Lab 1 – Concrete Proportioning, Mixing, and Testing

Supplemental Lab manual

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Objectives

Students make concrete according to the mix design. Slump and Kelly Ball testing would be performed to investigate workability of mixture. Six cylinders would be cast for calculating compressive stress of concrete specimen.

Concepts

Concrete is a mixture of cement, sand, aggregate, water, and possibly an admixture. Proportions of each ingredient are adjusted to produce a well-balanced mix. Concrete sets in as few as 10 hours and continues to harden and cure as long as moisture and unhydrated cement are present. However, most of the increase in strength occurs within a few weeks. Usually the concrete mixture is cast with steel reinforcing, forming a composite material called reinforced concrete. The reinforcing steel is designed to resist tensile stresses, and the concrete resists the compressive stresses within the structure.
Background

Concrete is a mixture of five components: coarse aggregate, fine aggregate, water, and Portland cement.

Coarse Aggregate
Often referred to as gravel. It normally consists of a distribution of particles, the minimum size being approximately 3/8 inch in diameter and the maximum being defined or restricted by the size of the finished structure. A common maximum size for coarse aggregate in structural concrete is 1.5 inches.

Fine Aggregate
Often called sand. Like coarse aggregate, it also has a distribution of particle sizes, which range from 0.005 to 0.25 inches. Particles are often sized by a sieve number. Sand refers to particles passing a number 4 through a number 100 sieves.

Water
Water suitable for drinking is usually good enough for concrete. The water should be free of all organic matter and certain chemicals such as alkaline and sulfate salts.

Portland Cement
Pulverizing clinker consisting essentially of hydraulic calcium silicates obtains a cementing material. It reacts chemically with water and hardens. These five basic ingredients are mixed in the varying proportions to obtain a workable mixture, which can be cast into desired shape of the framework. The concrete is consolidated, permitted to set, and then cured for several days in a damp condition. Concrete cylinders are usually cured under ideal conditions in the damp room for 28 days. Bad concrete is occasionally produced in spite of the efforts of everyone concerned. Therefore, control of the production is quite important since the quality of all ingredients, mixing time, mixing procedure, and curing can greatly influence the quality of the hardened.

Concrete is cured in a wet environment in order to avoid loss of moisture through evaporation. The chemical reaction of water and Portland cement binds the aggregate particles in concrete. This reaction, known as the cycle of hydration, takes place slowly, during which it is necessary to avoid the loss of moisture. You will discover in the course of your lab the varying effects of curing time on the strength of concrete.

Pure cement is too costly to be used as the sole solid in concrete, thus aggregates are used to fill the concrete and act as a bonding surface for the cement. It is hypothesized that the moisture in the aggregate will have a huge influence on the overall compressive strength of the concrete because if there is either too little or too much water, then the overall strength of the concrete will be too weak. There are formulas to help gain a better understanding of the complex chemical process in concrete:

Hydration process: \[2\text{CaO-SiO}_2 + x\text{H}_2\text{O} = 2\text{CaO-SiO}_2-x\text{H}_2\text{O}\]

Ideal ratios:  
- water to cement (by weight) = 0.65: 1  
- aggregates to cement (by weight) = 4.50: 1
Experimental Procedure

1. For strength requirements, select the water to cement ratio by weight.
2. Before mixing concrete, be sure that the mixer has been "buttered" with a mixture of cement, sand, and water.
3. Divide your water into two buckets, one with about 3/4 of the water. Put about half the coarse aggregate and the 3/4-bucket of water.
4. Start the mixer.
5. Add about half the fine aggregate.
6. Carefully add all the cement with the mixer running. Try not to make a lot of dust!
7. Mix until all the cement is blended in.
8. Add the rest of the coarse and fine aggregate.
9. Mix for a while.
10. Add enough water from the final quarter of the water to produce a workable mix.
11. Mix for three minutes, followed by a three-minute rest, followed by a two-minute final mixing.
12. Perform a slump test using the procedure given below. If results are satisfactory, skip to the next step.

