

Concrete Beam Competition

1.0 Introduction

- 1.1 This competition incorporates principles of both concrete proportioning and structural engineering. It requires problem solving and reasoning skills to optimize the design and construction of an unreinforced concrete beam with special dimensional and material constraints. Up to 30 possible points will be awarded to each team based on the (1) sustainability, (2) weight, and (3) flexural strength of its submitted beam. The weight and flexural strength reflect structural efficiency. The flexural strength will be determined using a modified version of a standard flexural test. Sustainability, an increasingly common requirement in concrete mixture design, will be evaluated based on the concrete's constituent materials and their proportions.

2.0 Participants

- 2.1 Graduate and undergraduate students are allowed to participate in this competition.

3.0 Required Dimensions and Features

- 3.1 The external dimensions for the beam shall be 20 in. × 6 in. × 5 in. with a tolerance of $\pm \frac{1}{4}$ inches on each of these dimensions. The 20-in. dimension is referred to herein as the length of the beam. The outer 6 in. x 5 in. surfaces are referred to herein as the ends of the beam.
- 3.2 All beams shall have one hole along which a 40-mm diameter ping pong ball can pass unobstructed from one beam end to the other beam end. This hole shall have a centerline length of at least $19\frac{3}{4}$ inches and open only on the ends of the beam. All surfaces of the beam, including all hole surfaces, shall be free of any non-concrete debris at time of submittal.
- 3.3 Failure to satisfy these dimensional requirements will result in disqualification from the competition.

4.0 Concrete Raw Material Requirements

- 4.1 Only materials approved in this section can be used in the concrete of the submitted beam. Use of any other material in the concrete mixture will result in disqualification from the competition.
- 4.2 Portland cement as defined in ASTM C 150 is allowed.
- 4.3 Fly ash as defined in ASTM C 618 is allowed.
- 4.4 Slag cement as defined in ASTM C 989 is allowed.
- 4.5 Chemical admixtures as specified in ASTM C 494 or ASTM C 260 are allowed.
- 4.6 Coarse aggregate that meets the No. 67 or 57 gradation requirements of ASTM C 33 is allowed. The concrete beam shall contain a minimum of 30 percent coarse aggregate by volume of concrete.
- 4.7 Fine aggregate as defined in ASTM C 33 is allowed.

- 4.8 Any source of potable water is allowed.
- 4.9 No fibers, coatings, or any forms of reinforcement are permitted.

5.0 Sustainability

- 5.1 Teams will be awarded points based on the overall sustainability of their concrete mixture. Up to 10 points will be awarded for this category.
- 5.2 Fly Ash Use (percent by weight of total cementitious material):
 - 5.2.1 $15\% \leq \text{Fly ash content} < 30\% = 2$ points
 - 5.2.2 $30\% \leq \text{Fly ash content} < 50\% = 3$ points
 - 5.2.3 Fly ash content $\geq 50\% = 4$ points
- 5.3 Slag Cement Use (percent by weight of total cementitious material):
 - 5.3.1 $20\% \leq \text{Slag cement content} < 40\% = 2$ points
 - 5.3.2 $40\% \leq \text{Slag cement content} < 60\% = 3$ points
 - 5.3.3 Slag cement content $\geq 60\% = 4$ points
- 5.4 Portland Cement Use
 - 5.4.1 Portland cement content < 188 pcy = 4 points
 - 5.4.2 188 pcy \leq Portland cement content < 282 pcy = 3 points
 - 5.4.3 282 pcy \leq Portland cement content ≤ 376 pcy = 2 points
- 5.5 Recycled Aggregate Use (percent by volume of total aggregate content):

To qualify as recycled aggregate for the purpose of this competition, aggregate shall be produced from construction or demolition *waste* of a real-world facility. Recycled aggregate may not be manufactured by competitors by making concrete for the specific use of recycling it for this competition.

