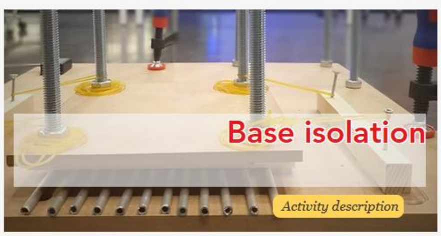
PolySDL - STRUCTURAL DESIGN LAB

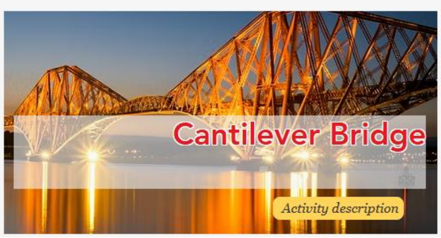
at Florida Polytechnic University

ACTIVE LEARNING IN CIVIL ENGINEERING THROUGH STRUCTURAL DESIGN, MODELING, TESTING, AND EXPERIMENTATION

STUDENT ACTIVITIES HANDBOOK

Structural Design Studio | Development Draft | August 2026





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Document Status and Scope

This handbook is a development draft for the PolySDL activity portfolio associated with Structural Design Studio and related Civil Engineering courses. It is written primarily for students: its purpose is to make each activity understandable, predictable, safe, and manageable from the first design decision through final reflection.

The handbook deliberately separates three kinds of content:

- Common expectations that apply to every PolySDL activity.
- Student-facing activity instructions that explain the design, modeling, fabrication, testing, and reporting workflow.
- Development notes for activities whose final dimensions, materials, or procedures are still being confirmed.

The website (www.polysdl.net) remains a concise visual introduction. This handbook carries the technical detail, procedural guidance, checklists, and reporting requirements needed to complete the activities successfully.

Contents

PART I | WORKING IN POLYSDL

1. Purpose of PolySDL

PolySDL is the Structural Design Lab at Florida Polytechnic University. It supports active, project-based learning in which students use physical models, digital analysis, fabrication, and experimental testing to develop structural intuition and professional engineering habits.

The activities in this handbook are designed to help students move through the complete engineering cycle:

PolySDL Activity Cycle

UNDERSTAND → DEFINE → DESIGN → MODEL → PREDICT → BUILD → TEST → COMPARE → REFLECT

Some activities are physical, some are digital, and others are hybrid. The common expectation is that students connect analytical ideas to observed structural behavior and explain the reasons for agreement or disagreement.

2. How to Use This Handbook

1. Read the Quick Reference and Learning Objectives before the activity begins.
2. Review the Technical Background and note all required dimensions, loads, assumptions, and units.
3. Complete the Before You Begin checklist and confirm access to required software, materials, and tools.
4. Follow the activity phases in order. Do not begin fabrication before the required design review or drawing approval.
5. Record decisions, calculations, measurements, photographs, and unexpected behavior as the work progresses.
6. Use the Deliverables and Assessment sections as a submission checklist.
7. Complete the reflection while the test observations are still fresh.

3. Standard Team Expectations

Every team member is responsible for understanding the complete project, even when work is divided into roles. A student should be able to explain the design concept, important assumptions, analytical model, construction method, test setup, observed behavior, and lessons learned.

Suggested Role	Primary Responsibility
Project coordinator	Tracks scope, schedule, meetings, decisions, and submissions.
Analysis lead	Develops and checks calculations and digital models; documents assumptions.
Drawing/detailing lead	Maintains drawings, dimensions, revisions, and fabrication templates.
Fabrication/quality lead	Plans assembly, tools, tolerances, inspection, and safe work practices.
Testing/data lead	Coordinates instrumentation, test records, photographs, plots, and observations.
Communication lead	Coordinates presentations, reports, captions, and source attribution.

Roles may be combined in smaller teams. Responsibility may be divided; accountability may not.

4. Standard Design Reviews

Review	Expected Evidence
Concept review	Problem definition, alternatives, load path, main variables, and feasibility.
30% review	Selected concept, preliminary geometry, analytical idealization, major risks.
60% review	Developed model, preliminary calculations, draft drawings, materials and test plan.
90% review	Near-final analysis, checked drawings, fabrication plan, safety plan, prediction method.
Test-readiness review	Completed specimen, dimensional inspection, instrumentation, loading sequence, emergency stop criteria.

Review	Expected Evidence
Closeout review	Prediction-versus-test comparison, failure interpretation, lessons, archived files.

5. Laboratory Safety and Stop-Work Authority

Safety takes priority over schedule, score, and specimen preservation. Any student may call a stop when a condition appears unsafe. Work resumes only after the instructor or authorized laboratory personnel confirms that the condition has been resolved.

- Complete required safety training before using tools, equipment, adhesives, concrete materials, or test systems.
- Wear the required personal protective equipment for the task.
- Use guards, restraints, safety supports, and exclusion zones during testing.
- Keep hands and tools clear of loaded specimens, actuators, weights, supports, and moving shake-table components.
- Do not change an approved test setup without instructor authorization.
- Maintain clean work areas and remove trip hazards, cutting waste, spilled adhesive, and loose hardware.
- Report damaged tools, unusual sounds, unexpected motion, or unstable specimens immediately.

Testing rule

A test may be stopped before failure when movement, cracking, debris, equipment response, or instability exceeds the safe operating condition established by the instructor.

