Floating Concrete

Team No. # 3

Lydia Jun Roo Yong, Reny Yohana Lende Mere, Ahmed Al-zeyadi, Punith Yadav

Department of Civil and Environmental Engineering

University of Massachusetts Lowell

Lowell, Massachusetts 01854

INTRODUCTION

Concrete is one of the most popular construction materials used since hundreds of years ago. Because of its flexibility in usage, it becomes more important and is preferred compared to timber or steel. The combination of cement, coarse aggregate, fine aggregate and water make up a concrete. It is an acceptable fact now that not only the strength of concrete which plays a main role, in deciding the quality of concrete but what matters most is the durability at services stage. This technological advancement forms a challenge to civil engineers to look into various ways and means to improve concrete.

Reducing concrete density will lead to economical construction because it reduces the cost of transportation, handling and constructability. One of the ideas to make concrete lighter is by the introducing of lightweight aggregate and air entraining agent. Using lightweight aggregate and air entraining agent in the concrete result in reduction of dead load, faster construction time and lower haulage and handling cost.

The goal of this report is to improve the concrete mix design to create concrete cube specimens that are both strong and light. This type of concretes can be used in structures such as concrete floating structures. The intent is to determine the optimal design of lightweight concrete, considering compressive strength and density ratio of lightweight concrete by using perlite as aggregate instead of normal coarse aggregate. Recommendations for design loads and design criteria are presented. Tests will be performed to determine properties in each mix and the results will be compared. Conclusions will be formulated based on these results. Some concrete properties are of primary importance in selecting a mix design for use in concrete structures. These properties include concrete workability, creep, shrinkage, compressive strength, and chloride permeability.

APPROACH

Equipment and materials

Materials used for casting are, water, perlite, Ottawa sand and Portland Cement type I/ II showed in Fig 1(a) and (b). Equipment use for casting is the 2” x 2” mold showed in Fig 1(a), shovel, and tamping rods. A weight scale was used for weighing purpose and curing tank in Fig 1(c) was used for the concrete curing process. Compressive strength of the concrete was tested using the Instron Model 1322 showed in Fig 1(d).

Description of materials

Type I/II Portland cement satisfies requirements for both Type I and Type II. Strength requirements meet those for Type I, and composition requirements meet those for Type II. The dual-type cement can be used where either type is specified. It cuts down on the costs of producing and storing two cements. It's also helpful on projects where out-of-town designers specify Type I, but local practice is to use Type II. Type I/II can be used without requesting a substitution for the specified material.

Perlite is an amorphous volcanic gas that has a relatively high water content, typically formed by the hydration of obsidian. It occurs naturally and has the unusual property of greatly expanding when heated sufficiently. It is an industrial mineral and a commercial product useful for its low density after processing. Obsidian is a naturally occurring volcanic glass formed as an extrusive igneous rock.

Fig. 1 (a) Materials and cube mold; (b) Portland cement; (c) Curing tank; (d) Instron Model 1332.

Procedure

The concrete specimens were mixed in the concrete lab at UMass Lowell. The weighed cement and sand were mixed together first on a sample tray which had been cleaned and dried. A certain percentage of water from the measured container was added to the cement-sand mixture. Carefully added the weighed admixture and achieve a uniform mix. Then, the rest of the water added and mixed with all the ingredients for at least three minutes and until the concrete mixture appeared to be homogeneous. Finally, a shovel used to level the surface of the cubes with any necessary precautions.

The concrete specimens were left for at least 24 hours to get hardened, and it were carefully separated from the cube molds to avoid any major chipping. The cube specimens were weighed before place it into the water for curing. The cubes were marked in such a way so as to not disturb the surface of the cubes. In this experiment, there were three trial batches that were casted. Since each batch consisted of three 2-in cube specimens, the designation of each specimen was labelled as T(X,Y); where X= Trial batch number, Y= sequence of specimen. Thus, there were nine sample of cubic specimens (T11, T12, T13, T21, T22, T23, T31, T32, and T33). After casted and cured for 20 days, each cube specimens were weighed again and two specimens of each trial batch were tested using Instron 1332 to find their compressive strength.

There were three design parameters in this experiment such as water-to-cement ratio (w/c), sand-to-cement ratio (s/c), and aggregate-to-cement ratio (a/c). These three design parameters were obtained by using weight batching method. Each of trial batches uniquely designed as shown in Table 1.

Table 1: Design parameters of three trial batches.

