by natural forces such as water and wind erosion, poor maintenance, or an inherent vice in the building design. Understanding this science is important for maintaining a structure's health and prolonging its service life. This involves identifying the root causes of decay and prescribing appropriate treatments or repairs.

Teams are to conduct a visual survey and identify three pathological conditions with their structure's arch and surrounding masonry. For each condition include the following:

- Name of the pathological condition
- Location on the building/structure
- Cause of the pathological condition
- A judgement on the severity of the pathological condition: Is it in good, fair, or poor condition? Is it urgent to fix, or can be fixed in the short or long-term?
- Proposed repair, treatment, or monitoring program for the condition
- One photo demonstrating the condition

Pathological conditions may fall under the umbrella of structural issues, moisture issues, materiality, aesthetics, and issues related to maintenance. The three pathological conditions must impact the masonry directly (e.g. cracked stone) or indirectly (e.g. poor water-shedding). Pathological conditions which only impact non-masonry elements such as windows, doors, etc. are not allowed.

2.1.4 Report Appendix

The report appendix does not count toward the report's word count or illustration limits, and shall include the following:

- Supplementary calculations from arch analysis (refer to Section 2.1.2)
- Mortar mix specifications including constituent ingredients (type and manufacturer), mix ratios, and mixing procedure (Section 2.2.1.2)
- Demonstration of dimensional compliance of the arch design-build (Section 2.2.2.1 and Figure 2)
- Construction and Safety Protocol (Section 2.2.5)
- Photos and a description of the monitoring set-up for loading, and a table of the measured movements/deflections at each load increment (Section 2.2.6)

2.2 Structural Arch Design-Build

Teams are to design an original structural masonry arch out of any masonry material in accordance with competition specifications. Teams will build and load-test their arch at their home campus. Videos must be submitted for both the build and the testing.

2.2.1 Material Requirements

2.2.1.1 Masonry Units

- Teams can select any type of masonry unit, including, but not limited to, brick, stone, and terracotta.
- Masonry units are to be joined with plane flat surfaces. No interlocking of masonry units beyond standard keying is allowed. No mortise and tenon, tongue and groove, and/or dowel type engagements are allowed.

2.2.1.2 Mortar

- Teams are to develop the mortar mix based upon research of historic masonry practice. Pre-bagged or pre-mixed mortar is not permitted.
- Mortar should be appropriate for historic structures. Mortar should have no, or very low, Portland cement content. No mortar admixtures or bonding agents are permitted.
- Mortar mix is to be recorded and documented in the report.
- Mortar cure time and procedures shall be considered as part of the mortar mix design. Record curing procedures and cure time in the report.

2.2.1.3 False Work

- Teams may use any material(s) to construct the arch false work.

2.2.2 Assembly Requirements

2.2.2.1 Overall Arch Requirements

Refer to Figure 1 for assembly requirements. Deductions from score will be made for violations.