 - 5.5.1 $25\% \leq \text{Recycled aggregate content} < 50\% = 2$ points
 - 5.5.2 Recycled aggregate content $\geq 50\% = 4$ points

6.0 Beam Weight

- 6.1 Teams will be awarded points based on the overall weight of their beam. Up to 10 points will be awarded for this category.
- 6.2 Each beam's weight shall be determined using a scale with accuracy to 0.1 lb.
- 6.3 The team with the lowest beam weight will be awarded 10 points. The team with the highest beam weight will be awarded 1 point. All other points will be determined using Equation 1 and rounded to the nearest 0.1. An example of the weight points awarded is shown in Fig. 1.

$$\text{Your team's points} = 10 - 9 \times \left(\frac{\text{Your weight} - \text{Lowest weight}}{\text{Highest weight} - \text{Lowest weight}} \right) \quad (\text{Eq. 1})$$

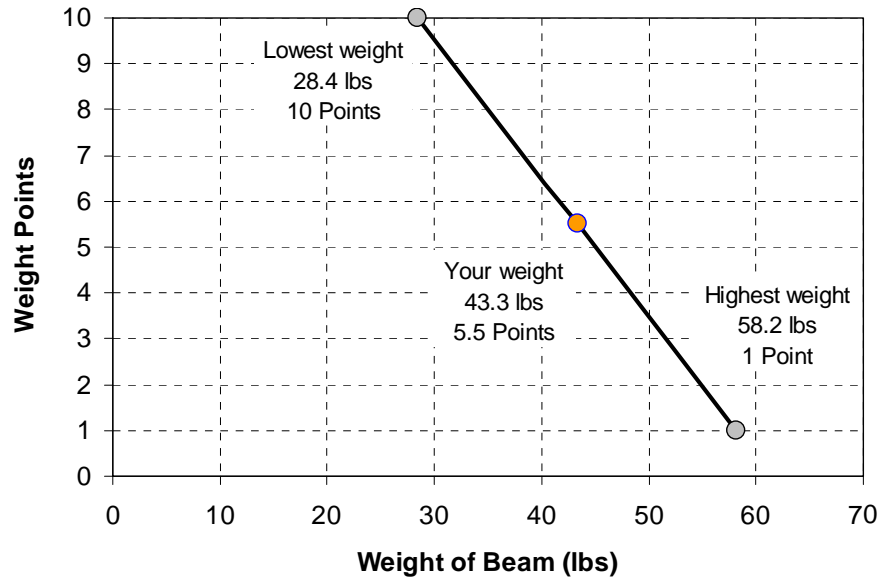


Figure 1: Example Calculation of Weight Points

7.0 Beam Flexural Strength

- 7.1 Each team will be awarded points based on the flexural strength of its beam. Up to 10 points will be awarded for this category.
- 7.2 The load that causes flexural failure of the beam will be determined in accordance with the loading configuration defined in ASTM C 78. Load will be applied perpendicular to the 20-in. dimension of the beam as shown in Figure 2. Load will be recorded to the nearest 1.0 lb.

