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# Effect of super plasticizer on the properties of medium strength concrete prepared with coconut fiber

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## HIGHLIGHTS

- Medium strength coconut fiber reinforced concrete (MSCFRC) is investigated.
- MSCFRC is compared with that of medium strength concrete.
- The MSCFRC with 0%, 0.5%, 1% and 1.5% super plasticizer contents are evaluated.
- Compressive, flexural and splitting-tensile behaviors are studied in detail.
- Optimized super plasticizer content for MSCFRC is 1%, by mass of cement.

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## ABSTRACT

The structural characteristics of concrete can be improved by addition of natural or artificial fibers. Among natural fibers, coconut fibers have the highest toughness. The silica fume concrete with the addition of coconut fibers and different super plasticizer content is not studied yet. In this study, the mechanical properties of medium strength concrete (MSC) and medium strength coconut fiber reinforced concrete (MSCFRC) with the addition of different super plasticizer content i.e. 0%, 0.5%, 1% and 1.5%, by mass of cement, are investigated. For optimization, the improvement in mechanical properties of MSCFRC is evaluated by comparing with that of MSC. The mix design ratio of MSCFRC is 1:2:2 (cement: sand: aggregate) with a water cement ratio of 0.50. The optimized silica fume content for MSCFRC is 15%, by mass of cement. Coconut fibers with a length of 5 cm and fiber content of 2%, by cement mass, are added in MSCFRC. The stress-strain curves, load-deflection curves and load-time curves for MSC and MSCFRC are recorded under compressive, flexural and splitting-tensile loadings, respectively. It is found that MSCFRC have generally improved modulus of elasticity, compressive strength, flexural strength, splitting-tensile strength, absorbed energy and toughness indexes than that of their respective MSC. MSCFRC with 1% super plasticizer content shows overall best properties as compared to that of MSC. Thus, the MSCFRC with optimized silica fume (15%), coconut fiber (2%) and super plasticizer (1%) content can be used for civil engineering applications.



## 1. Introduction

The use of fiber reinforced concrete with addition of super plasticizer has increased world-wide [1]. Medium strength concrete (MSC) can be produced by use of cementitious materials and mineral admixtures which improves the mechanical properties of concrete. Concrete with cementitious material and mineral admixture (like silica fume and super plasticizer, respectively) are extensively used throughout the world. Due to the environmental friendliness, superior structural performance and low impact on energy utilization, the use of such type of concretes is increasing day by day [2]. The use of concrete with cementitious material results in smaller cross-sections which ultimately decreases the dead load of structure which helps engineers to construct bridges with longer spans and taller building [3]. The use of MSC can results in decreasing the number of girders required, thus, giving economic advantages i.e. improved durability in aggressive environment, service life, reduce size of longer spans and fewer beams for the same magnitude of loading. The main applications of concrete with addition of cementitious material are in long-span bridges, columns for tall buildings,

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highway structures and offshore structures [4]. High-strength concrete is tentatively defined as the concrete having the compressive strength of more than 60 MPa [5]. Su and Miao [6] reported the compressive strength range of medium strength concrete from 28 MPa to 35 MPa. In this study, the concrete between 20 MPa and 45 MPa is considered as medium strength concrete (MSC).

The combination of silica fume (SF) with super plasticizer (SP) helps in maintaining a workable concrete material having less W/C ratio. The SF particles fill the space between interfacial transition zones [7,8]. Afroughsabet and Ozbakkaloglu [9] reported that the addition of silica fume has increased in the production of concrete. According to Banthia et al. [10], the silica fume in concrete has received greater consideration due to its use in high rise buildings, marine structures and bridges. Burgueno et al. [11] also reported that silica fume in concrete improves the mechanical properties. Due to the ability of increasing properties of concrete, silica fume is being widely used in civil structures [12–18]. The use of pozzolanic material and super plasticizer in the mix design is suggested for concrete having improved strength. However, in case of normal strength concrete, by using high cement content, the concrete will results in higher water demand and will lead towards segregation and bleeding. Hence, super plasticizer is required to obtain concrete for improved strength with low cement and water content. Generally, it is known that high cement content will produce high strength concrete [19]. According to ASTM C-125-97a [20], an admixture is a material other than hydraulic cement, aggregate and water which is used in the production of mortar or concrete, and is added before or during mixing in the batch. The water demand in concrete mix is significantly reduced by super plasticizer. Concrete with improved strength has greater mechanical properties and better durability and its use in construction of bridges, tall building and offshore structures is increased. The important chemical in preparing concrete with improved strength is super plasticizer. The addition of super plasticizer will have better effect on properties of fresh and hardened concrete. The utilization of super plasticizer in fresh state results in reduction of water content in concrete which ultimately reduces the bleeding. If more water is available, the super plasticizer prolongs the time of setting of concrete. In hardened state, the utilization of super plasticizer will enhance the compressive strength by improving the effectiveness of compaction which results in production of denser concrete [21]. The detailed guidelines for the use of super plasticizers are given by ACI 212.4R-06 [22].