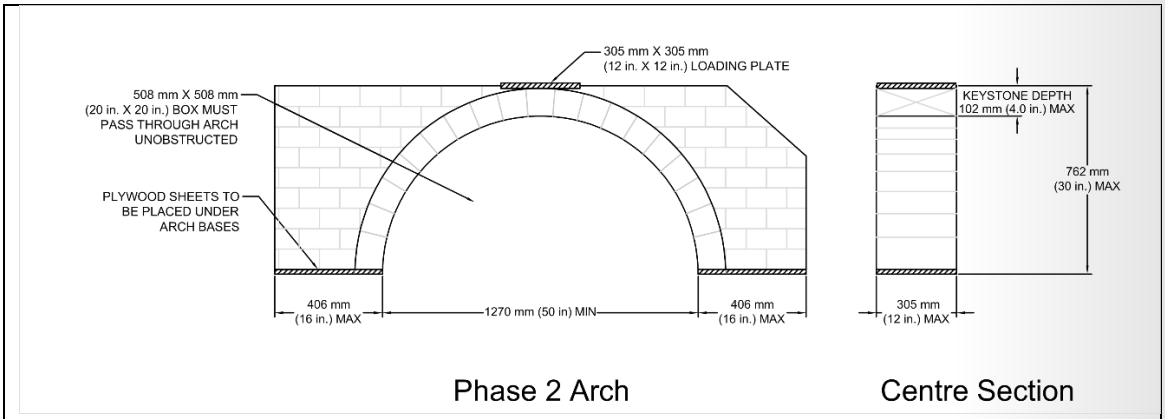


FIGURE 1: SKETCH OF THE PHASE 2 ARCH DIMENSIONAL REQUIREMENTS AND TEST SET-UP
Note: Diagram illustrates the dimensional and testing requirements; individual team arches do not need to look identical to the arch shown.

FIGURE 2: AN EXAMPLE OF A PHOTO TO BE INCLUDED IN THE REPORT APPENDIX TO DEMONSTRATE DIMENSIONAL COMPLIANCE FOR THE ARCH HEIGHT

2.2.2.2 Base Locations

The base of either side of the arch must fit inside two squares that are 16 inches by 16 inches (406 mm x 406 mm), with 50 inches (1270 mm) of clear space between the squares. The squares cannot be closer together or further apart.

Each base is to be built atop two separate plywood sheets, with no mechanical attachment between the two sheets or the ground during testing. The plywood should be exterior grade, A-Grade or B-Grade.

2.2.2.3 Build Surface

The arch is to be built on a flat, smooth, and level surface, preferably an interior concrete floor slab or exterior concrete paving slab. No obstructions (shear engagement) that restrain outward movement on the build surfaces are allowed. Encountering any obstructions in the surroundings during testing will be considered as an arch failure.

2.2.3 Construction

2.2.3.1 Protocol

Teams are to document the protocol they use for arch construction and assembly, including safety protocols approved by the Faculty Advisor. This protocol is to be provided in the report appendix and showcased in a video recording of the build (see Appendix C for video requirements).

2.2.3.2 Safety and Stability

Teams are to ensure all work is done safely following protocols approved by their Faculty Advisor. The following shall apply:

- All team members must wear proper Personal Protective Equipment (PPE), including steel toe boots, gloves, hard hats, and safety glasses.
- No work can be done by any team member without supervision by another team member.
- All team members must follow Workplace Hazardous Materials Information System (WHMIS) or Occupational Safety and Health Administration (OSHA) guidelines for safety and receive any supplemental lab or safety training required by their institution.

The stability of the arch during construction must be monitored to ensure no risk is posed to people or surrounding equipment.

2.2.4 Testing Requirements

2.2.4.1 Overview

Teams are to have loading protocols established in writing, and all members are to be familiar with required procedures. Teams are to record a video beginning with a review of all safety measures taken before loading. While recording, teams are to load the arch to failure or the greatest load that can be safely applied, whichever is reached first. See Appendix C for Video Requirements.

Phase 2 evaluation and judging will consider situations when an arch cannot reach failure safely after a team takes reasonable measures to find safe testing approaches.

2.2.5 Safety and Supervision

At any point a team member, Team Captain, or Faculty Advisor can halt the testing if any aspect of the testing is unsafe.

2.2.5.1 Individual Responsibilities

All team members are to be aware of the safety risks and abide by the safety plans approved by their Faculty Advisor. Plans should include emergency contingency plans.

2.2.5.2 Team Captain

The Team Captain will act as a visual observer during the arch testing, watching all aspects of the loading procedures and intervening in the case of unsafe execution.

If a safety concern is reported and the testing is halted, the Team Captain can either direct how the safety concern is to be addressed or refer to the Faculty Advisor.

2.2.5.3 Faculty Advisor

The Faculty Advisor is to be present during testing of the arch. In the case of an unsafe condition that has not been identified by team members or team captain, the Faculty Advisor can call a halt to the testing. If the testing is halted by the Faculty Advisor, the testing shall record the load at that point as the failure load. This is to penalize the team for not ensuring their safety.

2.2.6 Loading the Arch

2.2.6.1 Mechanics

Testing is to be performed by loading a 12-inch x 12-inch x 3/4-inch-thick (305 mm x 305 mm x 19 mm) plywood square placed on the top of the arch, centered.

