Materials Design Rules

Participants

- Each school may only have one team compete in the competition.
- Each team may have any number of students participate in the competition.
- Each team member must be a registered participant of the 2017 ASCE Great Lakes Student Conference.

Event Description

Create a foam concrete mix that will have a low thermal conductivity and density while also maintaining a high compressive strength. Foam material is defined according to ASTM C 796-04: Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam.

Relevance[1]

This year's materials competition is to create foam concrete. Foam concrete, also known as cellular concrete, is a low density material having a void or cell structure created by the addition of a preformed foam or the generation of gas within the fresh concrete mix. Since the material has such a low density, foam concrete has a relatively low strength, but can have great insulation properties. Foam concrete can be used in nonstructural applications for thermal and sound insulation, roof decks, firewalls, and underground thermal conduit linings. The purpose of this competition is to create a foam concrete mix that has good thermal insulation, while also considering the density and compressive strength of the mix.

[1] Lamond, Joseph F. Pielert, James H.. (2006). Significance of Tests and Properties of Concrete and Concrete-Making Materials: (STP 169D). ASTM International.

Definition

The definition of foam concrete (cellular concrete) will be according to the ASTM C796-04 standard. Listed in section 3, terminology, the definition is as follows:

> 3.1.1 Cellular Concrete – a lightweight product consisting of Portland cement, cement-silica, cement-pozzolan, lime-pozzolan, or lime silica pastes, or pastes containing blends of these ingredients and having a homogenous void or cell structure, attained with gas-forming chemicals or foaming agents (for cellular concretes containing binder ingredients other than, or in addition to Portland cement, autoclave curing is usually employed).[3] In cellular concrete the density control is achieved by substituting macroscopic air cells for all or part of the fine aggregate. Normal-weight coarse aggregate is usually not used but lightweight aggregates, both fine and coarse, are often utilized in cellular concrete.

While the definition of cellular concrete allows for the use of normal-weight coarse aggregate, this competition **WILL NOT ALLOW THE USE OF NORMAL-WEIGHT COARSE AGGREGATE.** Aggregate and mix design specifications are as follows:

Guidelines

Materials:

- **Cement and cementitious materials**
    - The sum of cement and/or other cementitious materials must not be more than 20% of the mix by volume.

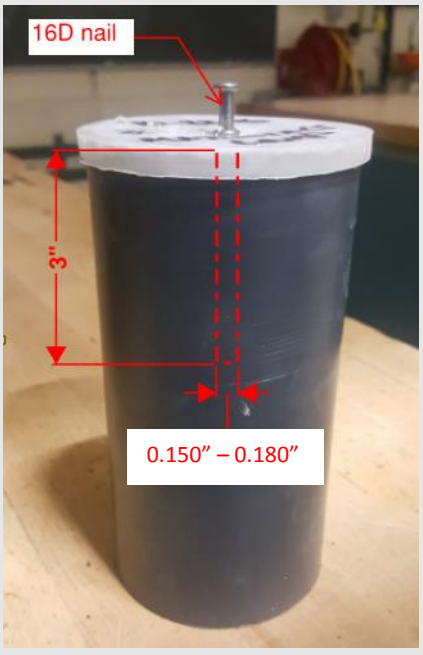
- **Aggregates**
    - The use of normal weight coarse aggregates is prohibited.
    - All coarse aggregate must adhere to ASTM C332 - Standard Specification for Lightweight Aggregates for Insulating Concrete.
    - All fine aggregates must pass through a #8 sieve and adhere to ASTM C332.

- **Admixtures**
    - Foaming agent admixture must be incorporated in the mix design and must adhere to ASTM C869/C869M – 11: Foaming Agents Used in Making Preformed Foam for Cellular Concrete.
    - The sum of foaming agents used must not be more than 10% of the mix by volume.
    - Other admixtures may be used, but must be noted on the mix design sheet.

- **Reinforcement**
    - Reinforcement materials of any kind, including structural fibers, are prohibited in the concrete mix.

- **Test Samples**
    - Two (2) standard (3” diameter by 6” height) cylinders (Cylinder A and Cylinder B) will be submitted for official testing at the competition.
    - Cylinder A will be used to measure density and test the compressive strength properties of the concrete.
    - Cylinder A shall be created in accordance with ASTM C192 – Making and Curing Concrete Test Specimens in the Laboratory.
    - Cylinder B will be used to test the insulation properties of the concrete.
    - Cylinder B shall be created in accordance with ASTM C192, but a cavity must be created in the radial center of the cylinder to facilitate thermal testing.
        - The cavity must be 3” long and 0.150” - 0.180” in diameter.
        - It is suggested, but not required, that a 3” 16D nail be used to create this cavity. See pictures below for an example.