Malagavelli et al. [23] studied the workability and strength properties of concrete having super plasticizers. The workability and strength results of concrete having super plasticizer were improved as compared to that of concrete without super plasticizer. The maximum, average and minimum average compressive strength were 40.68 MPa, 35.51 MPa and 30.62 MPa, respectively at 28 days with super plasticizer. Shah et al. [24] investigated the influence of super plasticizer on strength properties of concrete using different design mix ratios. The cement, fine aggregates and coarse aggregates were mixed in three nominal ratios of 1:1:2, 1:1.5:2.5 and 1:1.5:3 with a water cementitious ratio of 0.40, 0.35 and 0.30, respectively. The dosage of the SP was kept at 0.8%, by mass of the cement. The optimum design mix ratio for cement: sand: aggregate was (1:1:2) with a water cementitious ratio of 0.40. It was found that with the mix design ratio for cement: sand: aggregate (1:1:2), the compressive strength ($\sigma$), split tensile strength (SS) and flexural strength (F.S) were 45.17 MPa, 7.21 MPa and 7.21 MPa, respectively. Koksal et al. [25] reported the influence of admixture, steel fibers and silica fume on mechanical properties of concrete. The silica fume was added by 0%, 5%, 10%, 15% and 20%, by mass of cement. The mix design ratio for cement: sand: aggregate: water was 1: 2.1: 2.7: 0.38 with admixture content of 1%, by cement mass. For 15% silica fume content the $\sigma$, F.S and SS were increased by 85.8%, 118.1% and 53.7%, respectively, than that of normal strength concrete. Among natural fiber coconut fibers have the highest toughness [26–27]. Ali et al. [26] investigated the mechanical properties of coconut fiber reinforced concrete (CFRC). The mix design ratio was 1:2:2 (cement: sand: aggregate) with water to cement ratio 0.48. It was observed that with addition of 2% fiber content, having 5 cm length, the $\sigma$, F.S and STS were increased by 20%, 2% and 10%, respectively, than that of plain concrete. Baruah and Taukdar [27] studied the mechanical properties of CFRC. The mix design ratio was 1:1.67: 3.64 (cement: sand: aggregate) with 0.535 w/c ratio. With addition of 2% fibers, by volume fraction, the $\sigma$, F.S and SS were increased by 13%, 28% and 23%, respectively, than that of plain concrete. Therefore, the combination of coconut fibers, silica fume and admixtures can be helpful to produce concrete with enhanced mechanical properties for civil engineering applications.

The brittleness, i.e. relatively low tensile strength and poor resistance to crack opening and propagation are the disadvantages of concrete. The dispersed fibers play an important role in the development of concrete. The use of fibers is also beneficial for controlling shrinkage cracking [28]. The brittle building materials, e.g. clay sun baked bricks, were reinforced with horse-hair, straw and other vegetable fibers since Biblical times i.e. approximately 3500 years ago [29]. The ordinary concretes without fibers are used for low performance structures and non-structural elements due to obvious reasons. The aim of the paper is to describe the present state of knowledge and technology of natural fiber reinforced concrete and to discuss main directions of their application. The attention is concentrated on structural concretes for high-rise buildings and long-span bridges. The advantages of natural plants fibers can be evaluated from the ecological aspect, because this fiber is a waste fiber and inexpensive material. The coconut fiber is selected, because among natural, fibers, coconut fibers have the highest toughness [26–27]. Therefore, this study has been reported on the coconut fiber reinforced concrete (CFRC) along with addition of silica fume and super plasticizer for civil engineering applications. However, durability needs to be investigated in future due to organic nature of coconut fiber. In current study, properties of medium strength concrete (MSC) and medium strength coconut fiber reinforced concrete (MSCFRC) are determined for the structural applications. The corresponding strength, crack(s) behavior, absorbed energy and toughness indexes are discussed. The stress–strain curves, load–deflection curves and load-time curves of all MSC and MSCFRC specimens with different percentages of super plasticizer are emphasized under compressive, flexural and splitting-tensile loading, respectively.

## 2. Experimental procedure

### 2.1. Materials

The coarse aggregate, sand, cement, water, coconut fiber, silica-fume and super plasticizer were used. The coconut fibers were imported from Sri Lanka. The silica-fume and super plasticizers was provided by Sika Pakistan (Pvt.) Limited. The maximum size of aggregates was 13 mm. The specific gravity and water absorption of coarse aggregate were 2.7 and 0.81%, respectively. From physical observation and sieve analysis, the sand was found of reasonable quality. The fineness modulus (FM) of sand was 2.8. The specific gravity and water absorption of sand were 2.67 and 1.42%, respectively. The super plasticizers SikaVisco Crete-3110 W was used especially suitable for use in concrete mixes containing silica-fume and other pozzolanic materials like GGBS and Fly Ash. The super plasticizer conforms to the requirement of ASTM C494 / C494M-99a Type G and EN 934–2. The coconut fiber of 50 mm (2 in.) length is shown in Fig. 1. The range of coconut fiber diameter was from 0.20 mm to 0.40 mm. The specific gravity and water absorption of coconut fiber were 1.18 and 0.27%, respectively. A mature coconut has an outer covering made of fibrous material. This part of the coconut, called the husk, consists of a hard skin and a large amount of fibers embedded in a soft material. The fibers can be extracted simply by soaking the husk in water to decompose the soft material surrounding the fibers. This process, called retting, is widely used in the less developed countries [30]. So, the retting process is followed for treatment of coconut fibers.