6. Standard Digital Practice

- Use the unit system specified in the activity and show units in every calculation table.
- Record software version, model assumptions, support conditions, material properties, and load cases.
- Use meaningful element, joint, load-case, and file names.
- Save milestone versions rather than overwriting the only working file.
- Check equilibrium, deformed shape, reaction directions, and order of magnitude before trusting results.
- Archive the final model, exported tables, screenshots, drawings, spreadsheets, and report in the team folder.

7. Standard File Naming

Recommended pattern

Activity_Team_Document_Revision_Date.ext
Example: BBC_Team03_SAPModel_R02_2026-02-23.sdb

- Use R00 for the first shared draft and increase the revision number after each formal review.
- Do not use names such as final, final2, newfinal, or latest.
- Place superseded files in an Archive folder; do not delete the design history.

8. Standard Final Report Structure

1. Executive summary and activity objective.
2. Design concept and alternatives considered.

3. Technical background and analytical assumptions.
4. Drawings, geometry, materials, and fabrication method.
5. Digital model, calculations, and predicted response.
6. Test setup, loading procedure, instrumentation, and safety measures.
7. Results, photographs, plots, and observed failure behavior.
8. Prediction-versus-test comparison and sources of discrepancy.
9. Reflection, redesign recommendations, and team contribution statement.
10. Appendices containing detailed calculations, tables, drawings, and source files.

9. Activity Portfolio at a Glance

Activity	Mode	Status	Core Emphasis
Student Steel Bridge Competition	Hybrid	Program development	Professional-scale bridge design, fabrication, construction, testing, and team operations.
Seismic Design Competition	Hybrid	Implemented; analysis expansion	Balsa building design, SAP2000 dynamic response, prediction, fabrication, and shake-table testing.
Balsa Bridge Competition	Hybrid	Implemented - Spring 2026	Truss analysis, AutoCAD templates, SAP2000 capacity prediction, fabrication, efficiency, and collapse testing.
Base Isolation	Physical	In development	Compare fixed-base and isolated model buildings under common ground shaking.
Built-Up Beams in Action	Physical	In development	Shear flow, fastener demand, connection slip, load prediction, fabrication, and beam testing.
RC Beams in Action	Physical	In development	Reinforcement detailing, flexural and shear behavior, ductility, and failure modes.
Cantilever Bridge in Action	Physical	In development	Kinesthetic investigation of equilibrium, tension, compression, anchorage, and stability.
Canyon Bridge	To be finalized	Concept development	Activity brief, model form, analysis method, and test plan require confirmation.
Millennium Bridge	To be finalized	Concept development	Activity brief, model form, dynamic response measures, and student deliverables require confirmation.

ACTIVITY 1

Student Steel Bridge Competition

An extended student program in professional bridge delivery, fabrication, construction, and competition performance

STATUS: PROGRAM DEVELOPMENT

Course connection	Structural Design Studio; Structural Analysis; student competition pathway
Activity type	Yearlong design-fabricate-construct-test competition program
Mode	Hybrid
Team format	Broad program team with technical leads and a trained competition builder squad
Primary tools	Annual SSBC rules, analysis software, CAD/detailing tools, fabrication equipment, construction practice area
Primary deliverables	Analytical model, calculations, drawings, bills of materials, fabrication records, inspection records, construction plan, practice data, load-test results, competition documents

1.1 Purpose and Student Outcomes

The Student Steel Bridge Program is an advanced extension of PolySDL. The bridge is the annual deliverable; the larger purpose is to develop students as designers, analysts, detailers, fabricators, constructors, project managers, communicators, and future mentors.

- Connect strength, stiffness, stability, load paths, and constructability to observed bridge behavior.
- Work within changing annual rules and make decisions with incomplete information.
- Produce controlled models, calculations, drawings, schedules, cost estimates, and revisions.
- Develop fabrication literacy, inspection habits, safe construction planning, and measured practice.
- Conduct professional design reviews and transfer usable knowledge to the next team.

1.2 Program Structure

The program is organized as a broad learning community with a smaller competition-floor team. The 2026 rules permit no more than six builders during timed construction, but that limit does not define the total program roster. Students may contribute through design, modeling, detailing, fabrication, testing, documentation, sponsorship, communication, and construction practice.

Participation Layer	Description
Program team	All active students contributing to technical or operational work.
Technical and operations leads	Students accountable for coordinated workstreams and mentoring.

Participation Layer	Description
Builder squad	Up to six trained builders for timed construction, with alternates developed through practice.

1.3 Student Workflow

1. Read and annotate the current annual competition rules.
2. Establish the project schedule, roles, decision log, risk register, and design-review dates.
3. Develop and compare structural concepts within the rule-defined site and construction constraints.
4. Complete 30%, 60%, and 90% design reviews before releasing controlled fabrication drawings.
5. Fabricate components under approved shop procedures and document inspection results.
6. Develop the construction sequence, tool plan, builder assignments, and safety controls.
7. Rehearse timed construction and record time, errors, penalties, and recovery actions.
8. Complete lateral and vertical load testing as permitted by the current rules.
9. Close the season with archived records, lessons learned, and successor training.

1.4 Student Deliverables

- Rule-compliance matrix
- Analytical model, calculations, design checks, and sensitivity studies.
- Controlled assembly drawings, connection details, and bill of materials.
- Fabrication procedures, inspection records, nonconformance log, and as-built records.
- Construction sequence, tool layout, builder qualification records, and practice metrics.
- Load-test plan, instrumentation plan, test results, and redesign recommendations.
- Season closeout report and knowledge-transfer package.

