PROPERTIES OF CONCRETE

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February 20, 2002

Introduction

Concrete consists of cement, fine and coarse aggregate, and water. Sand and gravel are typically used for the fine and coarse aggregates, respectively.

An example of the composition by component volume is given in Table 1.

Table 1. Typical Concrete Composition by Volume	
Cement	7-15%
Water	14-21%
Aggregate	60-80%

The cement is typically Portland cement.

Portland cement is a mixture of processed limestone, shales, and clays. These components contain the following compounds: CaO (lime), Al_2O_3 (Alumina), SiO_2 (silica) and iron oxides.

The cement and water form a paste that binds other the other materials together. The chemical reaction that takes place during hardening is called hydration.

In addition, calcium chloride may be mixed with concrete in cold weather to accelerate hardening.

Water

A careful balance between the cement and water volumes is required when making concrete.

Too much water reduces concrete strength, while too little will make the concrete unworkable. Concrete needs to be workable so that it may be consolidated and shaped into different forms.

Cracks

The combination of the concrete materials produces a great deal of heat. As the concrete gets hotter, it expands. As concrete gets cooler, it contracts.

Cracks may thus form in the concrete after it is poured into a mold. This is a particular problem if the expansion and contraction motion is constrained.

The contraction in typical concrete amounts to about 500 millionths. This is about 1/16 of an inch in 10 feet (0.4 cm in 3 meters).

Contractors put joints in concrete pavements and floors is to allow the concrete to crack in a neat, straight line at the joint when the volume of the concrete changes due to shrinkage.

Compression

Concrete is strongest when loaded in compression. Concrete is thus most effective when used for columns, walls, and piers.

Concrete can withstand compressive stresses up to 6000 psi, depending upon the water-cement ratio.

Concrete loaded in compression undergoes failure by shear along a diagonal plane inclined near 55 degrees to the direction of loading.

Flexure

Concrete is also used for floors, roof slabs, road slabs, and beams. Flexure strength is important for these applications.

The flexure strength of concrete varies between about 400 and 800 psi.

Flexure causes both tension and compression. Concrete is rather weak in tension, however. Thus flexure failures tend to occur at surfaces in tension.

Steel reinforcing bars are placed in concrete near the regions of greatest tensile stress, in order to compensate for the inherent weakness. The tensile stress is carried by the steel bars rather than by the concrete.

The steel bars, or rods, also resist diagonal tensile stresses accompanying shear stresses.

The steel rod surface is usually deformed in order to improve the bond between concrete and steel. The steel is also cold worked to achieve high strength.

Analysis

For simplicity, the steel bars are assumed to carry the entire tensile load and none of the compressive loads.

Properties

Typical properties for concrete are shown in Table 2, as taken from Reference 1.

Table 2. Concrete Properties

Property	Value	Comment
Modulus of elasticity	2.5 (10^6) to 5.5 (10^6) psi	Improved by lowering the water-cement ratio.
Mass Density	0.08 lbm/in^3	The density varies according to the type of aggregate.
Compressive Strength	3000 to 6000 psi	Improved by lowering the water-cement ratio.
Tensile Strength	200 to 600 psi	Concrete is rarely loaded in direct tension. Tensile stresses occur in bending, however.
Fatigue Strength	About one-half the corresponding ultimate static strength.	"Rest" periods between cycles of loading permit the concrete to undergo partial recovery.
Coefficient of Thermal Expansion	5.5 (10^{-6}) in / in / °F	About the same as steel.

Prestressed Concrete

Prestressed concrete consists of slabs and beams that have high-strength steel or cable embedded in them. The steel members are anchored at the ends of the beam or edges of the slab and are subjected to tension, before the concrete is poured.

After the concrete is hardened, part of the tensile stress is transferred to the concrete, which is thereby placed in compression.

This induces compressive fiber stresses in the concrete that, under load, must first be overcome before tensile fiber stresses are produced.

The prestressed method allows greater span lengths and shallower, lighter weight beams and slabs, than do ordinary reinforced steel designs. In addition, prestressed members have greater resistance against cracking.

Note that there is some loss of tension in prestressed concrete as concrete shrinks during the drying process.

Reference

1. C. Keyser, Materials Science in Engineering, Second Edition, Merrill Publishing Company, Columbus, Ohio, 1974.