BEHAVIOUR OF SELF-COMPACTING CONCRETE USING DIFFERENT MINERAL POWDERS ADDITIONS IN TERNARY BLENDS

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Gainful utilization of mineral admixtures like Metakaolin (MK), Fly Ash (FA) and filler material like Waste Marble Powder (WMP) in various construction practices has become a new topic of interest in research area. This paper presents the studies regarding the use of MK and FA as cement substitution (partial) and WMP as fine aggregate replacement (partial) in Self-Compacting +Concrete (SCC). The pozzolanic nature of the MK and FA due to their high silica and alumina content enables them to be the most valuable Supplementary Cementing Materials (SCM's) for utilization in the production of SCC. The MK was used as partial replacement of cement in seven different proportions of 5, 7.5, 10, 12.5, 15, 17.5 and 20% while as the FA replacement level (by weight of cement) was kept fixed at 15%. The fine aggregate was partially replaced by 20% WMP. To evaluate the influence of FA, the control mix with 15% FA substitution of cement was also designed. Thus, a total of nine mixes including the reference mix without fly ash were designed. The different tests to evaluate the workability were performed, which are presented in this paper. The specimens were tested in the hardened state at different ages for assessing the mechanical properties of SCC. The use of ternary binding blends consists of OPC+FA+MK and addition of WMP as fine aggregate replacement have shown a positive impact on fresh and mechanical characteristics of SCC. A significant correlation has also been observed between fresh properties and hardened properties of SCC.

Keywords: *Self-compacting concrete (SCC); Pozzolans; Admixtures; Fly Ash (FA); Metakaolin (MK); and Waste Marble Powder (WMP)*

1. Introduction

The importance of concrete increases day by day owing to the escalating infrastructure development. The concrete industry has been subjected to the numerous innovations by the researchers to suit to the growing demands of the concrete industry. In 1988, a most relevant innovation was made by Prof. H. Okamura with the design of Self-Compacting Concrete (SCC). This SCC was capable of flowing and consolidating due to its own weight without any need of compaction, filling high density reinforced complex areas, achieving high degree of homogenization and provides better surface finish. Thus the casting of the concrete was completely changed with the development of SCC where no vibration is required [1,2]. There are many advantages of SCC over conventional concrete such as improving filling capacity in congested areas, reduction of noise pollution, decrease in construction time, improving strength, reducing permeability of concrete, showing good structural performance and positively effecting the ITZ (Interfacial Transitional Zone) between cement paste and aggregates [3]. SCC possess a high passing, filling ability and segregation resistance [4]. Passing ability refers to the ability of the concrete to flow without blocking through congested reinforcement, filling ability of concrete is its ability to flow and take the shape of any container or mould owing to its own weight and segregation resistance of the concrete is referred to its ability to remain uniform during transport and placing [5, 6]. There are some guidelines which researchers put for development of SCC such as reduction of volume ratio of aggregates, increase in the paste volume and water/cement ratio, maximum size of coarse aggregates, use of superplasticizer (SP) and viscosity modifying admixtures (VMA) [7,8]. The workability and cohesiveness of SCC is successfully reached with the low water/cement ratio, high powder content and use of a superplasticizer [9]. The concrete initiates electrostatic dispersion mechanism when mixed with Polycarboxylic Ether (PCE) based SP. This ultimately generates steric hindrance responsible for increasing the ability to separate, disperse and stabilize the cement particles. It has been observed that PCE based SP gives more workability, slightly increases of the strength and is more effective when used in small amounts as compared to traditional based SP [10]. The use of Viscosity Modifying Admixture (VMA) in SCC reduces bleeding and segregation. It has been found that there is a bad influence on fresh and mechanical characteristics of SCC in hot climate, so while concrete curing, some of the precautions should be taken into account [11].