Separate manual applies

The current annual SSBC rules govern all competition-specific dimensions, loads, scoring, construction constraints, and eligibility requirements.

ACTIVITY 2

Seismic Design Competition

A hybrid design-model-build-test activity in earthquake-resistant structural engineering

STATUS: IMPLEMENTED; SAP2000 COMPONENT BEING EXPANDED

Course connection	Structural Design Studio; Structural Analysis
Activity type	Design-model-build-test competition
Mode	Hybrid
Team format	Teams of 4-5 unless otherwise assigned
Primary tools	SAP2000, balsa fabrication tools, shake table, accelerometers, displacement/response data
Key deliverables	Design concept, rule-compliance check, SAP2000 model, response predictions, fabricated building, shake-table test, comparison report

2.1 The Challenge

Teams design a multi-story balsa-wood building that satisfies the adopted EERI Undergraduate Seismic Design Competition framework. The structure must combine architectural function, rule compliance, low weight, adequate stiffness and strength, stable load paths, and acceptable response under dynamic shaking.

The PolySDL implementation adds an explicit prediction-versus-test component: teams analyze the building in SAP2000 and predict maximum roof displacement and roof acceleration in the direction of shaking before the physical test.

2.2 Technical Baseline

Parameter	Activity Basis
Structural material	Balsa wood frame and/or wall members, with approved base and roof plates.
Number of floors	15 to 19 under the adopted 2024 rule framework.
Base plate	18 in × 18 in under the adopted activity basis; final course dimensions confirmed by instructor.
Roof plate	6 in × 6 in plywood or MDF, within the adopted thickness range.
Ground motions	Two motions of increasing intensity; GM#1 is known before testing and GM#2 represents a stronger, previously undisclosed demand in the official framework.
Predicted responses	Peak relative roof displacement and peak absolute roof acceleration.

Parameter	Activity Basis
Physical responses	Stability, damage, drift, acceleration, connection behavior, and collapse prevention.

2.3 Before You Begin

- Read the adopted rules and design guide; create a rule-compliance checklist.
- Confirm floor elevations, building zones, rentable floor requirements, member limits, connection rules, base/roof plate requirements, and dead-load locations.
- Establish north-south and east-west model axes that match the physical structure.
- Confirm the SAP2000 ground-motion file format, units, scale factors, damping assumptions, and output definitions.
- Plan how the physical model will be attached to the shake table and instrumented without violating the rules.

2.4 Digital Analysis Workflow

1. Create the structural geometry and assign balsa material and member properties.
2. Model mass sources and floor/roof dead loads consistently with the activity setup.
3. Check connectivity, supports, diaphragms or floor idealization, and local axes.
4. Run modal analysis and review periods, mode shapes, and mass participation.
5. Run the prescribed time-history analysis in each required direction.
6. Extract peak relative roof displacement and peak absolute roof acceleration.
7. Document sensitivity to stiffness, mass distribution, damping, and bracing arrangement.
8. Submit predictions before physical testing.

2.5 Fabrication and Quality Control

- Use approved balsa sizes and connection methods only.
- Maintain floor elevations, perimeter geometry, member straightness, and clear access for dead loads.
- Control glue area and excess adhesive; avoid unintended composite members or rule violations.
- Verify base and roof plate alignment and allow access for clamps and instrumentation.
- Label floors and orientations so the physical and digital models can be compared.

2.6 Shake-Table Testing

Before testing, the team completes a dimensional inspection, dead-load installation check, instrumentation check, and test-readiness review. The structure is then subjected to the prescribed motion while roof and base response are recorded.

- Observe first visible damage and its location.
- Record permanent deformation, connection opening, member buckling, floor movement, and loss of stability.
- Compare measured and predicted roof displacement and acceleration.
- Explain discrepancies using modeling assumptions, material variability, construction tolerances, damping, mass placement, and instrumentation.

2.7 Required Submissions

- Rule-compliance checklist and design concept.
- SAP2000 model, modal summary, time-history setup, and response plots.
- Four prediction values when both principal directions are required: drift and acceleration in each direction.
- Construction drawings, model photographs, and as-built dimensions.

- Test data, damage record, prediction-versus-test discussion, and redesign proposal.

Source and adaptation note

This activity is adapted from the 2024 EERI Undergraduate Seismic Design Competition Official Rules and Design Guide. PolySDL course instructions may simplify selected scoring and administrative requirements while retaining the technical design, prediction, fabrication, and shake-table learning objectives.

ACTIVITY 3

Balsa Bridge Competition

A hybrid design-model-build-test competition in truss analysis, structural efficiency, and experimental validation

STATUS: IMPLEMENTED - SPRING 2026

Course connection	Structural Analysis; Structural Design Studio
Activity type	Design-model-build-test competition
Mode	Hybrid
Team format	Small teams, typically 3-4 students
Primary tools	AutoCAD, SAP2000, Excel, balsa fabrication tools, precision scale, physical loading system
Key deliverables	1:1 drawings, SAP2000 model, member-force table, failure prediction, fabricated bridge, presentation, collapse test, reflection report

3.1 Activity Overview

Teams design, analyze, fabricate, present, and test a lightweight balsa-wood truss bridge. Each bridge spans 24 inches and is 6 inches wide. Before testing, the team predicts the failure load and governing member. On competition day, bridge self-weight and collapse load are measured so structural efficiency and prediction accuracy can be evaluated.

Engineering objective

Create a bridge that is efficient, accurately modeled, carefully fabricated, and supported by defensible engineering judgment - not merely a bridge that carries the largest absolute load.