Trial	*w/c*	*s/c*	*a/c*
1	0.88	0.71	1.13
2	0.65	1.2	0.4
3	0.55	1.2	0.4

RESULTS AND ANALYSIS

A summary of individual maximum compressive load by Instron 1332 is presented in Table 2 along with its weight, mass, area and volume. It is no surprising that the performance criterion Eq. (3) for each trial batch will yield different result since each trial batch has different design parameters except for trial 2 and 3 which only differ by its water-to-cement ratio.

$$f_c{}' = \frac{P}{A} \qquad (1)$$

where $f_c{}'$= compressive strength (psf), P= load (lbf) and A= surface area (ft^2).

$$\rho = \frac{m}{V} \qquad (2)$$

where $\rho =$ specimen's density (slug/ft^3), m= specimen's mass (slug), V= volume of the specimen (ft^3). Table 3 summarizes all the computed value for Eq. (1), (2), and (3) for each tested specimen.

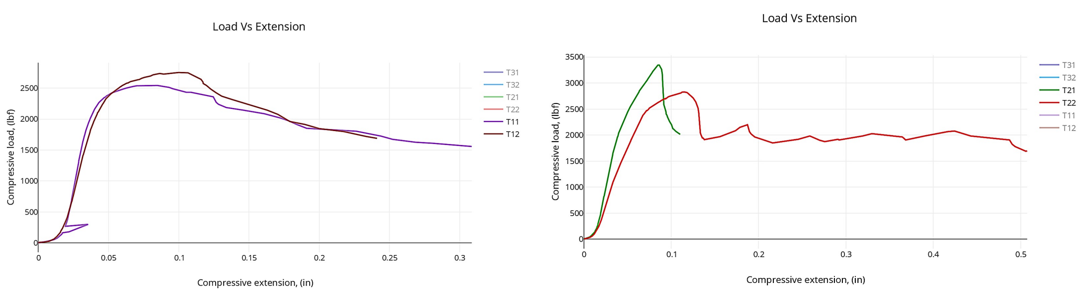
$$p = \frac{f_c{}'}{\rho} \qquad (3)$$

where $p =$ specific strength or strength-to-weight ratio (lb·ft/slug).

Plotted graph in Fig. 2-5 are based on the data obtained by testing machine Instron 1332. In Fig. 1(a), it shows that among two specimens of first trial batch, T12 has the highest compressive load of 2755.07 lbf. While in Fig. 2(b), T21 has the highest compressive load of 3347.53 lbf for the second trial batch. And as shown in Fig. 3 (a) and (b), T32 has the highest peak value of the compressive load among all the specimens tested. Table 2 summarizes all the compressive load and mass of tested specimens as well as its area and volume.

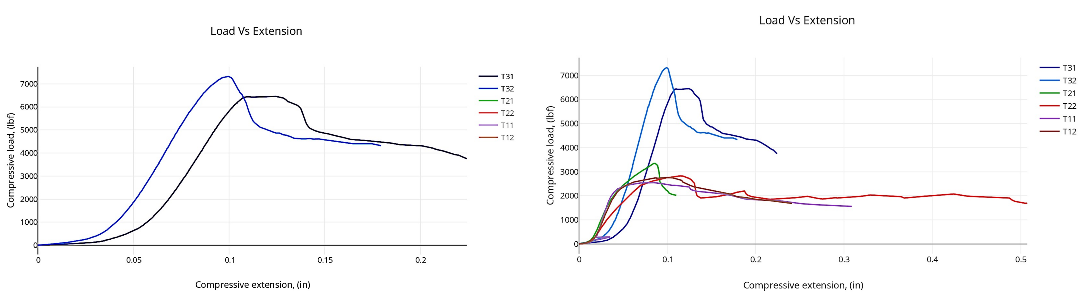
Table 4 summarizes the average computed value of Eq. (1), (2), and (3) for each trial batch with percent error of compressive strength ranging from 3.96 to 7.45% and absolute average error of 5.9166%. In addition, individual errors of each batch trial density ranging from 0.08 to 0.59% and absolute average error of 0.2714%.

Notice that in Table 2, volume of second trial batch are off by $\pm$ 23.91% in comparison with trial 1 and 2. These are because of major chipping of the concrete due to difficulties with removal of the lightweight concrete from the cube molds. Thus, the surface area of T21 and T22 are approximated as specified in Table 2.



(a) **(b)**

Fig. 2. (Color) (a) Load versus extension of T11 and T12; (b) Load versus extension of T21 and T22



(a) **(b)**

Fig. 3. (Color) (a) Load versus extension of T31 and T32; (b) Load versus extension of T11, T12, T21, T22, T31, and T32

Table 2. Summary of Instron 1332 Output, Weight, Mass and Volume of Specimens

Specimen	***Max Load, lbf***	***Weight, lb***	***Mass, slug***	***Area, ft²***	***Volume, ft³***
T11	2544.80	0.28145	0.0087477	0.02777776	0.0046
T12	2755.07	0.2819	0.0087617	0.02777776	0.0046
T21	3347.53	0.3505	0.0108939	0.02117359	0.0035
T22	2830.21	0.3400	0.0105675	0.020784709	0.0035
T31	6451.36	0.4272	0.0132778	0.02777776	0.0046
T32	**7323.23**	0.4260	0.0132405	0.02777776	0.0046

