

Analysis of Self Compacting Concrete for Tensile Strength and Bonding Characteristics

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ABSTRACT

Self-compacting concrete, also referred to as self-consolidating concrete, is able to flow and consolidate under its own weight and is desecrated almost completely while flowing in the formwork. It is cohesive enough to fill the spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily-reinforced concrete members or in complicated work forms. The objectives of this research were to compare the Splitting Tensile Strength and Compressive Strength values of self-compacting and normal concrete specimens and to examine the bonding between the coarse aggregate and the cement paste using the Scanning Electron Microscope. Cylinder specimens (8” by 4”) were tested for Splitting Tensile and Compressive Strength after 28 days of standard curing, in order find out if self-compacting concrete would show an increase in these strengths and a better bonding between aggregate and cement paste, compared to normal concrete. The mix design used for making the concrete specimens was based on previous research work from literature. The water - cement ratios varied from 0.3 to 0.6 while the rest of the components were kept the same, except the chemical admixtures, which were adjusted for obtaining the self-compatibility of the concrete.

INTRODUCTION

Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self-compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances. The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura (1997), but the prototype was first developed in 1988 in Japan, by Professor Ozawa (1989) at the University of Tokyo. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design method and self-compatibility testing methods have been carried out from the viewpoint of making it a standard concrete. Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like “honey” and has a very smooth surface level after placing. With regard to its composition, self-compacting concrete consists of the same components as conventionally vibrated concrete, which are cement, aggregates, and water, with the addition of chemical and mineral admixtures in different proportions. Usually, the chemical admixtures used are high-range water reducers (super plasticizers) and viscosity-modifying agents, which change the rheological properties of concrete. Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement. In this study, the cement content was partially replaced with mineral admixtures, e.g. fly ash, slag cement, and silica fume, admixtures that improve the flowing and strengthening characteristics of the concrete.

World-wide Current Situation of Self-Compacting Concrete

Self-compacting concrete has already been used in several countries. In Japan, major construction projects included the use of SCC in the late '90s. Today, in Japan, efforts are being made to free SCC of the “special concrete” label and integrate it into day-to-day concrete industry production. Currently, the percentage of self-compacting concrete in annual product of ready-mixed concrete (RMC), as well as precast concrete (PC), in Japan is around 1.2% and 0.5% of concrete products.

In the United States, the precast industry is also leading SCC technology implementation through the Precast/Prestressed Concrete Institute (PCI) which has done some research on the use of SCC in precast/prestressed concretes starting with 1999. It is estimated that the daily production of SCC in the precast/prestressed industry in the United States will be 8000 m³ in the first quarter of 2003 (around 1% of the annual ready-mix concrete). Furthermore, several state departments of transportation in the United States (23 according to a recent survey) are already involved in the study of SCC. With such a high level of interest from the construction industry, as well as manufacturers of this new concrete, the use of SCC should grow at a tremendous rate in the next few years in the United States. However, even if it is made from the same constituents the industry has used for years, the whole process, from mix design to placing practices, including quality control procedures, needs to be reviewed and adapted in order for this new technology to be applied properly.

LITERATURE REVIEW

Present-day self-compacting concrete can be classified as an advanced construction material. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction. An important improvement of health and safety is also achieved through elimination of handling of vibrators and a substantial reduction of environmental noise loading on and around a site.

Influence of Admixtures on Concrete Properties

In the following are presented several papers, found in the literature, on the effects of mineral and chemical admixtures on the fresh and hardened concrete. The mineral admixtures referred to are blast-furnace slag, fly ash, and silica fume. The chemical admixtures considered are high range water reducer or super plasticizer and viscosity-modifying agent.

Mineral Admixtures

Mineral admixtures are added to concrete as part of the total cementitious system. They may be used in addition to or as a partial replacement of Portland cement in concrete depending on the properties of the materials and the desired effect on concrete. Mineral admixtures are used to improve a particular concrete property such as workability, strength or compact ability. The optimum amount to use should be established by testing to determine whether the material is indeed improving the property, and the correct dosage rate, as an overdose or under dose can be harmful or not achieve the desired effect, because they react differently with different cements.

Tensile Strength

The main purpose of measuring the strength of concrete test specimens is to estimate its strength in the actual structure. This estimation gives an indication of the strength of concrete in a structure, which is dependent on the adequacy of compaction and curing.

The splitting test is rather simple to perform, does not require other equipment than that needed for the compression test, and gives an approximately similar value of the “true” tensile strength of concrete.

SELF-COMPACTING CONCRETE COMPOSITION

Self-compacting concrete (SCC) is a fluid mixture, which is suitable for placing in difficult conditions and in structures with congested reinforcement, without vibration. In principle, a self-compacting or self-consolidating concrete must:

- Have a fluidity that allows self-compaction without external energy,
- Remain homogeneous in a form during and after the placing process, and
- Flow easily through reinforcement

The technology of SCC is based on adding or partially replacing Portland cement with amounts of fine material such as fly ash, blast furnace slag, and silica fume without modifying the water content compared to common concrete. This process changes the rheological behavior of the concrete.

Portland Cement

Portland cement concrete is foremost among the construction materials used in civil engineering projects around the world. The reasons for its often use are varied, but among the more important are the economic and widespread availability of its constituents, its versatility and adaptability, as evidenced by the many types of construction in which it is used, and the minimal maintenance requirements during service. Concrete is unique among major construction materials in that it is generally designed specifically for a particular project using locally available materials.