3.2 Learning Objectives

- Develop a stable three-dimensional truss configuration within geometric constraints.
- Prepare 1:1 AutoCAD fabrication templates using centerline geometry and detailed joints.
- Model the bridge in SAP2000 with the physical supports and four loading joints.
- Identify tension and compression members and predict failure through tension rupture or Euler buckling.
- Determine an effective balsa modulus through a small bending calibration test.
- Evaluate the influence of member length, section, bracing, joint quality, and workmanship.
- Compare analytical prediction with observed collapse behavior and structural efficiency.

3.3 Technical Requirements

Requirement	Value / Meaning
Span	24 in, measured using the defined centerline geometry.
Width	6 in.
Structural form	Three-dimensional balsa-wood truss bridge.
Load transfer	Four required joints directly below the four legs of the loading board.
Reference model load	100 lb total, represented by four 25 lb joint loads in SAP2000.
Efficiency	Measured load-carrying capacity divided by bridge self-weight, LCC/SW.
Primary analytical failure modes	Tension rupture and compression buckling.
Joint assumption	Joints are assumed overdesigned for the prediction; physical joint failure is treated as a construction/modeling discrepancy.

3.4 Materials and Tools

Item	Purpose / Notes
Balsa sticks	Approved sizes and quantities issued or authorized by the instructor.
Adhesive	Approved CA glue or other specified adhesive; use minimal controlled quantities.
Cutting tools	Cutting mat, sharp hobby knife or balsa cutter, straightedge, sanding block.
Assembly aids	1:1 printed templates, protective sheet, pins/weights/jigs as approved.
Digital tools	AutoCAD, SAP2000, Excel capacity-prediction template.
Testing tools	Precision scale, bridge supports, loading board, approved weights or loading system, safety supports.
Documentation	Camera, inspection checklist, presentation slides, test-data sheet.

3.5 Material Calibration

Because balsa stiffness varies, each team determines an effective modulus of elasticity using a 0.25 in × 0.25 in stick in three-point bending over a 7.0 in span. Recommended midspan loads are 0.5, 1.0, and 1.5 lb.

Create the matching SAP2000 beam model and update the assumed modulus using:

Calibration equation

E_new = E_old × (delta_SAP / delta_exp)

Repeat until the SAP2000 displacement reasonably matches the measured displacement across the selected load levels. Report the average effective modulus and preserve the calibration data.

3.6 Concept Selection

- Compare multiple truss forms and document why the selected form is appropriate.
- Identify the expected load path from the loading board to the supports.
- Minimize long, weak compression members or provide effective bracing.
- Balance additional members and joint complexity against the self-weight penalty.
- Plan how the two side trusses will be connected and stabilized out of plane.
- Ensure the loading board and supports contact the intended joints.

3.7 AutoCAD Drawings

Prepare side, plan, and front views at 1:1 scale. Draw member centerlines first; then offset them to create actual member outlines. Trim intersecting outlines to define the joint geometry that will be used during fabrication.

- Verify the printed 24 in span and 6 in width before fabrication.
- Show loading joints, support locations, member sizes, and key joint details.
- Use the approved drawing revision as the fabrication template.
- Do not fabricate from an unapproved or superseded drawing.

3.8 SAP2000 Unit-Load Analysis

1. Model the truss joints and members using lb-in units.
2. Assign the calibrated balsa modulus and actual member sections.
3. Apply supports that represent the physical test.
4. Apply the 100 lb reference load as four 25 lb loads at the designated joints.
5. Run the analysis and export member axial forces N_ref.
6. Calculate axial force per unit applied load: n_i = N_ref / P_ref.
7. Classify each member as tension or compression.

3.9 Failure Prediction

For a tension member:

Tension capacity

N_t = sigma_t,allow × A and P_t = N_t / |n_i|

For a compression member, use Euler buckling with K = 1.0 unless otherwise instructed:

Compression buckling

N_c = pi^2 E I / (K L)^2 and P_c = N_c / |n_i|

The predicted bridge capacity is the minimum applicable member failure load. Identify the governing member and whether the predicted mode is tension rupture or compression buckling.

3.10 Fabrication and Quality Control

1. Protect the full-scale template from adhesive.
2. Cut and label members accurately.
3. Assemble the two side trusses flat and allow adequate curing time.
4. Join the side trusses using transverse members and lateral bracing.
5. Install and verify the four loading-board joints.

6. Inspect span, width, symmetry, straightness, joint contact, glue use, and support compatibility.
7. Measure and record final bridge self-weight.

3.11 Competition Day

- Present the design concept, load path, critical members, predicted capacity, and predicted failure mode.
- Complete dimensional and workmanship inspection.
- Place the bridge on the prescribed supports and position the loading board.
- Increase load gradually while observing deformation, buckling, joint opening, and load redistribution.
- Record collapse load, failure sequence, failure location, photographs, and video.
- Do not approach the failed bridge until the test area is declared safe.

3.12 Scoring and Deliverables

The implemented competition combines technical presentation, prediction accuracy, fabrication quality, and structural efficiency:

Competition score

FINAL SCORE = PPT + PRD + FABQ + LCC/SW

- AutoCAD side, plan, and front views.
- SAP2000 model and screenshots of supports and loads.
- Member axial-force and capacity table.
- Predicted failure load, governing member, and governing mode.
- Fabricated bridge and technical presentation.
- Measured self-weight and collapse load.
- Final report with prediction-versus-test comparison and redesign recommendations.

