Rheological properties of self compacting concrete with partial replacement of metakaolin in cement and plastic fibre

M Arun Kumar1*, S Selvapraveen2, P DharaniPrasath3, R Bavithran3 and G Dhanabal3

1Assistant Professor, Department of Civil Engineering, Kongu Engineering College Perundurai, Erode, Tamil Nadu - 638060, India
2PG Scholar, Department of Civil Engineering, Kongu Engineering College Perundurai, Erode, Tamil Nadu - 638060, India
3UG Scholar, Department of Civil Engineering, Kongu Engineering College Perundurai, Erode, Tamil Nadu - 638060, India

*E-mail: rsmanoharan@gmail.com

Abstract. This work deals with the experimental study of SCC with plastic fibre and metakaolin. Metakaolin with 20% replacement for cement and also addition of plastic fibre in SCC are tested. The influence of mineral admixture and the addition of plastic fibre in physical and mechanical properties in SCC are investigated. Plastic fibre is added to SCC with five various ratio are 0%, 0.25%, 0.5%, 0.75% and 1% respectively. The fresh concrete is tested by L – box test, V – funnel test and U – box test. The hardened concrete is tested by compressive test, flexural strength test and split tensile test. The properties of fresh concrete demonstrated that filling and passing capability of SCC are weak because of introduction of plastic fibre but are not greatly affected the properties. The hardened concrete properties show that metakaolin and plastic fibre has an impact on the strength of SCC.

Keywords: SCC, Mechanical properties, Metakaolin, Plastic fibre.

1. Introduction

Self-compacting concrete (SCC) was established in the 1980s in Japan[1]. Nowadays, the usage of SCC in the industries is increased[2]. Additional Compaction is not required for SCC, it flows with its properties[3]. Placing of concrete in a congested area, with a high number of rebars are easy by using SCC[4]. No additional vibration is needed, like conventional concrete. The incorporation of a mineral mixture is among the most noticeable variations between SCC and Conventional concrete[2]. Use of mineral admixture increases the workability and reduces the cement content in concrete [2, 5, 6]. Since cement has been the most expensive ingredient of concrete, an economical solution is to reduce the cement content. Additionally, particle packing is improved and concrete permeability decreases because of using mineral admixture. So the concrete durability also improved[2, 7]. Among other cement-based materials, metakaolin is with a feasible growth rate in the concrete industry. Even before the 1960s, metakaolin was a well-known substance, but its use either as pozzolanic material in cement...
or as supplementary cementitious materials (SCM) in the concrete only gained researchers’ attention after the early 1980s[8-12]. The key characteristic of metakaolin is its high calcium hydroxide reactivity, Ca(OH)₂, and its ability to speed up cement hydration[8]. The processing of MK requires lower temperatures than Portland cement. Because of low production, the cost will be increased[13, 14].

A review carried out by Arun et al.[3] revealed that workability of SCC with MK is in satisfactory level and high replacement increases the compressive strength. Madandoust and Mousavi[13] conducted an experiment in SCC with MK and says that compressive strength increased both the initial and final stage. Sfikas et al.[12] revealed that high replacement MK reduces the workability but it increases the compressive strength.

Besides, plastic fibre is added to the concrete mix. Reuse of waste plastic plays a major role in solid waste management[15]. Waste materials are increased day by day, as the world faces the issue of disposing of them[16]. Among these plastic waste, its disposal has adverse effects. Due to the long biodegradation duration, the use of these materials in other industries is one of the rational methods for reducing their negative effects on the environment. Much research has concentrated on the reuse of waste plastic materials in concrete. The addition of plastic waste to concrete represents a new viewpoint in the field of research and fields of concrete technology[15].

Chemical admixtures, identify those additives would be adding directly into concrete mixture earlier or at that time of preparing the concrete[17]. To improve certain properties of hardened and fresh concrete, chemical admixtures such as high-range water reducers[18], viscosity-modifying agent[19] are used. It increases concrete properties and workability.

The current investigation is to examine the hardened and fresh properties of SCC having Metakaolin and plastic fibre. For that several tests had conducted, V-funnel, L-box and U-box for fresh concrete properties[20, 21] and for hardened properties compressive strength test, splitting tensile test and Flexural test are done.

From the literatures it observed that partial replacement of cement with metakaolin increases the compressive strength and use of plastic fibre in concrete increases the bonding strength of concrete and reduces the cost of SCC by utilizing the waste and it also avoid dumping of plastic wastes in environment. So it is planned to use metakaolin and plastic fibre in SCC to analyze the properties of fresh and hardened concrete and it useful for future researches.