Slump Tests

WORKABILITY is the relative ease or difficulty of placing and consolidating concrete. When placed, all concrete should be as stiff as possible, yet maintain a homogeneous, and void less mass. Too much stiffness, however, makes it too difficult or impossible to work the concrete into the forms and around reinforcing steel. On the other hand, too fluid a mixture is also detrimental. The slump test is performed on newly mixed concrete. To perform the test, you need a slump cone and a tamping rod. The slump cone (fig. 3.1), 12 in. in height, with a base opening 6 in. Both the top and bottom openings are perpendicular to the vertical axis of the cone.

Cylindrical plastic molds are used to cast the concrete specimens. The molds should be filled in three approximately equal layers. Each layer should be riddled (poked with a bullet nosed steel rod) 25 times to eliminate unwanted air bubbles. The top of the molds should be struck off with the rod and then with a wooden float.

Once the specimens have been struck off, the outside of the molds should be cleaned as well as the mixer and tools. Fresh concrete is a lot easier to clean than when it has set. The cylinders should now be placed in the lab fog room for curing. After 24 hours a member of your group must strip off the mold and carefully mark your specimen with your group number. If the slump is less than required, return the concrete to the mixer, add the remaining water, and mix for one minute. Perform a second slump test. If results are satisfactory, go on to step 10.
If the slump is still less than required, return the concrete to the mixer, add additional water, as well as additional Portland cement to maintain the desired water/cement ratio \((\text{Wt. of PC added} = \text{Wt. of water added}/\text{WC ratio})\), and mix for one minute.

Continue taking slump tests and adding water and cement until the desired slump is obtained.

13. Record the final slump.
14. Record the actual weight of water and cement used
15. Cast 6 cylinders

**Compression Test**
The compressive strength of concrete is one of the factors, which controls the loads, which may be applied to a concrete structure. Therefore, for every significant structure it is important to check the compressive strength from a representative number of concrete cylinders cast from the same batches of concrete used to form the structure. For some structures, such as concrete pavements, the modulus of rupture is also important.

In the design of concrete structures, the design engineer specifies given strengths that the final concrete products must be capable of attaining. When trial batches are prepared during mix design or as a quality control measure to ensure that concrete mixed or delivered in the field satisfies those specified strengths, the following tests are performed.

Compression tests (ASTM C 39) are conducted to determine the compressive strength of concrete (or its ability to resist a crushing force). In this test, a standard test load is applied parallel to the longitudinal axis of a premolded and properly cured concrete cylinder of a standard size. When the test is properly conducted, a maximum load is obtained at the point at which the cylinder ruptures. With this maximum load, the compressive strength, measured in pounds per square inch (psi), can be easily calculated. The equipment you will use to perform the compression test is a compression-testing machine, having a capacity of 250,000 pounds. An example of that machine, shown with a test cylinder in place, is illustrated in figure 3.2.

The procedures for conducting the compression test are as follows;
1. Prepare the testing machine by cleaning the bearing plates and, if needed, cleaning and lubricating
Figure 3.2. Compression-testing machine.

Figure 3.3. Normal fracture of concrete test cylinder in compression.
Report Requirements

1) Calculate the compressive strength of the concrete using the following formula:

\[ f'c = \frac{P}{A} \]

Where:
- \( f'c \) = compressive strength (in psi)
- \( P \) = maximum load (in pounds)
- \( A \) = cross-sectional area of specimen (in inches)

The known and measured quantities are:

- Original cross sectional area of the specimen----------\( Ao \)
- Applied load at various points-------------------\( F \)
- Original height of the cylinder-------------------\( Lo \)
- Original diameter of cylinder-------------------\( Do \)

- Maximum compressive stress-------------------\( f'c \)
2) Provide written definitions for all results calculated, from the aggregate, mix and strength labs.
3) Compare, using percent difference, the design compressive strength with actual results.
4) Will your concrete mix work for the designs project you chose?
5) The effect of water on the mixture before and after setting
6) How does aggregate affect the mixture?
7) Draw the stress-strain curves for concrete cylinders have a shape similar to those shown in Fig. X, where \( f'c \) is the ultimate compression stress. (Note: Several factors influence the magnitude of \( f'c \) including moisture content of cylinders, speed of tests and size of cylinders, usually 6" diameter by 12" long, Discus with your classmates how the shape of the sample also influences strength test results.)

![Stress-Strain Curve](image)

Figure 3.4- Concrete Cylinder Strengths at 7 and 28 days

References: "Principles of Materials Science and Engineering" by W.F. Smith