CIVE.5050 Concrete Materials

Term Project – Floating Concrete

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Introduction

Throughout history concrete has been used, and improved by many generations because it's really affordable and moldable in terms of its shape and design. The term concrete is about interpretation because back in time ancient materials were crude cement made by crushing and burning gypsum or limestone. When sand and water were added to these combinations they became mortar which was a material used to adhere rocks or stones to each other. As the years and generations passed these elements were improved and molded to what we know today as modern concrete which is made using Portland cement, coarse and fine aggregate with sand and water. Also, the addition of admixtures added according to the desired construction's setting or requirements to improve the settling time and properties of the concrete. Table 1.4 shows typical properties of concrete, also we have to denoted that these values are standard, but they can vary according to the use of the material and preparations.

TABLE 1.4 Typical Engineering Properties of Structural Concrete

Compressive strength	= 35 MPa (5000 lb/in.^{2})
Flexural strength	= 6 MPa (800 lb/in.^{2})
Tensile strength	= 3 MPa (400 lb/in.^{2})
Modulus of elasticity	= 28 GPa (4×10^6 lb/in.^{2})
Poisson's ratio	= 0.18
Tensile strain at failure	= 0.001
Coefficient of thermal expansion	= 10×10^{-6}/°C (5.5×10^{-6}/°F)
Ultimate shrinkage strain	= 0.05–0.1%
Density	
Normal weight	= 2300 kg/m^3 (145 lb/ft^3)
Lightweight	= 1800 kg/m^3 (110 lb/ft^3)

Concrete is a very important material in the modern world, it is very strong, versatile, and moldable. Also, the consistency of concrete is Portland cement, sand, and aggregate mixed with water as mentioned before. The cement and water react chemically; they form hydrations products. The percentages of this hydration products defines the characteristics or type of concrete. The initial process of hardening occurs in hours, but it takes some weeks for concrete to reach full hardness, 28 days to obtain fc'. However, concrete can continue hardening and gain strength over the years, but there is other factors in consideration such as serviceability.

The main focus of this project is to demonstrate how the manipulation of this elements can lead to a specific type of concrete. In this project, we are going to focus on low density concrete. The principal parameters to analyze and investigate in this experiment are: water to cement ratio (w/c), sand to cement ratio (s/c), and aggregate to cement ratio (a/c).

Water to cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. This ratio can lead to different strength with the conjugations of other properties and procedures. However, it is demonstrated with researches that the lower water to cement ratio the higher strength and durability. One of the problems is that as the ratio becomes to small the concrete losses its workability, but there are some admixtures that can be used to overcome that problem. Moreover, sand to cement ratio and aggregate to cement ratio have to be calculated in order to obtain a specific grade of concrete. The grade of the concrete is connected to the desired strength. In other words, we have to calculate the ratios to generate a desired strength. Table 20.3 shows the relationship between density and compressive strength. Also, this demonstrates the effect of course aggregate vs fine aggregate.