Teams can select their own loading plans and types of weights. Based on accessibility to load testing equipment, PETC understands that multiple loading approaches may be employed. All approaches will be evaluated equally.

2.2.6.2 Load Monitoring and Measurements

Teams are to monitor the following movements during loading:

- Load increments applied to the arch, and total load placed on the arch at each increment. The load amount should be recorded on a card, whiteboard, or tablet that is clearly visible in the video.
- Lateral movements at the top of the arch
- Outward movements of each arch footing
- Vertical deflection at the top of the arch
- Loads applied to the arch

Teams can take measurements manually or digitally. The details of the procedure and measurements are to be documented clearly in the report appendix, with measurements reported to the nearest 1/16th of an inch (1.6 millimeter).

2.2.6.3 Failure Load

The failure load is to be identified as the last recorded load at which the arch sustained the load for 10 seconds with no visible movement occurring. In the case that the arch failed while load was increasing/being placed on the arch, the failure load is to be identified as the load on the arch 15 seconds prior to failure.

2.2.7 Compliance

Teams are to provide photographic and written evidence of compliance with the mortar, dimensional, and measurement requirements in an appendix to the Phase 2 Report.

2.2.8 Videos

The purpose of recording the arch build and loading with videos is to demonstrate and document the working procedure, construction approach and testing procedure, and to provide a visual for the Judges conference attendees in Phase 3.

The video shall include:

- A time-lapse of the arch construction
- A feature showing the mortar mixing procedure
- Load testing of the arch including the load amount being applied

The suggested length of each video is about 4 - 7 minutes, and students are encouraged to time-lapse the repetitive and/or irrelevant portions of the work (particularly the build). Videos longer than about 7 minutes will be edited by PETC for brevity.

One video file is required to show the arch construction, and one separate video file is required to show the testing. Refer to Appendix C for video requirements.

3 Phase 3 – Finals

As many as five teams will be selected to take part in the competition finals as part of the APT's Annual Conference. The finals provide the teams with an opportunity to meet and network with the Competition Judges, PETC members, and other conference attendees. The finals are also an opportunity for teams to demonstrate their presentation, communication, and teamwork skills. In-person and virtual options are as outlined below:

In-Person Option *Finalist teams travel to Washington DC and compete at the APT Conference*	**Virtual Option** *Finalist teams remain at their home campus and compete during the APT Conference*
• Provide a printed poster about their project to display at the conference for the Competition Judges to review. • Provide the digital poster file to load onto the online conference platform.	• Provide only the digital poster file to load onto the online conference platform. Competition Judges will review the digital submissions.
• Teams attend the Student Workshop in-person.	• Teams attend the Student Workshop virtually.
• Present the Phase 2 work in-person for the Competition Judges and other attendees during the Conference. This will include PETC showing the Phase 2 videos.	• Present the Phase 2 work to the Competition Judges and other attendees during the Conference. This will include PETC showing the Phase 2 videos.
• Teams construct and test their dry stack arch in front of the Competition Judges and other attendees during the Conference.	• Teams build and load their dry stack arch at their home campus, sharing virtually with the other teams and Competition Judges.
• Teams present their Preservation Problem solutions in front of the Competition Judges and other attendees during the Conference.	• Teams present their Preservation Problem solutions virtually to the Competition Judges and other attendees during the Conference.

3.1 Posters

The Phase 3 competition finalists are to prepare a poster for presentation during the APT conference. The poster will act as a "guided tour" through the team's project and should be a condensed version of the Phase 2 report. The poster should follow the general guidelines given in Appendix B.

3.2 Presentations

The team will present their project at the conference. Presentation requirements include:

- **Maximum length** - 10 minutes
- **Format** - PowerPoint (or similar) presentation slides with verbal presentation by student team members. Each student is to introduce themselves and speak for at least 1 minute.

- **Content** – The presentation should summarize information from the Phase 2 report (historic research and structural analysis) and the design-build and testing process.
- **Questions** - After each presentation, the team will have approximately 10 minutes for a live Q&A session with the judges and conference attendees.
- **Judging Criteria** - The presentations will be judged on both content and quality/professionalism. All team members are encouraged to participate in the presentation and the Q&A session, and this will factor into scoring.