2. Experimental program

2.1. Materials

2.1.1. Cement. Ordinary Portland cement (OPC) Grade 53 can be used for investigation of SCC with the replacement of metakaolin of about 20% by total weight of cement.

2.1.2. Fine aggregate (FA). M sand of less than 4.75 mm size is used and its properties are Water absorption 1.2%, specific gravity 2.57.

2.1.3. Coarse aggregate (CA). All Natural crushed stone (size- 12.5 mm) is used and its properties are specific gravity of CA 2.71, Water absorption 0.79%.

2.1.4. Admixture. Mineral admixture - Metakaolin (20%) has been used as partial replacement for cement. Chemical admixture - Master Glenium Sky 8233 superplasticizer of 1.1 is used.

2.2. Mix proportion

Various mixes were prepared with varying mix ratios. After several trials, the SCC mix which fulfilled that requirements were designed. The mix design of M40 grade concrete are designed as per the guidelines of EFNARC. The values of mix proportion shown in table 1.
The addition of plastic fibre and metakaolin 20% in SCC are added with five different ratios are SCC 1 (Conventional concrete), SCC 2 (20% MK and 0.25% fibre), SCC 3 (20% MK and 0.5% fibre) SCC 4 (20% MK and 0.75% fibre) and SCC 5 (20% MK and 1% fibre) respectively.

### Table 1. Values of mix proportion

| Materials | Values          |
|-----------|-----------------|
| Cement    | 440 kg/m³       |
| Water     | 157 kg/m³       |
| CA        | 919.512 kg/m³   |
| FA        | 1033.32 kg/m³   |
| w/c ratio | 0.4             |
| Admixture | 0.9%            |

Cement: FA: CA = 1: 2.34: 2.08

3. Results and discussions

3.1. Test results of hardened concrete

3.1.1. Compressive strength. Compressive test can be used to measure the compressive strength of concrete, the sample is tested at curing period of 7 and 28 days. The cube size are 150 x 150 x 150 mm. Test values are shown in figure 1.

![Figure 1. Values of compression strength](image)

3.1.2. Split tensile test. The tensile strength of concrete were measured by using Split tensile test. The size of a cylindrical specimen is 150 mm dia and 300 mm in height. The specimen is tested at interval of 7 and 28 days of curing. The test values were shown in figure 2.
3.1.3. Flexural test. It is used to find the bending properties of concrete. The size of specimen are 500 x 100 x 100 mm. It is tested at a period of 7 days and 28 days of curing. The results were shown in figure 3.

![Diagram](image)

**Figure 2.** Values of split tensile

3.2. Test results of fresh concrete

3.2.1. V-funnel results. SCC fresh concrete flowability with adding of plastic fibre and partial replacement of metakaolin (20%) with cement is found using the V – funnel test. The experiment values are shown in figure 4.

![Diagram](image)

**Figure 3.** Values of flexural test
3.2.2. L-box results. L – Box test are used to find passing and filling ability of the fresh concrete. In figure 5 the experiment values are shown.

3.2.3. U-box results. The fresh concrete flowability with adding of plastic fibre and partial replacement of metakaolin (20%) with cement is found using the U – box test. In figure 6 the test results were shown.
From the test results it is observed that in fresh concrete the flowability is gradually increased when the amount of plastic fibre ratio is increased with constant of metakaolin (20%). It shows that the plastic fibre ratio does not affect the fresh concrete properties, badly. For hardened properties of concrete, compared with 7 days curing, the strength of hardened concrete is increased for 28 days of curing. So the curing period increases the strength of concrete also increased.

Replacing cement with 20% of MK and adding different ratios of plastic fibres influences the strength of concrete. Test results demonstrate that replacement of metakaolin about 20% by cement’s total weight and adding Plastic fibre about 1% have maximum strength related to other mixtures. Adding of plastic fibre into the concrete improved the bonding of a cement paste and have the significant effect on the strength is achieved.

4. Conclusion
The main aim of the paper is to analyse the fresh and hardened properties of SCC with metakaolin (20%) and use of plastic waste in the concrete as addition material and noticed the impact of plastic fibre in concrete. From this the following conclusion are drawn.

- The experiment demonstrate that use of metakaolin and plastic fibre develops the high strength in SCC.
- The optimum OPC replacement level for Metakaolin is 20% and plastic fibre (1%), which have highest compressive strength compared to other replacements.
- Similar to that, flexural test and tensile test are maximum at replacement of metakaolin (20%) with 1% of the plastic fibre.
- The adding of plastic fibre to concrete eliminates the dumping of plastic waste in atmosphere and thus decreases environmental contamination.

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