3.13 Common Failure Sources

- Compression buckling of a long or weakly braced member.
- Tension rupture at a reduced or damaged section.
- Joint separation or inadequate glue area.
- Out-of-plane instability or poor transverse bracing.
- Eccentric loading caused by misaligned loading joints.
- Crooked members, dimensional errors, local crushing, or material variability.

ACTIVITY 4

Base Isolation

A design-build-test activity in vibration reduction, stability, and earthquake-resistant structural response

STATUS: IN DEVELOPMENT

Course connection	Structural Design Studio; Structural Analysis
Activity type	Design-build-test comparative experiment
Mode	Physical
Team format	Five teams of approximately five students for a class of 25
Primary tools	Shake table, accelerometers, threaded rods, wood plates, isolation materials, fabrication tools, video/data recording
Key deliverables	Isolation concept, drawings, materials list, test-ready model, response comparison, reflection report

4.1 Activity Overview

Two nominally identical model buildings are tested side by side under the same horizontal shake-table motion. One building is fixed to the base. The second building is supported on a team-designed isolation system. The comparison shows how the interface between the ground and the structure changes the motion transmitted to the building above.

4.2 Common Superstructure

Component	Description
Columns	Four long threaded-steel rods located at the corners.
Roof platform	Wood plate with four holes matching the column locations; the plate slides onto the threaded rods.
Roof mass indicator	A bowl containing marbles attached to the roof plate to provide elevated mass and visible motion.
Common base	A rigid wood platform sized for secure shake-table attachment; final dimensions supplied by the instructor.
Comparison requirement	Fixed and isolated buildings should be as similar as practical above the base-isolation interface.

4.3 The Design Challenge

Each team develops an isolation concept that must satisfy two competing requirements:

- Support the vertical weight of the building and remain stable.
- Allow controlled horizontal movement that reduces motion transmitted to the roof.

Possible concepts include rubber, foam, marbles, rollers, tubular elements, elastomeric pads, sliding interfaces, or other instructor-approved systems. Teams must justify their selection using stiffness, friction, restoring force, displacement capacity, durability, and constructability.

4.4 Required Design Evidence

- Plan and section sketches showing the isolation interface.
- Material list and component dimensions.
- Estimated vertical load capacity and horizontal travel.
- Explanation of the restoring or recentering mechanism, if present.
- Prediction of which model will show greater roof motion and why.
- Test-readiness checklist confirming that components cannot detach during shaking.

4.5 Test Setup

- Mount both buildings on the same shake-table platform so they receive the same input motion.
- Verify equivalent roof mass and comparable superstructure geometry.
- Install accelerometers consistently at the roof level and, when available, at the base.
- Measure or estimate isolation-layer displacement using video, a scale, an LVDT, or another approved method.
- Secure roof bowls with identical lightweight transparent covers when marbles are used.

4.6 Responses to Compare

- Peak roof acceleration.
- Peak roof displacement or visible roof motion.
- Relative displacement across the isolation interface.
- Residual offset or recentering after shaking.
- Stability, rocking, impact, binding, or component damage.
- Movement of the roof mass indicator.

4.7 Deliverables

- Isolation concept sheet and labeled drawing.
- Materials and fabrication record.
- Pre-test prediction and test-readiness inspection.
- Time-history plots or comparison measurements when instrumentation is available.
- Photographs/video and observation table.
- Reflection explaining why the design succeeded or failed and how it would be improved.

Design lesson

Base isolation does not eliminate movement. It intentionally permits controlled displacement at the base to reduce acceleration and deformation transmitted to the structure above.

ACTIVITY 5

Built-Up Beams in Action

A design-build-test activity in transverse shear, shear flow, fastener demand, and connection behavior

STATUS: IN DEVELOPMENT

Course connection	Strength of Materials; Structural Design Studio
Activity type	Design-build-test
Mode	Physical
Team format	Groups of five
Primary tools	AutoCAD, hand calculations/Excel, woodworking tools, reaction frame, 60-kip actuator, displacement/load measurement
Key deliverables	Construction drawings, analytical prediction, fabricated girder, test data, prediction-versus-test report

5.1 Activity Overview

Teams design, draw, fabricate, and test a double-web built-up timber girder. The activity brings the transverse-shear and shear-flow concepts from Strength of Materials into a full-scale laboratory setting.

5.2 Planned Technical Basis

Parameter	Planned Basis
Span	Approximately 8 ft, simply supported.
Structural system	Double-web girder with solid-wood top and bottom chord members and plywood side webs.
Chord concept	Nominal 4 × 6 timber members at the top and bottom; final lumber dimensions confirmed before drawings are released.
Web concept	Two nominal 1/2-in plywood panels.
Loading	Concentrated midspan load applied in the Structural Design Lab reaction frame.
Primary variables	Fastener spacing s and connection type, such as screws versus through-bolts.
Responses	Load capacity, stiffness, connection slip, deformation, fastener behavior, and failure mode.

5.3 Technical Background

The wood chords and plywood webs act together only when the connection transfers longitudinal shear. The shear flow along an interface is calculated using:

Shear flow

$q = VQ / I$

When discrete fasteners are spaced a distance s apart, the force transferred by an individual fastener is approximated by:

Fastener demand

$F_{fastener} = q \times s$

Increasing fastener spacing generally increases the force demanded from each fastener and may increase connection slip or reduce composite action. The activity asks teams to connect this analytical relationship to actual beam response.