3.3 Dry Stack Arch Design-Build

Each team will participate in a dry stack arch design-build, which will occur under timed conditions at the conference or virtually, with viewing open to conference attendees.

Teams are to ensure all requirements and intent of the specifications are met.

3.3.1 Masonry Units

The masonry units can be made from **any** material, so long as the material and the units meet the following requirements:

1. Units must be of 'regular' shape commonly seen in masonry construction, with a maximum of six-sides and no convex shapes (L-shapes, T-shapes, U-shapes). Units are to be joined with plane flat surfaces. No mortise and tenon, tongue and groove, and/or dowel type engagements are allowed.
2. No mortar, adhesive, magnetic, or mechanical attachments of units are allowed. Rubber or rubber-like materials will be deemed adhesive. A unit will be deemed adhesive if a piece of paper can hold to the underside of a unit.
3. The surface of the units should be less rough to the touch than 80 grit sandpaper. Competition judges will be the evaluators if questions arise.
4. All units must be solid and safe for use in a hotel/conference environment.
5. Units cannot be made of a material that could easily shatter into pieces from improper handling, such as glass.
6. All units must be clean and leave no mess at the competition site.
7. The arch system must be composed of no fewer than 31 units. The largest unit must be no more than 3 times the size of the smallest.

3.3.2 Material Weight and Volume Restrictions

The competition finals are designed to provide some practical allowances for teams travelling various distances. Therefore, restrictions have been placed on material allowed:

1. All units to be used in the arch must fit inside 4 cases (boxes/containers/suitcases) that would each be accepted as a checked-bag item. That is, maximum dimensions of 62 inches (1580 mm) (length + width + height) and maximum weight of 50 lbs (23 kg). These 4 cases may contain materials for falsework and tools for use during erection, so long as the size and weight limits are met.
2. An additional 2 cases containing only falsework and tools to be used during the erection of the arch and that would each be accepted as airline check-in items are allowed; that is, maximum dimensions of 62 inches (1580) mm (length + width + height) and maximum weight of 50 lbs (23 kg). No individual piece of falsework may be larger than would fit in a 4-inch x 4-inch x 2-inch box.

Before construction, each of the cases used by the teams will be weighed and recorded. Except for PPE and materials provided by APT, nothing to be used for construction can be outside the cases. The weight of the arch material will be included in the final judging score.

3.3.3 Assembly Requirements

3.3.3.1 Overall Arch Requirements

The Phase 3 dry stack arch is to meet the requirements illustrated in Figure 3:

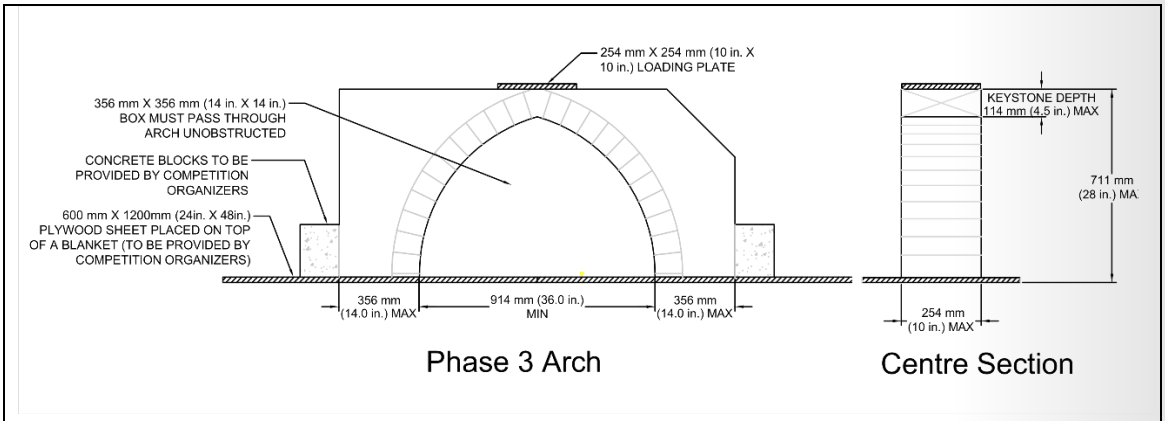


FIGURE 3: SKETCH OF THE PHASE 2 ARCH DIMENSIONAL REQUIREMENTS AND TEST SET-UP

Note: Diagram is representative of dimensional and testing requirements; individual team arches do not need to look identical to arch shown.

