The Concrete Contest

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Abstract
At the University of Arkansas, Structural Materials is a required course for all civil engineering students. The course is normally taken by students in the second semester of their sophomore year or by students who are in the first semester of their junior year. As the course is presently taught, concrete materials and mixture designs makes up approximately 60 percent of the class with the remaining portion split amongst steel, timber, and fiber reinforced polymers (FRP). In an effort to create interest in the class and enthusiasm about concrete, the "Concrete Contest" began in 2003. For the contest, the students are divided into teams of four or five. Each team must develop their own mixture, batch their mixture, and test the fresh and hardened concrete properties. The students are graded on the cost of their mixture, quality control, and compressive strength at 28 days of age. Fall 2003, one group of students designed a concrete mixture which had a one day compressive strength of almost 10,000 psi, and at 28 days the winning group's concrete mixture had a strength of almost 15,000 psi. The "Concrete Contest" has taught the class many lessons, of which the one most often heard is "the concrete was not workable enough to produce concrete cylinders of good quality". The "Concrete Contest" has been a success, and it will continue to introduce HPC to new students every semester.

Introduction
Structural Materials, CVEG 2113, is a sophomore level class that is required of all civil engineering students at the University of Arkansas. The class schedule consists of two fifty-minute lectures and a three hour laboratory each week of the semester. The laboratory is used to reinforce the information presented during the class lectures. Concrete materials account for almost 60 percent of the course material. In an effort to create interest in the class and in concrete materials, the "Concrete Contest" began in the fall semester of 2003.

Concrete Contest
The "Concrete Contest" is divided into three sections; cost, performance, and a written report. Students are provided with a concrete mixture proportion shown in Table 1 which serves as the control mixture. The control mixture is part of an ongoing research program and has been batched numerous times; therefore the fresh and hardened concrete properties of the mixture are well documented. Along with the mixture proportion, the students are also provided the 28 day compressive strength of the mixture and the cost of the mixture per cubic yard. The cost of the individual ingredients of the mixture is also provided to the students along with the material properties (Table 2). Students are allowed to use any material in the concrete lab, and they are also encouraged to search literature for HPC mixture designs.

Table 1. Control Mixture.

Materials	$Weight_{SSD}$ (lbs)
Cement	650
Coarse Aggregate	1890
Fine Aggregate	1155
Water	293
Mix Statistics	
w/c	0.45
Unit weight (lb/ft^3)	147.7
28-d compressive strength (psi)	7470
Air Content (%)	2.0
Cost ($/$yd^3$)	$53.56

Table 2. Material Properties and Cost.

Materials	Specific Gravity	Absorption Capacity	Cost ($/ton)
Cement	3.15		80
Fly Ash	2.2		35
Blast Furnace Slag	2.9		75
Silica Fume	2.2		500
Coarse Aggregate	2.68	0.38	18
Fine Aggregate	2.6	0.48	18
Water	1		$2.50/1000 gal
HRWR			$8.00/gal

Points are awarded based on cost, performance, and a written report. The control mixture given in Table 1 serves as a starting point for most students and students will receive a grade of 60 percent (D) for batching the control mixture. Points are earned if they improve on the mixture proportion, and points are also lost if certain performance requirements are not met. The scoring system is shown below.

SCORING SYSTEM

For every 100 psi greater than 7470 (control mixture's 28 day strength),
you will receive **1 point**.
For every 100 psi less than 7470, you will lose **1 point**.

For every 1 lb that you are off on the unit weight (calculated vs. measured) you will lose **10 points.**

You will lose **5 points** if your slump is less than 1 inch or greater than 11 inches.

You will also lose **1 point** for every dollar that your mixture costs more than $53.56.
You will receive **1 point** for every dollar that your mixture costs less than $53.56.

In addition to the "Scoring System" shown above, students will automatically receive a score of 100 percent on the project if their 28 day compressive strength is greater than 15,000 psi. Also, future students will have the option of not taking the final exam for the course if their mixture has a 28 day strength of at least 20,000 psi.

Mixture Proportions

Students have developed some impressive concrete mixtures over the past two semesters. Groups have developed concrete mixtures with one day strengths of almost 10,000 psi and 28 day strengths of over 16,000 psi. For those who are not familiar with concrete compressive strengths, most home foundations are cast with 3000 psi concrete. Prestressed bridge girders may have 28 day compressive strengths of 12,000 psi. The mixture proportions for the last two semesters along with their 28 day compressive strength and cost are shown in Table 3 and Table 4, and a picture of the winning group from Fall 2003 is shown in Figure 1.

Table 3. Mixture Proportions from Fall 2003

Materials (lb/yd3)	Mixture Proportions			
	Group 1	Group 2	Group 3	Group 4
Cement	1150	469	487	416
Silica Fume	150	104	0	83
Blast Furnace Slag	0	156	0	0
Fly Ash	0	313	163	332
Coarse Aggregate	1800	1901	1890	1950
Fine Aggregate	793	886	1189	1068
Water	275	254	260	191
Mixture Statistics				
w/cm	0.21	0.24	0.40	0.23
Cost/yd3	154.96	82.39	50.13	70.45
28 day strength (psi)	13,940	10,810	8,315	14,210

Table 4. Mixture Proportions from Spring 2004.

Materials (lb/yd3)	Mixture Proportions			
	Group 1	Group 2	Group 3	Group 4
Cement	468	254	950	750
Silica Fume	52	7	150	100
Blast Furnace Slag	0	195	0	0
Fly Ash	130	195	200	150
Coarse Aggregate	1884	1890	1500	1800
Fine Aggregate	1423	1415	897	982
Water	170	163	286	250
Mixture Statistics				
w/cm	0.26	0.25	0.22	0.25
Cost/yd3	63.82	55.45	100.58	89.72
28 day strength (psi)	16,558	14,828	14,459	13,874

Figure 1. Winning Group from Fall 2003.

Conclusion

The Concrete Contest has been a success with the students. Each year students have been very interested in the contest and they have learned numerous lessons. The most often heard comment "our cylinders were poorly consolidated which decreased our compressive strength". Students have learned the no matter how exotic their concrete mixture design may be, they must be able to cast quality cylinders. The concrete contest will continue, and as the instructor of the course, it will be interesting to note winning compressive strengths and costs throughout the years.

Biography

STEPHAN DURHAM is a research assistant at the University of Arkansas where he received both his BSCE and MSCE degrees. He is currently pursuing a doctoral degree examining various repair strategies for strengthening bridge superstructures. He has been the recipient of several ACI fellowships, including the ACI Concrete Research Education Foundation Fellowship. His interests include concrete materials and repair.

W. MICAH HALE is an assistant professor at the University of Arkansas in the Department of Civil Engineering. He obtained his MSCE and Ph.D from The University of Oklahoma in the area of high performance concrete and its applications in precast/prestressed bridge girders. His current research includes the effect of blast furnace slag in concrete mixtures and bond strength of prestressing strands.