To better analyze the result, three approaches will be evaluated to find the relationship between the design parameters and the design criteria. First, evaluating the relationship between w/c ratio with average density and 28-day average compressive strength between trial 2 and 3 since both trial carries two same design parameters (s/c and a/c) and only water-to-cement ratio that varies as shown in Fig. 4. Second, evaluating the relationship between s/c ratio with average density and 28-day average compressive strength of trial 1 and 2 [Fig. 5(a)] as well as trial 1 and 3 [Fig. 5(b)]. Third, evaluating the relationship between a/c and the design criteria of trial 1 and 2 [Fig. 6 (a)] as well as trial 1 and 3 [Fig. 6 (b)]. Noted that, in Fig. 5 and Fig. 6, the other two design parameters are not constant; therefore, for the sake of clarity only its pattern will be observed.

Table 3. Computed Average Value of Design Criteria and Performance Criterion

Specimen	*f_c', psf*	*ρ, slug/ft^3*	*f_c'/ ρ*
T11	91612.943	1.890	48484.963
T12	99182.718	1.893	52407.377
T21	158099.079	3.087	51214.182
T22	136167.680	3.051	44636.829
T31	232249.279	2.868	80979.412
T32	263636.531	2.860	**92182.287**

Table 4. Computed Average Value of Design Criteria and Performance Criterion

Trial	*f_c'(average), psf*	*ρ (average),slug/ft^3*	*f_c'/ ρ, (average)*
1	95397.830	1.891	50447.736
2	147133.380	3.069	47945.036
3	247942.905	2.864	**86572.971**

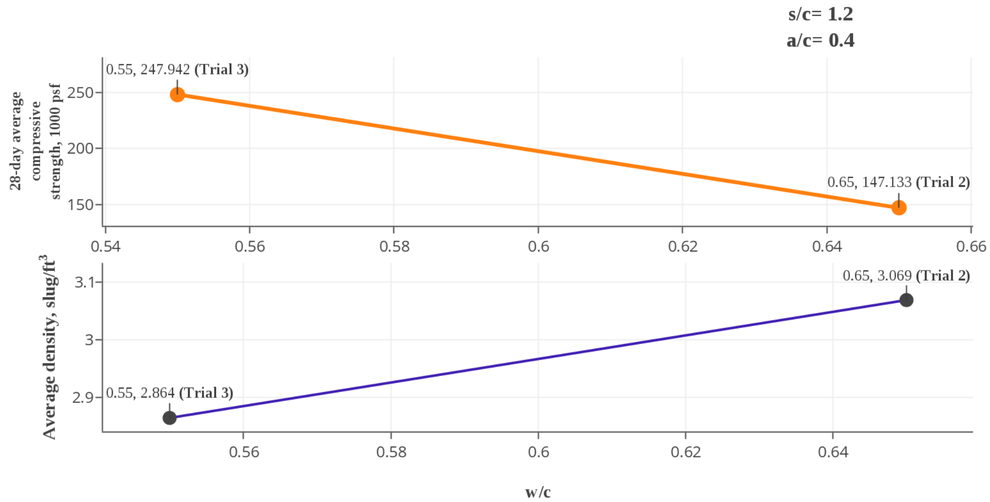
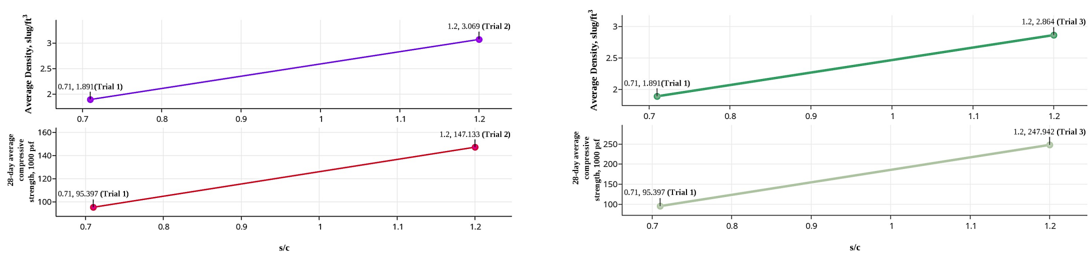
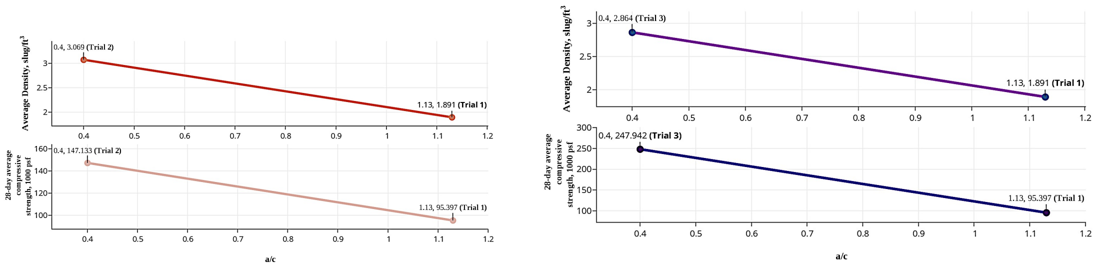