SPLITTING TENSILE STRENGTH

The tensile strength of concrete is much lower than the compressive strength, because of the ease with which cracks can propagate under tensile loads, and is usually not considered in design (it is often assumed to be zero). However, it is an important property, since cracking in concrete is most generally due to the tensile stresses that occur under load, or due to environmental changes. The failure of concrete in tension is governed by microcracking, associated particularly with the interfacial region between the aggregate particles and the cement, also called interfacial transition zone. The load applied (compressive force) on the cylindrical concrete specimen induces tensile and shear stresses on the aggregate particles inside the specimen, generating the bond failure between the aggregate particles and the cement paste, as shown in Figure 4.1.

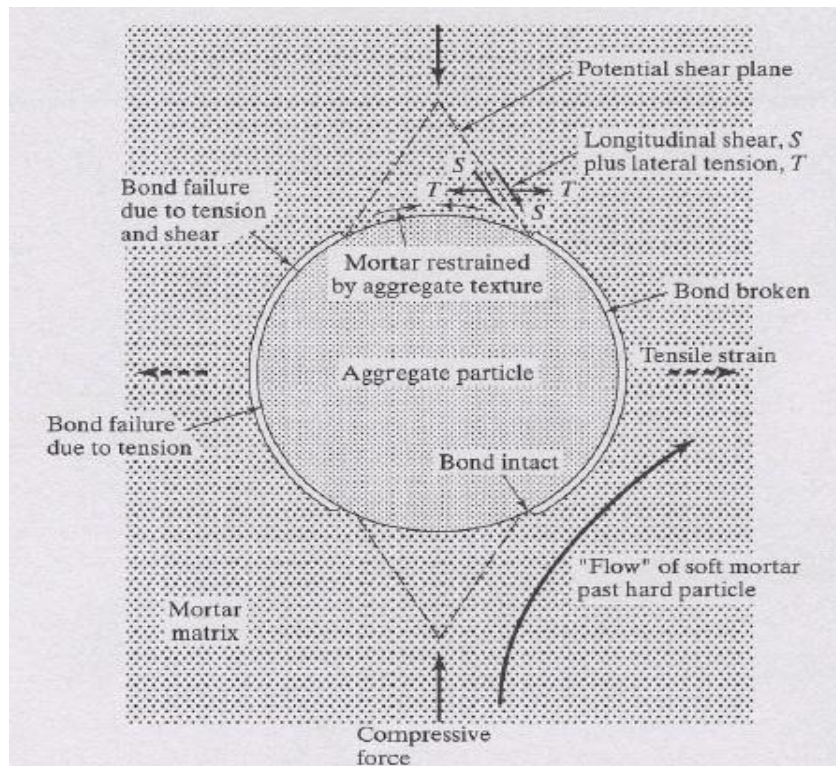


Figure 4.1 Stresses around an aggregate particle.

Investigations have shown that very fine cracks at the interfacial region exist even prior to application of the load on concrete, due to the shrinkage. These cracks remain stable up to about 30 percent or more of the ultimate load and then begin to increase in length, width, and number. The overall stress under which they develop is sensitive to the water-cement ratio of the paste, and this is considered the stage of slow crack propagation. At 70 to 90 percent of the ultimate strength, the cracks open through the cement paste and fine aggregate and they bridge until a continuous crack pattern is formed. This represents the fast crack propagation stage and, if the load is sustained, failure may take place with time.

Aggregate-Cement Bonding Characteristics

Bonding between aggregate and cement paste is an important factor in the strength of concrete, especially the tensile strength, and regarding the fracture properties of concrete. Bond is due, in part, to the interlocking of the aggregate and the paste owing to the roughness of the surface of the former. A rougher surface, such as that of crushed particles, results in a better bond, usually obtained with softer, porous, and mineralogical heterogeneous particles.

Generally, texture characteristics, which permit no penetration of the surface of the particles, are not conducive to good bond. In addition, bond is affected by other physical and chemical properties of aggregate, related to its mineralogical and chemical composition. So, aggregate shape, surface structure and hardness are all factors affecting the strength of the aggregate-matrix bond. However, today little is known about these phenomena, and relying on experience is still necessary in predicting the bond between the aggregate and the surrounding cement paste.

Experimental Procedures

Conventional concrete tends to have a difficulty regarding the adequate placing and consolidation in thin sections or areas of congested reinforcement, which leads to a large volume of entrapped air voids and compromises the strength and durability of the concrete. Using self compacting concrete (SCC) can eliminate the problem, since it was designed to consolidate under its own weight. Therefore, it is important to verify the mechanical properties of SCC before using it for practical applications.

This research was conducted to find out if self-compacting concrete would show an increase in splitting tensile strength and compressive strength and a better bonding between aggregate and cement paste, in order to be used as a replacement for conventional concrete in the construction industry. The experimental program was divided into two phases.

CONCLUSIONS AND RECOMMENDATIONS

Taking into account the findings from this study, previously presented, the following conclusions can be drawn: It has been verified, by using the slump flow and U-tube tests, that self-compacting concrete (SCC) achieved consistency and self-compact ability under its own weight, without any external vibration or compaction. Also, because of the special admixtures used, SCC has achieved a density between 2400 and 2500 kg/m³, which was greater than that of normal concrete, 2370-2321 kg/m³.

Self-compacting concrete can be obtained in such a way, by adding chemical and mineral admixtures, so that its splitting tensile and compressive strengths are higher than those of normal vibrated concrete. An average increase in compressive strength of 60% has been obtained for SCC, whereas 30% was the increase in splitting tensile strength.

Also, due to the use of chemical and mineral admixtures, self-compacting concrete has shown smaller interface microcracks than normal concrete, fact which led to a better bonding between aggregate and cement paste and to an increase in splitting tensile and compressive strengths. A measure of the better bonding was the greater percentage of the fractured aggregate in SCC (20-25%) compared to the 10% for normal concrete.

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