3.3.3.2 Testing

Teams are to clearly mark off the construction area surrounding their arch. Protective blankets for the build area will be provided by APT.

A 24-inch x 48-inch (610mm X 1219 mm) sheet of plywood will be placed on the protective blankets. This is the surface on which the arch will be built

Each team will have two 8-inch x 8-inch x 16 inch (203 x 203 x 406 mm) concrete masonry units provided to them by the competition. These concrete blocks are to be placed on the plywood sheets against the arch side. The arch cannot be under the blocks or on top of the blocks.

3.3.4 Construction and Testing of the Dry Stack Arch

3.3.4.1 Construction

All conference construction work will be carried out under the supervision of PETC.

1. Prior to construction, all materials should be inside their respective suitcases, with the construction area marked out and blankets down.
2. All team members to be involved with the arch construction and loading are to wear gloves, safety glasses, and steel toed boots.
3. Construction will begin upon the organizer's announcement. All builds will be timed.
4. Teams are responsible to ensure the safe erection of the arch.
5. All masonry units are to be put in place one at a time, as is done in conventional practice. No placing of units in groups or tilt-up construction will be allowed.

6. If competition organizers or judges feel that a team's construction practices are unsafe, they will request that the team halt construction. Teams will be allowed appeal to the judging panel for any requested stop; however, the time will continue during this process. If the appeal feels that safety had been adequately considered, then teams may continue the built. If the construction is deemed unsafe, the team must disassemble and reassemble or receive last place in the conference build.
7. When all units have been placed, the timer stops.

3.3.4.2 Testing

1. Prior to loading, judges will ask each team to discuss the expected failure mode of their arch.
2. Testing will be performed by loading the arches with pre-defined masses up to a maximum of 220 lbs [100 kg].
3. Loading will be done by individuals wearing the required personal protective equipment.
4. No lateral loads will be applied.
5. Deflections will not be measured or judged.
6. All testing will be done under the direction of PETC and the Judges.
7. The arch will be deemed to have failed if more than one unit has fallen, or, the arch collapses within 30 seconds of loading.

The arches will be left in place for viewing by the conference attendees immediately after loading; however, teams are responsible for clean-up and removal of their arches by the required date/time defined by PETC or the APT Conference Committee.

3.3.4.3 Virtual Option

For the virtual option, teams will be required to build and load their arch to the same requirements outlined above, at their home campus. The build and loading will be shown (live-streamed) with the other competing teams to be shown at the APT Conference.

Teams competing virtually will be responsible for supplying their own materials and equipment to meet the conference requirements.

Lastly, teams will be required to walk the judges through their measurements to ensure that the outlined requirements are achieved. This includes:

- Largest and smallest masonry unit dimensions
- Suitcase dimensions and weight
- Falsework dimensions and weight
- Overall arch dimensions

3.4 Preservation Problems

Teams will select a pair of two preservation problems during the conference (four total questions). The selection of problem pairs will be done as follows:

1. The PETC Competition Committee will show all problem pairs to all teams.
2. Teams will select their problems in order, based upon their ranking from Phase 2.

Teams are encouraged to engage conference attendees to discuss information to develop solutions for their selected preservation problems (Phase 3 on-campus builds will be provided with contacts).

Teams will have until judging starts to develop their solutions. As a final part of the competition, each team will give an oral presentation where they will present an overview of their historic structure,

their analysis and load test findings of their historic arch, and their solutions to the preservation problems using their historic arch as the referenced structure. All team members must participate. Presentations are to be 15 minutes, with an additional 15 minutes allowed for questions. Visual solutions (sketches, etc.) to show during the Presentation Problem presentation are encouraged.