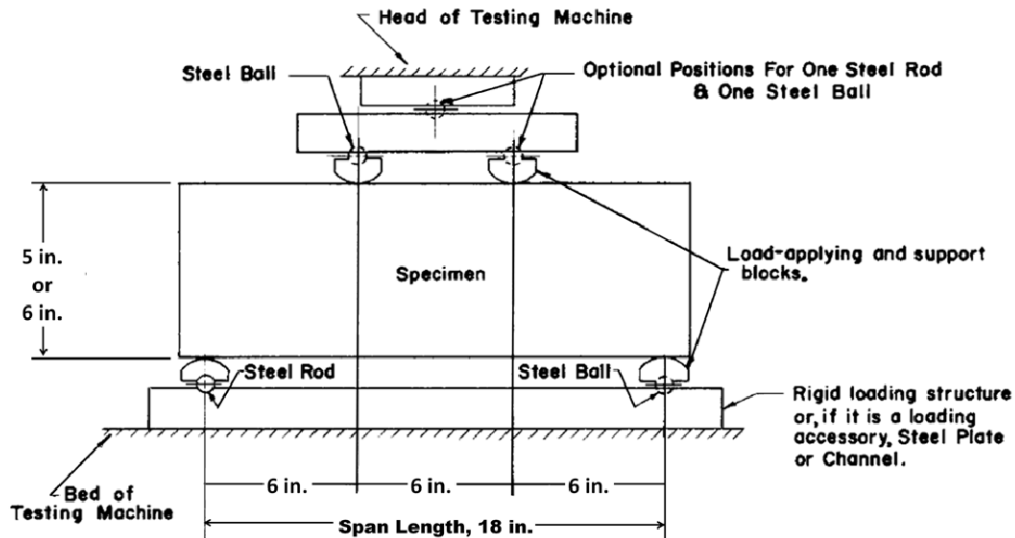


Figure 2: Flexural Test Setup (adapted from ASTM C 78 2008)

- 7.3 Beams will be tested in an order determined by the judges. The testing order will be posted by the judges after all beams have been submitted.
- 7.4 The team captain shall be present at the time of loading to orient and position the beam for loading. If the team captain is not present when called, that team will be reassigned to the end of the testing order.
- 7.5 Each beam will be loaded in flexure at a rate between 1,500 and 2,100 pounds per minute.
- 7.6 Each beam will be loaded until failure occurs. The maximum load resisted by the beam will be taken as the failure load.
- 7.7 If a team has been reassigned to the end of the testing order and no captain is present at the reassigned time of loading, that team will be awarded zero (0) points for beam flexural strength.
- 7.8 The team with the highest beam failure load will be awarded 10 points. The team with the lowest beam failure load (of all beams tested) will be awarded 1 point. All other strength points will be determined using Equations 2 and 3 and will be rounded to the nearest 0.1. An example of the strength points awarded is shown in Figure 3.

$$x = \frac{\text{Your load} - \text{Lowest load}}{\text{Highest load} - \text{Lowest load}} \quad (\text{Eq. 2})$$