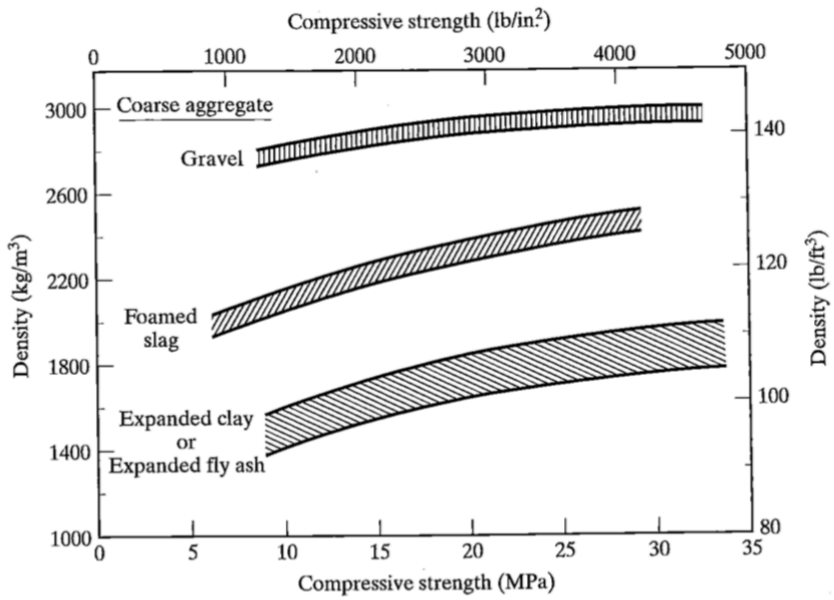


FIGURE 20.3

Lowering the size of the aggregate leaves us with a low dense concrete, but we have to consider the water to cement ratio, sand to cement ratio, aggregate to cement ratio, curing, and casting temperature to achieve the maximum desired strength. We used Portland cement mixed with water, sand and a low dense aggregate. Casting concrete can seem really simple; however, casting concrete requires precautions and measurements to obtain a specific quality.

Approach

Materials and Equipment used:

- Perlite Miracle-Gro (lightweight aggregate)
- Sand
- Water
- Portland cement
- Cube mold
- Mixing tray
- Scale
- Scraper
- Brush

The objective of the project is to create a concrete cube that is both strong and light. With the objective in mind, we wanted to create a concrete design with a low water to cement ratio because the lower the water to cement ratio, the stronger the concrete. We decided on a water-to-cement ratio of .42. A rule of thumb for mixing concrete is 1 cement : 2 sand : and 3 gravel by volume depending on the aggregate used. Because we were using Perlite Miracle-Gro as our aggregate, which is extremely light, we decided to not use nearly as much aggregate as more traditional concrete mixture suggest.

Figure 1

The initial concrete formula yielded the end product in Figure 1, so obviously changes in the formula needed to be made.

Based on the outcome of our first attempt, we found out that the Perlite Miracle-Gro absorbs a lot of water making the mix difficult to work with and form. To solve this problem, we decided to raise the water-to-cement ratio to .5 by adding more water to the mix. We also lowered the amount of sand and aggregate creating a sand-to-cement ratio of .59 and an aggregate-to-cement ratio of .04. This brought our final measurements for our mix to 1.7 lbs. of water, 3.4 lbs. of cement, 2lbs. of sand, and .15 lbs. of aggregate. The final product can be seen in Figure 2 which was taken the day the cube came out of the mold.

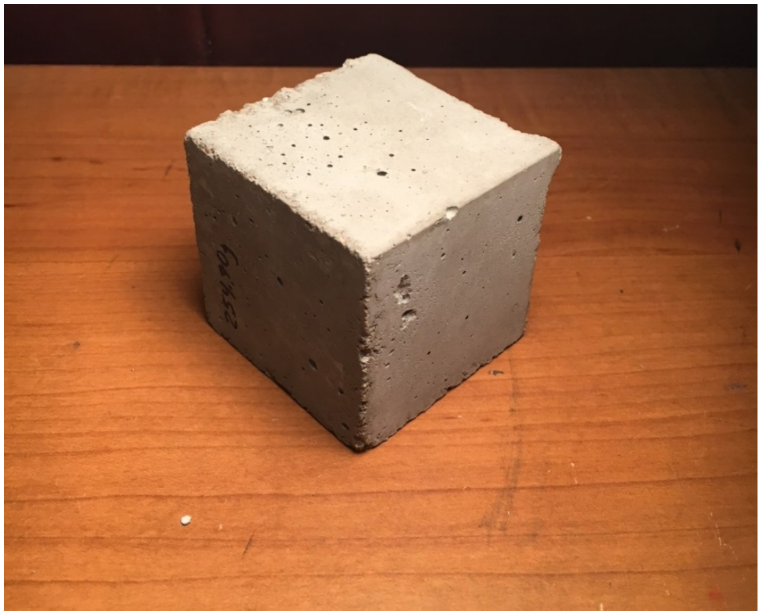


Figure 2

Once our block with the desired formula parameters was complete the final step was the curing process. Curing is the maintenance of a satisfactory moisture content and temperature in concrete during its early stages (28 days) so the desired properties can develop. We decided that the cubes should be kept in about a 35 to 50 degrees' Fahrenheit environment and be watered daily. To accomplish this the cubes were kept in a garage that averages about 40 degrees' Fahrenheit and each cube was sprayed with water thoroughly every day. The curing process in our point of view, made a huge impact in terms of the strength of our specimen.