Teams competing virtually will provide their presentation via live-streamed video. All team members must participate and be online for the 15-minute question period.

Once the presentations are concluded, the judges will deliberate, tally up their judging cards, and provide some constructive feedback to the teams.

Appendix A – Report Format

The report should clearly identify the following:

- Project Title
- Name of institution, individual team members, Faculty Advisor(s), and mentors
- References (educational references, literature, etc.)

The report should be formatted as per below:

- Word count: 4,000-5,000
- Page size: Letter (8-1/2 inches x 11 inches), Portrait orientation
- Font: Other fonts may be used at the equivalent size to the recommended font below:
  - Title/Headings: Calibri, size 14
  - Subheadings: Calibri, size 11
  - Body: Calibri, size 11
- Alignment: Left aligned
- Standard Margins and Headings
- Six to ten labeled illustrations (including tables)
- For endnotes, bibliography, and other matters of style, authors should follow the *Chicago Manual of Style.*
  - Endnotes, if applicable, must be numbered consecutively throughout the text in superscript, then placed at the end of the paper.
  - A bibliography is not necessary if all important sources are given in the endnotes.

Submit one electronic .pdf file of the paper with all embedded photos, figures, and attachments.

Appendix B – Poster Content

The poster should clearly identify the following:

- Project Title
- Name and insignia of institution
- Names of team members
- Acknowledgements: Names of Faculty Advisor(s), APT mentors, collaborators, donors, etc. who aided in the work (including funding, materials, and other resources)
- References (educational references, literature, etc.)

The purpose of the poster is to provide a brief introduction to the arch that was studied, including clear identification of the following:

- Name of structure
- Location
- Material makeup
- Date of construction and construction methods

Most of the poster should present the structural analysis findings. Provide 4-10 photos, sketches, figures, or charts to convey findings. Provide a brief statement of the Preservation Plan from the report.

Poster Format

- Poster Size: 36 inches (91.4 cm) high x 48 inches (121.9 cm) wide, Landscape orientation
  - Printing, transportation, and set-up of the poster is the responsibility of the team. Teams are to supply poster board for mounting their posters on an easel or table provided by APT.
- Font: Other fonts may be used at the equivalent size to the recommended font below:
  - Title/Headings: Calibri, size 130 (minimum)
  - Subheadings: Calibri, size 54 (minimum)
  - Body: Calibri, size 32 (minimum)
- Four to ten illustrations (including tables):
  - Each illustration must have its own number (Fig. 1, Fig. 2; not Fig. 1a, 1b) and its own caption. Indicate citation at end of each caption (if not produced by the team). Images should be referenced within the narration of the poster.
  - Illustrations should be a minimum of 100 dpi and imported at the same size they will be on the poster (or smaller). Ideal resolution for poster presentations is 150 dpi (smaller resolution will create pixilated images while larger resolutions create large file sizes).
  - Illustration size is at the discretion of the team but should be large enough to be read/interpreted clearly.

Many institutions have examples of research poster presentation templates and tips are available online.

Poster Tip: Keep presented information simple. This poster will be read by judges and conference attendees who will want to know only the most important aspects of the project. The viewers should be able to review the poster within 5 minutes.

Appendix C – Video Requirements

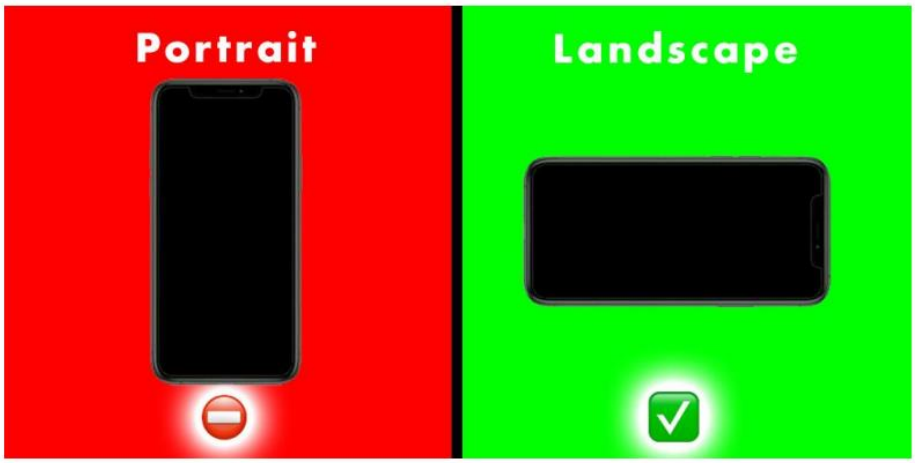
Each team is to submit two videos that record their Phase 2 on-campus build and testing:

1. **One video** that captures your team building the arch and verifies compliance to the Phase 2 specifications. This video documents the team's working procedures, materials (including mortar mixing), construction approach, sequence of laying the masonry units and building up the arch, and the dimensions and unique features of the team's arch.
2. **One video** that captures the safety procedures, loading sequence, displacements/deflections at each loading sequence, and, if relevant, the failure of the team's arch. This video is to have a timer placed within the view of the camera. Narration or captions may be used for clarity.

The videos provide visuals for the Competition Judges and conference attendees. The Phase 2 videos by the Finalist Teams that move to Phase 3 will be uploaded to the online conference platform.

Video Requirements:

- Record videos in in .MOV or .MP4 file type
- Record videos using landscape orientation



Portrait vs. Landscape orientation

- Android phone/tablets: Adjust camera settings to 1080p resolution.
- iPhone/iPad users:
    1. Select "Camera" settings
    2. Select "Record Video" settings and select "1080p at 30fps"
    3. Select "Formats"
    4. Select "Most Compatible"

iPhone Camera Settings Navigation

- If the team needs to record the Arch Build using more than one MOV/MP4 file, then each file must be named using the following naming convention:
  "Institution Name_Build_File #", with the # being sequentially ordered files 1, 2, 3, etc.
- If the team needs to record the Arch Load Test using more than one MOV/MP4 file, then each file must be named using the following naming convention:
- "*Institution Name_Load_File #*", with the # being sequentially ordered files 1, 2, 3, etc.

PETC will provide a link to a shared folder on Google Drive to upload your files. The link will be provided prior to the Phase 2 submission deadline.

Appendix D – Judging Criteria

Submissions will be reviewed by the PETC Competition Committee and the Competition Judges. The Committee and Judges will act in good faith to conduct objective and fair evaluations to the greatest extent possible. Final scoring will be at the Judges' discretion. Numeric score or weighting may be changed by PETC; if so, PETC will notify all teams in writing in advance of the relevant Phase submission deadline.

Teams must pass Phase 1 to proceed to Phase 2. Teams will be notified via email of their Phase 1 acceptance. Phase 2 submissions are evaluated to determine the finalist teams for Phase 3. Phase 2 ranking also determines the order of Preservation Problem selection during Phase 3.

During the APT Conference, a group of selected professionals from different sectors of the design and construction industry will form the Judges' panel. The Judges will evaluate the Phase 3 posters, Preservation Problems, and the conference build.

PHASE 1 SCORING		
Deliverable	**Criteria**	**Score**
Notice of Participation	Submission includes all required team and team member information	Pass/Fail
Masonry Arch Selection	Submission narrative document includes all required information, including references and images	Pass/Fail

PHASE 2 SCORING		
Deliverable	**Criteria**	**Total Possible Score**
Report	Background Research - All required information is included - Points credited for quality of report content - Points credited for quality of report format	10
	Structural Analysis - Loads, load cases, and assumptions are documented - Two analysis methods implemented, each analysis method is clearly described, and each analysis method provides required calculations and/or graphics - Inputs for computer analysis are provided (if relevant) - Load carrying capacity for each method is clearly documented	20