$$\text{Your team's points} = 6.9x^2 + 2.1x + 1.0 \quad (\text{Eq. 3})$$

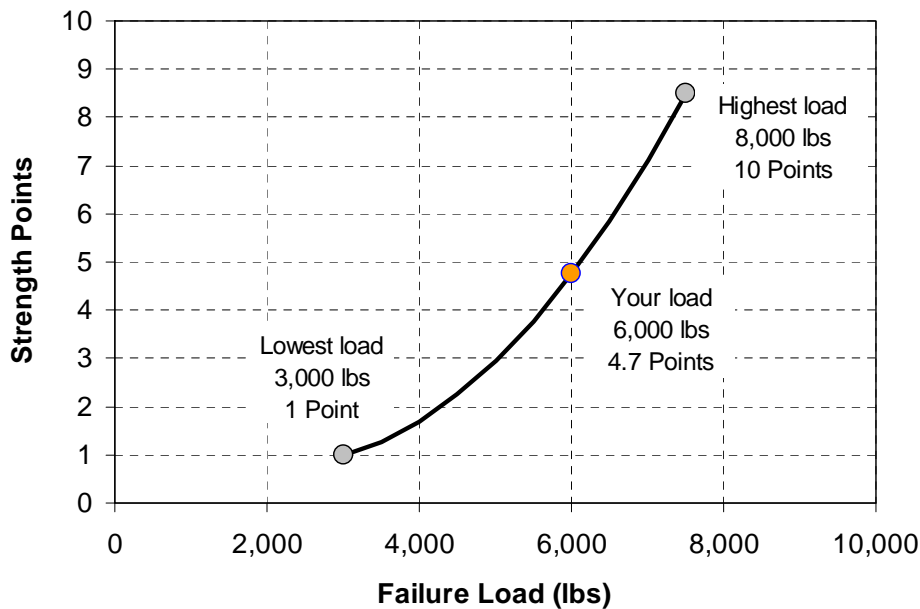


Figure 3: Example Calculation of Strength Points

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8.0 Team Submittals

- 8.1 Each team shall submit its beam and Mixture Proportion Submittal by the time specified on the official schedule. Late submissions will not be permitted.
- 8.2 Each team shall submit one (1) beam that complies with all rules specified. The name of the school shall be clearly written with permanent marker on the beam.
- 8.3 Each team shall report the raw material properties and mixture proportions of the concrete used in the beam by completing and submitting the Mixture Proportion Submittal in Appendix A. The judges may deduct up to 5 points from the *Sustainability Category* for any errors or omissions in the Mixture Proportion Submittal. When completing the Mixture Proportion Submittal, each team must estimate the number of sustainability points that it expects to be awarded.
- 8.4 Beams will be kept in an air-conditioned room after submittal. No participant contact with beams, other than to position the beam for loading, will be permitted after submittal.

9.0 Judging and Scoring

- 9.1 All rules specified will be enforced at the discretion of the judges. All judges' rulings will be final.
- 9.2 Sustainability, strength, and weight of each beam will be considered. Points will be awarded in these categories as specified in Sections 5.0, 6.0, and 7.0. The points awarded in these categories will be summed to obtain each team's total points for this competition.
- 9.3 The team with the most total points wins this competition. All teams shall be ranked in descending order of total points obtained. In the event of a tie for the most points, the tied team with the lightest beam will win this competition.
- 9.4 Judges may retain any of the submitted beams to verify the validity of the submitted raw materials and mixture proportions.

10.0 References

ASTM C 78 (2008), "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)," *ASTM International*, West Conshohocken, Pennsylvania.

APPENDIX A – Mixture Proportion Submittal

Team Name:			
Team Captain:			
MATERIAL PROPERTIES:			
Coarse Aggregate:			
Type and Gradation	=	_____	
Bulk Specific Gravity (SSD)	=	_____	Absorption Capacity = _____ %
Fine Aggregate			
Type and Gradation	=	_____	
Bulk Specific Gravity (SSD)	=	_____	Absorption Capacity = _____ %
Recycled Aggregate			
Source and Gradation	=	_____	
Bulk Specific Gravity (SSD)	=	_____	Absorption Capacity = _____ %
Portland Cement:			
ASTM C 150 Type	=	_____	Bulk Specific Gravity = _____
Fly Ash:			
ASTM C 618 Class	=	_____	Bulk Specific Gravity = _____
Slag Cement:			
ASTM C 989 Grade	=	_____	Bulk Specific Gravity = _____
MIXTURE PROPORTIONS:			
		Weight	Volume
Water Content		_____ lbs/yd ³	_____ ft ³
Portland Cement Content		_____ lbs/yd ³	_____ ft ³
Fly Ash Content		_____ lbs/yd ³	_____ ft ³
Slag Cement Content		_____ lbs/yd ³	_____ ft ³
Coarse Aggregate Content (SSD)		_____ lbs/yd ³	_____ ft ³
Fine Aggregate Content (SSD)		_____ lbs/yd ³	_____ ft ³
Recycled Aggregate Content (SSD)		_____ lbs/yd ³	_____ ft ³
Total Air Content		0 lbs/yd ³	_____ ft ³
Chemical Admixtures <small>Note 1</small>		_____ lbs/yd ³	_____ ft ³
		Total	27.00 ft ³
Water-Cementitious Materials Ratio	=	_____	
Course Agg. Volume / Concrete Volume	=	_____ %	
Recycled Aggregate Content	=	_____ %	
Fly Ash Dosage	=	_____ %	
GGBF Slag Dosage (%)	=	_____ %	
SUSTAINABILITY POINTS:			
		Team's Estimate	Judges' Decision
Fly Ash Use	=	_____	= _____
Slag Cement Use	=	_____	= _____
Portland Cement Use	=	_____	= _____
Recycled Aggregate Use	=	_____	= _____
Total	=	_____	= _____

Note 1: Submit a separate sheet that clearly identifies all chemical admixtures and their dosages.