In terms of EFNARC [12], the performance of the SCC can be judged on the basis of fresh, mechanical and durability properties. During the last two to three decades the researchers have been able to enhance the mechanical as well as durability characteristics of SCC with the use of Supplementary Cementitious Materials (SCM's). The SCM's possess the high pozzolanic activity,

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filling effect and their incorporation can produce cohesive, consistent and compact concrete thereby enhancing its fresh, mechanical and durability characteristics coupled with reduction in permeability [13,14]. The various SCM's used in SCC are Metakaolin (MK), Silica Fume (SF), Fly Ash (FA), Blast Furnace Slag (BFS) and Rice Husk Ash (RHA) etc. In this investigation which forms the part of wide research studies on SCC, the SCM's like MK and FA were used. Besides, the WMP was used as a partial replacement of fine aggregate. The only disadvantage of the SCC is the slight increase in cost of its production than normal concrete [15,16]. This increase in cost can be reduced to a greater extent by the use of a siliceous aluminous material called as pozzolans. The great grinding fineness pozzolan reacts chemically with CH and forms compounds which possess binding properties. The pozzolans are of two origins, either industrial origin or in natural form. The industrial origin of pozzolans are the by-products of industries such as FA, SF, slag etc. In natural form, the pozzolans are in raw or calcined natural material such as MK, RHA, calcined shale, volcanic ash, etc. A reduction in the demand for cement has been observed with the addition of pozzolans, thereby reducing the shrinkage, creep, permeability, and pore size in concrete. It has been found that the addition of pozzolans enhance the mechanical properties of concrete [17].

Metakaolin (MK) is a mineral admixture obtained as a result of thermal treatment of a kaolin clay at 600-750 ºC and belongs to class N pozzolana conforming to ASTM C 618-05 [18]. The hydration reactions of cement form Calcium hydroxide, which by reaction with MK forms an additional C-S-H gel thereby increasing the strength [19-21]. The colour of metakaolin is off-white. It is highly reactive as it contains 50-55% SiO_2 and 40-45% Al_2O_3 [22]. This pozzolan reduces total porosity, refines the pore structure and as such improves the impermeability coupled with the strength increase of the concrete [23]. The higher replacement levels by MK have as consequences, the increase of the resistance of SCC to the sulfate attack, chloride penetration and a decrease in water absorption [24]. A reduction in open porosity, gas permeability, chloride penetration and an improvement in the resistance against sorptivity were observed with the inclusion of different proportions of MK as partial replacement of cement [25]. Owing to the greater content of Al_2O_3 and SiO_2 in Metakaolin, the CaO/SiO_2 of C-S-H gel is higher as compared to other pozzolanic materials like blast furnace slag and FA. The CaO/SiO_2 ratio is determined by various factors such as mix proportion, curing time, and pozzolanic material [26, 27]. The MK substitution in SCC increases the strength, reduction in permeability thereby enhancing the durability of concrete [28].

Fly Ash (FA) is obtained by burning of coal and is generally used as a cement replacement (partial) which is beneficial in terms of the environmental concerns [29,30]. It doesn't affect the compressive strength because of its slow pozzolanic and hydration reactions [31]. FA incorporated in SCC has been found to enhance the workability and reduces the cracking due to the lower heat of hydration. However, hydration reactions in concrete with FA are more slowly than in the normal concrete made with Portland cement and therefore requires more time to gain maximum strength. It has been reported that because of small spherical appearance of FA particles, its addition in SCC has been found to enhance rheological properties of SCC while reducing demand of water [32]. An outstanding workability of super flowing concrete was observed with the replacement of 30% cement by FA [33].

The processing of the marble for use in the different applications generates a huge quantity of wastes at the processing plants or in queries. The accumulation of this marble waste and its disposal poses an alarming threat in terms of the global environmental hazards [34]. The amount of the WMP produced after cutting of marble blocks and stone is so high that it is very difficult to manage its storage. These concerns can be addressed with the re-use of waste marble sludge's [35, 36]. In a marble block which weighs about 15-20 tons, about 70% is wasted during their finishing process [37]. It has been observed by a number of researchers that WMP use in SCC has proven to be effective on fresh and mechanical characteristics of SCC [38, 39]. WMP gives quite good cohesiveness in the concrete mixture due to its high fineness and filling ability which enhances the properties of the concrete [40]. The increase of WMP content used as sand replacement in SCC has as result the increase of the compressive strength, dynamic modulus of elasticity and decrease in sorptivity [41].