PHASE 2 SCORING		
Deliverable	**Criteria**	**Total Possible Score**
	Preservation Plan - Discussion is complete regarding materials, deterioration, and proposed repair	15
	Appendix - All required elements are included	5
Design-Build	Design - Design approach - Aesthetics of the completed arch	20
	Construction - All materials are documented - All dimensions meet specifications	20
	Loading - All loading procedures meet specifications - All load increments and deflections/displacements are documented	5
	Protocol Deductions - Deduct points for safety/PPE violations - Deduct points for use of non-masonry materials (except for falsework) - Deduct points for use of admixtures, bonding agents, etc. - Deduct points for dimensional violations - Deduct points for loading violations	n/a
	Build and Load Videos	5
	TOTAL POSSIBLE SCORE	**100**

PHASE 3 SCORING		
Deliverable	**Criteria**	**Total Points Possible**
Poster	- Digital and/or paper formats conform to the specification. - All required content is provided on the poster. - Posters are legible and readable. - Content is engaging and describes the team's project and unique features.	10

PHASE 3 SCORING		
Deliverable	**Criteria**	**Total Points Possible**
Student Workshop	- All members of each student team must attend all Student Workshop presentations. - Points will be deducted for teams/students that do not attend some or all sessions. - Points will be credited to teams/students that are actively engaged in the Workshop by asking thoughtful questions or providing ideas from their research or build.	10
Presentation	- Each team member presents a portion of their Phase 2 research, arch construction, and arch loading. - Points will be credited for clarity, relevance, interest, and staying within the time limit. - Points will be deducted for going over the time limit.	20
Dry Stack Arch Build and Loading	Speed of Build: - First team completed: 10/10 - Second team completed: 8/10 - Third team completed: 6/10 - Fourth team completed: 4/10 - Fifth team completed: 2/10 - Any team that has safety issues: 0/5	10
	Strength: - Reached and sustained load of 220lbs (100kg) 15/15 - Reached and sustained load of 200lbs (90kg) 13/15 - Reached and sustained load of 175lbs (80kg) 11/15 - Reached and sustained load of 155lbs (70kg) 9/15 - Reached and sustained load of 130lbs (60kg) 7/15 - Reached and sustained load of 110lbs (50kg) 5/15 - Reached and sustained load of 55lbs (25kg) 3/15 - Sustains self-weight 2/15 - Does not sustain self-weight or incomplete 0/15	15
	Weight of materials used (arch + falsework + tools + cases) - Lightest total weight 10/10 - 2nd lightest weight 8/10 - 3rd lightest weight 6/10 - 4th lightest weight 4/10 - 5th lightest weight 2/10 - Exceed maximum allowed weight: 0/10	15

PHASE 3 SCORING		
Deliverable	**Criteria**	**Total Points Possible**
Preservation Problems	- Points will be awarded for correct responses and thoroughness of responses. Credit will also be given for connecting a response to a real-world situation, such as elements researched or observed from their selected building/arch.	20
	PHASE 3 TOTAL	**100**

FINAL SCORE FOR PHASE 3 FINALISTS
Final Score = (Phase 2 Score + Phase 3 Judges Score) / 2

Appendix E – Financial

PETC will pay the APT conference registration fee (non-ticketed events) for up to 6 students, and up to 3 hotel rooms, for each team selected to attend the Phase 3 Finals. Details will be provided to Finalist teams. All other expenses (travel, extended stay, additional lodging, food, competition materials, etc.) are the responsibility of the teams. The PETC will not financially support any Faculty Advisors or mentors.

Each team is to raise money for their expenses. One of the values in a competition of this nature is that it allows and encourages students to reach out to companies to ask for support, and while doing so, make connections that may be of future value. The PETC Competition Committee can provide a general list of potential sponsors to share with the teams upon request to assist in finding potential sources of sponsorship, especially pertaining to the masonry industry for this year's competition. Teams are encouraged to define their own ways in which to acknowledge the support they received (sponsored T-shirts, posters, etc.).

Each team is to develop their own financial plans, including all anticipated costs and anticipated funds raised, to be included in the Phase 2 submission if the team intends to vie for travel to the APT Conference. The Competition Committee will use these plans to help teams that may be short of travel funds.

Teams should make their own travel arrangements and are responsible for travel visa application and costs if required. APT may be able to support or sponsor a visa; please contact the PETC Competition Committee if this is needed.