5.4 Team Design Variations

The instructor assigns or approves variations so the class produces a meaningful comparison. Variations may include:

- Different uniform fastener spacings.
- Variable spacing that follows the shear-force demand.
- Screw-connected versus through-bolted configurations.
- Connection detailing or washer/bearing variations approved by the instructor.

5.5 Required Analysis

- Section properties and bending stress.
- Shear force and bending moment diagrams.
- Transverse shear and interface shear flow.
- Fastener demand based on the selected spacing.
- Applicable wood, plywood, and connection capacity checks using properties supplied or approved by the instructor.
- Predicted maximum load and predicted failure mode.
- Predicted load-deflection response when the required material properties are available.

5.6 Construction Drawings and Fabrication

- Prepare AutoCAD plans, elevations, sections, dimensions, fastener layout, and support/loading locations.
- Mark all fastener locations before drilling or installation.
- Control edge distances, spacing, alignment, and fit between webs and chord members.
- Inspect for damaged plywood, split wood, eccentricity, loose fasteners, and out-of-straightness.
- Record as-built dimensions and any deviations from the approved drawing.

5.7 Test Procedure

1. Complete dimensional and connection inspection.
2. Install the simply supported beam and verify support alignment.
3. Position the actuator and loading block at midspan.

4. Install load and displacement measurement and establish the exclusion zone.

5. Apply a small seating load and confirm stable contact.

6. Increase load in controlled increments or displacement control as directed.

7. Record load, deflection, connection slip, audible/visible damage, and failure progression.

8. Stop the test when the instructor-defined termination criterion is reached.

5.8 Final Deliverables

- Approved construction drawings and as-built record.
- Calculation package and predicted maximum load.
- Fabrication photographs and quality-control checklist.
- Load-deflection data and selected plots.
- Observed failure sequence and failure photographs.
- Prediction-versus-test comparison and redesign recommendation.

ACTIVITY 6

Reinforced Concrete Beams in Action

A comparative design-build-test activity in flexure, shear, reinforcement detailing, and ductility

STATUS: IN DEVELOPMENT

Course connection	Strength of Materials; Reinforced Concrete Structures; Structural Design Studio
Activity type	Design-build-test comparative experiment
Mode	Physical
Team format	Groups of 4-5
Primary tools	Rebar detailing tools, formwork, concrete mixer and placement tools, curing equipment, reaction frame, four-point loading system, instrumentation
Key deliverables	Reinforcement drawing, cage/formwork inspection, beam fabrication, strength prediction, test participation, behavior comparison, reflection report

6.1 Activity Overview

Six reinforced concrete beams share the same nominal geometry and four-point bending setup but use different longitudinal reinforcement and stirrup spacing. By producing and testing the beams, students observe how detailing changes cracking, stiffness, ductility, strength, and failure mode.

6.2 Common Geometry and Loading

Parameter	Value / Description
Beam length	6 ft.
Cross section	6 in wide × 10 in deep.
Support condition	Simply supported.
Loading	Four-point bending through a spreader beam, producing two equal loads and a constant-moment region between them.
Primary variables	Longitudinal tension reinforcement and #3 stirrup spacing.
Responses	Cracking load, stiffness, deflection, ductility, capacity, shear behavior, and failure mode.

6.3 Beam Matrix

Specimen	Longitudinal Reinforcement	Transverse Reinforcement
Beam 1	(2) #3 bottom bars	#3 @ 8 in

Specimen	Longitudinal Reinforcement	Transverse Reinforcement
Beam 2	(3) #3 bottom bars	#3 @ 8 in
Beam 3	(2) #6 bottom bars	#3 @ 3 ft
Beam 4	(2) #6 bottom bars	#3 @ 18 in
Beam 5	(2) #8 bottom bars	#3 @ 18 in
Beam 6	(2) #8 bottom bars	#3 @ 4 in

6.4 Before Fabrication

- Review the assigned reinforcement drawing and identify all bars, stirrups, hooks, cover requirements, and support/loading regions.
- Prepare a bar list and cutting/bending plan.
- Verify form dimensions and reinforcement supports or chairs.
- Predict the expected flexural and shear behavior using methods provided in the course.
- State the expected cracking pattern, governing mode, and relative ductility before the beam is cast.

6.5 Fabrication Sequence

1. Fabricate and inspect the reinforcement cage.
2. Prepare, seal, and brace the formwork.
3. Position the reinforcement and verify cover, alignment, and cage stability.
4. Batch and place concrete under instructor supervision.
5. Consolidate and finish the concrete; prepare required material test specimens when assigned.
6. Label the beam and record batch, placement, and curing information.
7. Cure the specimen using the approved laboratory procedure.
8. Remove forms only when authorized and inspect the beam before testing.

6.6 Quality and Safety Checks

- Wear required PPE for reinforcement, formwork, mixing, placement, and testing.
- Control sharp bar ends and pinch points.
- Keep reinforcement position and cover from changing during placement.
- Do not lift or move beams without the approved handling method and adequate personnel/equipment.
- Inspect supports, spreader beam, actuator alignment, safety supports, and exclusion zone before loading.

6.7 Four-Point Bending Test

- Mark anticipated crack zones and a measurement grid before testing.
- Apply a seating load and verify instrumentation.
- Increase load in controlled increments while recording load, deflection, crack initiation, crack width/location, and visible reinforcement-related behavior.
- Observe whether flexural cracks, diagonal shear cracks, compression crushing, anchorage effects, or another mechanism governs.
- Record the complete failure sequence and compare all six beams under the common test setup.