Fig. 4. (Color) w/c's relationship with average density and 28-day average compressive strength on Trial 2 and 3.



(a) **(b)**

Fig. 5. (Color) s/c's relationship with average density and 28-day average compressive strength on (a) Trial 1 and 2; (b) Trial 1 and 3.



(a) **(b)**

Fig. 6. (Color) a/c's relationship with average density and 28-day average compressive strength on (a) Trial 1 and 2; (b) Trial 1 and 3.

Fig. 4 shows that as w/c ratio increases from 0.55 to 0.65 holding s/c and a/c constant, the density also increases; however, the 28-day average compressive strength decreases. This pattern agrees with the fact that reducing w/c ratio will also increase compressive and flexural strength.

Meanwhile, Fig. 5 and Fig. 6 show a non-reverse relationship between ρ and f_c'. As sand-to-cement-ratio increases from 0.7 to 1.2, ρ and f_c' also increases as shown in both Fig. 5 (a) and (b). Although, Fig. 5 and Fig. 6 show a non-reverse relationship between ρ and f_c' unlike Fig.4; Fig 6 (a) and (b) shows that there is a downward sloping trend of ρ and f_c' as the lightweight aggregate-to-cement ratio increases from 0.4 to 1.13. Table 5 summarizes the relationship between ρ and f_c' as design parameter increasing and decreasing based on Fig. 4, 5, and Fig. 6.

Table 5. Relationship Between Design Parameters and Design Criteria

	w/c	*f_c'*	*ρ*
Trial 2 & 3	↓	↑	↓
Trial 2 & 3	↑	↓	↑

	s/c	*f_c'*	*ρ*
Trial 1&2/ Trial 1&3	↓	↓	↓

Trial 1&2/ Trial 1&3	↑	↑	↑

	a/c	f_c'	ρ
Trial 1&2/ Trial 1&3	↓	↑	↑
Trial 1&2/ Trial 1&3	↑	↓	↓

Since the performance criterion is based on reverse relationship between the density and 28-day compressive strength, it is safe to say the best optimal design from this experiment is depicted in Fig. 4.

DISCUSSION

Handling of lightweight aggregate(perlite) was the most challenging part. During the first trials we mixed the sand, cement and perlite together and then added water which was a mistake. It was not a suitable mix. We corrected this mistake by mixing sand and cement to gain a uniform mixture. Then proceeded to add water. Perlite was added at the last to obtain a concrete mix. It was observed that Perlite has a higher absorption rate than cement and sand. To obtain high strength concrete while having a low density was very challenging as there are no exact mix design guides for this procedure.

The accuracy of specific strength of trial 2 could be improved if the trial batch were not chipped significantly, this resulted in reducing surface area and volume. Thus approximated calculation were performed instead. This incident was due because of human error when separating the specimens from the cube molds.

CONCLUSION

In conclusion, the best optimal design found in this experiment to be the trial batch 3 with design parameters of w/c= 0.55, s/c= 1.2, a/c= 0.4. This optimal design satisfies the reverse relationship between the specimen's 28-day compressive strength and its density. Although, the average density of trial batch 3 is calculated to be the second lowest, however, its 28-day average compressive strength is the greatest. Thus, yield the highest average specific strength (f_c'/ ρ) of 86572.971 lb·ft/slug in comparison to the rest of trial batches; the average f_c'/ ρ of trial batch 3 is 41.73% greater than trial batch 1 and 44.62% greater than trial batch 2. In these tests, the absorption of the perlite should be carefully examined first by conducting absorption test using ASTM C127-15 to not overestimate the water-to-cement ratio.

REFERENCES

1) ASTM (American Society for Testing and Materials) C-150-07 (2007), Standard Specification for Portland Cement, West Conshohocken, PA.
2) S. Mindess, J.F. Young, and D. Darwin (2003), Concrete, 2^{nd} ed., Prentice Hall, Upper Sanddle River, NJ.
3) Testing Concrete, Construction Standard, CS1: 2010, Volume 2, The Government of the Hong Kong Special Administrative Region.
4) Gilkey, H.J. (1937), "The Moist Curing of Concrete." Eng. News Record, Oct., pp. 630-633.