Result and Analysis:

We tested both batches that had different water, cement and aggregate ratios and so we came up with different results. We will certainly discuss in this part only about the specimen that gave us the highest fc' and the Performance criterion (P) value. The performance criterion depends on the compressive strength of the specimen and it's density.

$$P = f_c' / \rho$$

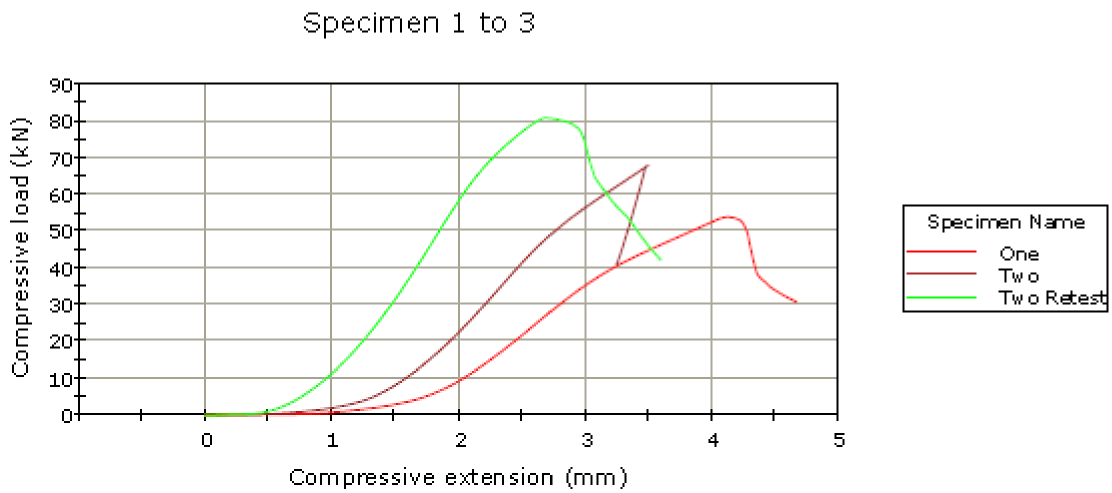
Where: P – Performance criterion

fc' – Compressive strength of concrete

ρ - Density

So the best design depends on how big is the Performance value (P) .i.e. greater the P value, the better is the design. In order to obtain a higher P value, we need to have maximum possible fc' and minimum density.

Our group tested the specimens in the lab with the lab instructor to make sure that there are no certain errors in our testing. The following graph and table shows the results obtained for 3 different specimens.



Specimen label	Compressive extension at Maximum Compressive load (mm)	Maximum Compressive load (kN)	Compressive strain at Maximum Compressive load (mm/mm)	Compressive stress at Maximum Compressive load (kPa)
One	4.12822	53.79837	0.08126	20846.91048
Two	3.49112	67.74802	0.06872	26252.40898
Two Retest	2.68745	80.72851	0.05290	31282.35817

The specimen named, (Two Retest) provided the best testing results and that it is why we are considering it for this project. Our cube managed to bear a compressive load of 80.72851 KN which is equal to 18148.398 lbs. As the cubes we tested were 2in by 2in by 2in, the compressive strength (fc') obtained was 4537.09 PSI.

$$f_c' = 18148.398 \text{ lb} / 4 \text{ in}^2 = 4537.09 \text{ PSI}$$

The value of fc' that we obtained seemed to be reasonable enough to get a higher performance criterion value. Our cube weighed 239.05g which is equal to 0.52700 lb and hence the density was calculated as follows:

$$\text{Density} = \text{mass/volume}$$

$$\rho = 0.527\ (\text{lb}) / 8\ \text{in}^3 = 0.0658\ \text{lb/in}^3$$

Next, we calculate the performance criterion-

$$P = \text{compressive strength/ Density}$$

$$P = 4537.09\ (\text{lb/in}^2) / 0.0658\ (\text{lb/in}^3)$$

$$\mathbf{P = 68952.7\ in}$$

In order to make sure that the units remain constant, we converted the density in lb/in^3 and similarly the fc' in lb/in^2. Hence the final value of the performance criterion was given in (inches). Conventional concrete generally used in pavements and structures has a density ranging from 2200 kg/m^3 to 2400 kg/m^3 (Kosmatka 15th Ed) whereas our light weight specimen had a density of 1824 Kg/m^3. To design concretes for higher strength, a water to cement ratio should be low, generally around 0.42 but our design maintained a water to cement ratio of 0.5 which is probably because of the aggregate we used as perlite requires more water.