6.8 Analysis and Reporting

- Calculate or estimate cracking moment, nominal flexural strength, shear capacity, and expected governing mode using the course method.

- Plot load versus midspan deflection when displacement data are available.
- Compare longitudinal reinforcement ratio with strength and ductility.
- Compare stirrup spacing with shear cracking and failure behavior.
- Explain why heavily reinforced beams may not provide the desired ductile flexural response.
- Recommend a revised reinforcement layout for improved performance.

Source and inspiration note

The comparative beam matrix is inspired by reinforced concrete beam failure demonstrations presented by Dr. Brock Hedegaard of the University of Minnesota Duluth and has been reorganized as a PolySDL student fabrication and testing activity.

ACTIVITY 7

Cantilever Bridge in Action

A participatory investigation of force balance, tension, compression, anchorage, and structural stability

STATUS: IN DEVELOPMENT

Course connection	Statics; Strength of Materials; Structural Analysis
Activity type	Participatory demonstration / kinesthetic investigation
Mode	Physical
Team format	Whole class with student volunteers
Primary tools	Human cantilever model, wood planks, rope, seats/anchors, free-body diagrams, observation worksheet
Key deliverables	Prediction, free-body diagram, tension/compression identification, observation notes, reflection

7.1 Activity Overview

The class recreates the human cantilever demonstration associated with Benjamin Baker and the Forth Bridge. Student volunteers become part of the load-carrying system so the class can see and physically experience how the suspended central load is transferred through cantilever arms to the supports and anchors.

7.2 Learning Sequence

Predict → Participate → Explain

Students first predict the load path, then experience the physical model, and finally revise their free-body diagrams and explanations using what they observed.

7.3 Technical Snapshot

Concept	Interpretation
Structural concept	Balanced cantilever system supporting a suspended central span.
Primary load	Central suspended weight W.
Symmetric behavior	Each side supports one-half of the central load under an ideal symmetric arrangement.
Upper elements	Primarily tension in the physical analogy.
Lower elements	Primarily compression in the physical analogy.
Key ideas	Equilibrium, load path, anchor force, tension, compression, symmetry, and stability.

7.4 Model Components

- Four wood planks approximately 30 × 4 × 1.5 in.
- One central plank approximately 24 × 6 × 1.5 in.
- Nylon rope and drilled connection holes sized for safe assembly.
- Stable seats/supports and approved anchoring weights or restraints.
- Rounded or smoothed edges and inspected rope knots/connections.

7.5 Student Procedure

1. Study the arrangement and draw a simplified free-body diagram.
2. Predict the force shared by the two sides when the central load is W.
3. Label the elements expected to carry tension and compression.
4. Explain the purpose of the anchors and what would happen if one side were released.
5. Assemble the model under instructor supervision and apply the central load gradually.
6. Ask the volunteers to describe what they feel in the upper and lower elements and at the anchors.
7. Repeat the reasoning for a different central load or an intentionally unbalanced condition without creating an unsafe setup.
8. Revise the free-body diagram and submit the reflection.

7.6 Safety

- Instructor approval is required before students sit, pull, suspend, or load any component.
- Inspect planks, holes, ropes, knots, seats, and anchors before each use.
- Use spotters and apply load gradually.
- Do not place students beneath suspended weights or unstable components.
- Stop immediately if a connection slips, a participant loses balance, or an anchor moves.

7.7 Deliverables and Reflection

- Initial and revised free-body diagrams.
- Tension/compression labeling and explanation of anchor forces.
- Short response to how forces change when the central load doubles.
- Comparison between the model and the actual Forth Bridge.
- One paragraph explaining what the physical participation revealed that a static diagram did not.

Source and adaptation note

This activity is adapted from The Human Cantilever Model of the Forth Bridge presented through Princeton University’s Creative Art of Structural and Civil Engineering teaching resources. PolySDL uses original student instructions and should credit the Princeton contributors on the final page and handbook reference list.

ACTIVITY 8

Canyon Bridge

Development framework for a future PolySDL bridge activity

STATUS: CONCEPT DEVELOPMENT

Course connection	To be confirmed
Activity type	To be confirmed
Mode	To be confirmed
Team format	To be confirmed
Current status	Website concept exists; technical activity brief has not yet been finalized
Handbook purpose	Provide a structured checklist for completing the activity definition

8.1 Current Development Position

The Canyon Bridge appears in the PolySDL activity portfolio, but the current project record does not yet establish a final structural system, model scale, design constraints, analysis requirement, loading procedure, or student deliverables. This chapter is therefore intentionally presented as a development framework rather than a completed student instruction.

8.2 Decisions Required Before Release

- Define the structural concept and learning objective.
- Decide whether the activity is a demonstration, digital study, design-build-test project, or hybrid project.
- Establish model geometry, scale, materials, supports, loading, and allowable design variations.
- Define the analytical model and required software, if any.
- Specify measurable responses and success criteria.
- Prepare material and tool lists, drawings, risk assessment, and test procedure.
- Define student team size, milestones, deliverables, assessment rubric, and handbook figures.

8.3 Proposed Student-Facing Chapter Structure

1. Overview and real-bridge inspiration.
2. Learning objectives and technical background.
3. Design challenge and constraints.
4. Materials, tools, and model geometry.
5. Analysis and prediction requirements.
6. Fabrication and quality-control steps.
7. Test setup, instrumentation, safety, and loading sequence.
8. Deliverables, grading, and reflection.

Instructor development note

Do not issue this activity to students until the missing technical parameters and safety controls have been confirmed and trial-tested.