FAILURE TO FOLLOW ANY OF THE ABOVE CRITERION WILL RESULT IN IMMEDIATE DISQUALIFICATION FROM THE MATERIALS COMPETITION.



Testing

- **Density**
  - Cylinder A will be weighed at the start of competition. A standard scale using units of pounds will be used. The density will be measured by dividing the mass of the cylinder in pounds by the volume of the cylinder in cubic feet. A standard calculation value of 0.0981 ft^3 will be used for the volume of the cylinder.
- **Compressive Strength**
  - After the density measurement, Cylinder A will be tested using the standard compression test guidelines of ASTM C495 – Standard Test Method for Compressive Strength of Lightweight Insulating Concrete. The cylinder will be subjected to a compressive force until severe failure. Severe failure is defined as the point when the load drops more than 20%. The maximum force applied to the cylinder will be divided by the surface area of the 3" diameter base of the cylinder to compute the compressive strength of the concrete in pounds per square inch. A standard calculation value of 7.0685 in^2 will be used for the area of the base.
- **Thermal Insulation**
  - Before thermal insulation testing is conducted, the cavity located in Cylinder B will be clear of all obstructions. Cylinder B will then be placed into a 300° F oven for 15 minutes. After 15 minutes, the cylinder will be removed and the internal temperature and surface temperature of the cylinder will be measured as follows. An infrared thermometer will be aimed at the vertical (6" dimension side) surface of the cylinder to measure the surface temperature after 20 seconds has elapsed after removal from the oven. An instant-read stick thermometer will be inserted into the cavity of the cylinder immediately upon removal from the oven to measure the core temperature. The core temperature will be taken using the instant-read stick thermometer after 2 minutes have elapsed after removal from the oven. The difference

between the core temperature and the surface temperature will be used for scoring.

Submittals

- Each team must complete the attached mix design sheet by Thursday, March 2, 2017. The mix design sheet must be submitted via email to prestonm@msoe.edu by 11:59 p.m. CST. Failure to submit the mix design sheet by the specified deadline will result in an automatic withdrawal from the materials design competition.
- Along with the mix design sheet, each team must submit material technical data sheets (MTDS) for each material used. ASTM compliance must be clearly marked on aggregate and foam agent MTDS.
- All cylinders considered for official compression and thermal testing must be submitted at the time of registration on Thursday, March 30, 2017. This will allow all cylinders to start at the same room temperature prior to official testing on Saturday, April 1. Teams may bring up to four cylinders to competition, however, only two will be used for official testing. Cylinders must be created on or after Saturday, March 4 to limit a maximum 28 day cure by the date of official testing. Cylinders must arrive **UNOPENED** in original casing at the time of registration. Teams may open and prepare cylinders on Saturday, April 1, prior to their allotted time slot. At this time, teams may determine the two cylinders they wish to submit for official testing. Testing will take place in the MSOE materials lab, SG-100. Time slots for testing will be announced at registration.

Scoring

The total score will be weighted based on 50% for thermal insulation, 35% for compressive strength and 15% for density. The lowest score for density and the highest scores for compressive strength and thermal insulation will earn the maximum possible score of 100 points for that category; points thereafter will be directly proportional based off the top score in the category, please see figure 1 for examples. The final score will be a summation of the weighted values of the score in each category.

	Thermal Insulation		Compressive Strength		Density		Total Score	
Teams	ΔT (°F)	Points in Catergory	Strength (psi)	Points in Category	Density (pcf)	Points in Category	(0.5*ΔT+0.35*Strength+0.15*Desnity)	Final Place
A	15	75.00	800	80.00	3.00	50.00	73.00	Third
B	20	100.00	650	65.00	4.50	33.33	77.75	Second
C	13	65.00	900	90.00	1.50	100.00	79.00	First
D	10	50.00	750	75.00	6.00	25.00	55.00	Fourth
E	5	25.00	1000	100.00	5.50	27.27	51.59	Fifth

Figure 1: Example of competition scoring.

Mix Design Sheet

School Name: _____

Faculty Advisor: _____

Faculty Advisor Signature: _____

Team Members: _____

_____

_____

Component	Type	Amount (lbs)	Unit Weight (lbs/ft³)	Volume (ft³)	Percent of Total Volume (%)
Cementitious Material(s)					
Coarse Aggregate(s)					
Fine Aggregate(s)					
Foam Agent (s)					
Chemical Admixture(s)					
Water					
				TOTAL	100%