The image above was taken in the lab while testing our specimen and it shows how the cubes were compressed.

Discussion

In creating the lightweight concrete cubes some issues that came across were to determine how much of each substance; water, cement, sand and aggregate would be added to make the 2 x 2 x 2-in cubes. Some common issues that happen but were not involved in the experiment when making concrete are segregation, bleeding, and cracking. Segregation would mean that the aggregates would separate from the concrete surface due to poor compaction and introduce results such as honeycomb, laitance, and scaling. Segregation would make the concrete weaker and less durable but due to the cubes only being 2 x 2 x 2-in such results did not appear on the surface of the concrete cubes. Figure 4.1 shows concrete segregation.

Figure 4.1 Concrete Segregation

Another issue that could have occurred during the experiment is bleeding. Bleeding refers to when water appears on the top surface of the concrete after it is finished. If such an issue were to have occurred in the experiment then less water content would be added into the mix and greater sand, aggregate and cement would be needed. Figure 4.2 demonstrates bleeding on concrete.

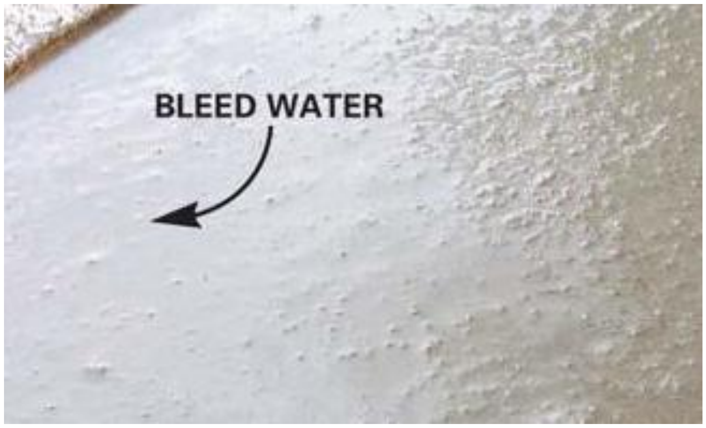


Figure 4.2 Concrete Bleeding

Cracking is another issue that could have occurred but did not. Shrinkage of the concrete is the main cause of cracking. As the concrete hardens and dries up it shrinks due to the evaporation of excess water. Figure 4.3 illustrates concrete cracking. An important issue that was come across was that curing of the concrete was to be done immediately after the concrete was finished. The cubes needed to have an environment where the temperature was neither too hot nor too cold and needing dampness. After finding an appropriate environment, the cubes were then set for curing for 28 days.

Figure 4.3 Concrete Cracking

Conclusion

The objective of the project is to create a concrete cube that is both strong and light. At first, we decided to keep our water-to-cement ratio below 0.5, so we used 0.42 as our water-to-cement ratio to make our cube stronger. We also used Perlite Miracle-Gro (PMG), a lightweight aggregate, to reduce the weight of our cube. However, the cube broke apart, because the Perlite Miracle-Gro to require more water than the traditional aggregate. Secondly, we decided to change our water-to-cement ratio to 0.5 and we also lowered the amount of sand and aggregate to make sure PMG aggregate absorbs enough water in second cube. We kept our cubes in about 40 degrees' Fahrenheit environment and cube is sprayed with water every day. After 28 days, we obtained 4537.09 PSI as the compressive strength (fc') and 1824 Kg/m3 as the density. Comparing our density of the cube to conventional concrete's density range, our cube has lower density.

Concluding all the data, results and analysis, we believe that we were successful in making strong, light specimens and achieving desired results.

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