ACTIVITY 9

Millennium Bridge

Development framework for a future PolySDL structural-response activity

STATUS: CONCEPT DEVELOPMENT

Course connection	To be confirmed
Activity type	To be confirmed
Mode	To be confirmed
Team format	To be confirmed
Current status	Website concept exists; detailed technical brief and model have not yet been finalized
Handbook purpose	Establish the questions that must be answered before student implementation

9.1 Current Development Position

The Millennium Bridge page is part of the PolySDL portfolio, but the current project record does not yet contain an approved student model, response measurement method, loading protocol, analysis assignment, or deliverable set. This chapter therefore avoids inventing specifications and records the development work still required.

9.2 Decisions Required Before Release

- Define the specific structural behavior to be demonstrated or analyzed.
- Select the physical or digital model and establish its scale and boundary conditions.
- Define how excitation will be introduced and how response will be measured.
- Identify the variables students may change and the comparison they must make.
- Establish analysis equations or software requirements.
- Confirm materials, tools, safety controls, and test termination criteria.
- Prepare a pilot test and verify that the activity produces repeatable, interpretable data.

9.3 Proposed Student-Facing Chapter Structure

1. Historical or real-structure context.
2. Target behavior and learning objectives.
3. Model description and technical snapshot.
4. Prediction task and analysis method.
5. Experimental or digital procedure.
6. Data reduction and required plots.
7. Design intervention or response-control comparison.
8. Deliverables and reflection.

Instructor development note

A future revision should replace this framework with tested student instructions, drawings, photographs, data sheets, and a completed risk assessment.

APPENDICES | STUDENT TEMPLATES AND CHECKLISTS

Appendix A. Team Charter Template

Field	Team Entry
Team name	
Activity	
Members and roles	
Meeting schedule	
Decision method	
File location	
Communication channel	
Conflict/escalation plan	
Safety responsibilities	

Team approval date: ____

Appendix B. Design Review Checklist

- Problem statement and success criteria are clear.
- Current rules and instructor requirements have been checked.
- Units and coordinate systems are consistent.
- Load path and likely failure modes are explained.
- Geometry and interfaces are defined.
- Material properties and sources are documented.
- Supports and loads match the planned physical test.
- Model equilibrium and deformed shape are reasonable.
- Critical members or components have been identified.
- Drawings match the analysis model.
- Fabrication and test risks are documented.
- Prediction method and required outputs are complete.
- Revision number and reviewer decisions are recorded.

Appendix C. Fabrication Quality Checklist

- Approved drawings are available at the workstation.
- Materials and components match the specified type and dimensions.

- Cut lengths, holes, fastener locations, and reinforcement positions have been checked.
- Members are straight and undamaged.
- Joints have adequate contact and controlled adhesive or fastening.
- The specimen is square, symmetric, aligned, and within tolerance.
- As-built deviations are marked on the drawing.
- The specimen is labeled and protected during curing/storage/transport.
- The completed specimen passes the test-fixture compatibility check.

Appendix D. Test-Day Checklist

Category	Check
Specimen	ID, dimensions, condition, orientation, mass, and pre-existing damage recorded.
Fixture	Supports, loading points, fasteners, clamps, and interfaces checked.
Instrumentation	Load, displacement, acceleration, and video channels verified and zeroed.
Safety	PPE, exclusion zone, safety supports, debris control, and stop criteria confirmed.
Prediction	Predicted response and failure mode submitted before loading.
Data sheet	Names, date, file name, sampling settings, and observation roles assigned.
Test control	Loading sequence, operator, communication commands, and emergency stop confirmed.
Closeout	Area declared safe before approach; failed specimen and data preserved.

Appendix E. Reflection Report Prompts

- What did the team predict, and what actually happened?
- Where did the analytical idealization represent the physical system well?
- Which assumption produced the largest discrepancy?
- How did material variability, geometry, connections, or workmanship affect the result?
- What evidence supports the explanation of failure?
- What would the team change first in a second design?
- What did each member contribute, and what knowledge should be transferred to the next team?
- What new question did the activity create?

Appendix F. Standard Data Table

Step / Time	Applied Load or Input	Measured Response 1	Measured Response 2	Observation / Damage
0				
1				

Step / Time	Applied Load or Input	Measured Response 1	Measured Response 2	Observation / Damage
2				
3				
4				
5				

Appendix G. Glossary

Term	Meaning in This Handbook
As-built	The final specimen geometry and details after fabrication, including deviations from the approved design.
Capacity	The maximum load or demand a member, connection, or structure can resist under the stated criterion.
Ductility	Ability to undergo substantial deformation before loss of capacity.
Failure mode	The physical mechanism that governs loss of performance, such as buckling, rupture, crushing, shear, or joint separation.
Hybrid activity	An activity combining digital analysis/modeling with physical fabrication or testing.
Load path	The route by which applied forces travel through members and connections to the supports.
Prediction-versus-test	A comparison between analytical or computational expectations and measured physical response.
Structural efficiency	Performance relative to material use or self-weight, defined specifically by the activity.
Test readiness	Documented confirmation that the specimen, fixture, instrumentation, and safety controls are prepared for testing.
Traceability	Ability to identify the source, revision, assumption, and decision associated with a result or document.

Appendix H. Draft Revision Log

Revision	Date	Description
0.1	August 2026	Initial integrated student handbook draft covering common expectations, seven developed/program activity chapters, two development frameworks, and standard appendices.

Revision	Date	Description