The present study which forms a part of research project focusses on determining of the effects of different mineral powders additions in ternary blends on the main characteristics of SCC. The addition of pozzolanic and non-pozzolanic material in SCC have been reported to influence the fresh and mechanical characteristics of SCC. In this study, metakaolin and fly ash have been used as cement replacement (partial) whereas WMP has been used as sand replacement (partial). The MK was used to partially replace of cement in seven different proportions of 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and 20% while as FA replacement level (by weight of cement) was kept fixed at 15% in all the 8 mixtures. In addition to this, the fine aggregate was partially replaced by 20% WMP. In order to find the influence of FA, a control mix with 15% FA was designed. Thus, a total of nine mixes including a reference mix without FA were designed. The results of different tests performed for determine the fresh and mechanical characteristics of SCC are presented in this paper.

2. Research significance

The review of the literature suggests that a lot of study has been made on the use of the pozzolanic materials as binary blended binders and some studies have been made on ternary blended binders especially with addition of non-pozzolanic filler material. So, a need is being felt to have an in-depth study on the use of ternary blended binders in combination with the non-pozzolanic filler material especially in SCC to investigate their impact on its fresh and mechanical characteristics. Further, the novelty of this research study is to use industrial by-product (FA) and a waste product (WMP) of the marble industry, the storage of which otherwise poses a lot of environmental and ecological problems. As such, a detailed experiment has been laid out in this research study to find out the effect of ternary blended binders (OPC+FA+MK) in combination with non-pozzolanic filler material like WMP (as a sand replacement) on fresh and mechanical characteristics of Self-Compacting Concrete.

3. Experimental Investigations

3.1 Materials

In this study Ordinary 53 grade Ramco Portland cement which conformed to IS 12269:2013 [42] was used. Gravel size of 10-12.5 mm available locally was used as coarse aggregate and locally available river sand which satisfied the requirement for grading zone II was used as fine aggregate (IS: 383-2016) [43]. Metakaolin (MK) of class pozzolana conforming to ASTM C 618 [18] with 1.2 - 2.5 µm particle size was used. Fly ash (class C) procured from Neyveli Lignite Corporation Indian Limited (NLC), Neyveli conforming to IS 3812:2003 [44] was used in this study. Waste Marble Powder (WMP) obtained from marble cutting factory near Vellore, Tamil Nadu (India) was used. In order to achieve high workability Polycarboxylic Ether (PCE) based superplasticizer also called as High Range Water Reducer Admixture (HRWRA) conforming to IS: 9013, 2014 [45] was used. The VMA was used to obtain the bleed free mixes. The portable water available in the laboratory conforming to IS 456-2002 [46] was used. Tables 1-3 show the physical and chemical properties of constituent materials used in this research study.

3.2 Mix Design

The cognisance of the previous studies were considered for producing a mix design and a

Table 1

Composition of OPC, MK, FA and WMP

	OPC	MK	FA	WMP
Chemical Composition (%)				
SiO_2	21.62	52.0	51.55	3.12
Al_2O_3	5.30	46.0	21.55	0.35
Fe_2O_3	3.20	0.60	12	0.09
CaO	63.5	0.09	5	55.15
SO_3	2.1	0.30	3.80	0.01
Loss on ignition	1.2	1.00	3.1	38.55
Physical properties				
Bulk density (kg/m^3)	1580	3550	1350	1280
Specific gravity	3.15	2.60	2.18	2.68
Physical form Colour	Powder Grey	Powder Off-white	Powder Grey	Powder white

Table 2

Physical characteristics of fine and coarse aggregates

Properties	Fine aggregate	Coarse aggregate
Specific gravity	2.58	2.65
Water Absorption	1.0	0.65
Size (mm)	< 4.75	10-12.5
Fineness modulus	2.66	5.8

Table 3

Properties of Superplasticizer (HRWRA) and Viscosity Modifying Admixture (VMA).

Properties	Superplasticizer (HRWRA)	VMA
Specific Gravity	1.08	-
Aspect	Reddish Brown Liquid	Colourless free flowing liquid
pH	≥ 6	≥ 6 at 25 ºC
Relative Density	1.08 ± 0.02 at 25ºC	1.01 ± 0.01 at 25ºC
Chloride ion content	< 0.2%	< 0.2%

* As per the manufacturer's manual.

modification was made by performing 65 trial mixes to find the optimum mix proportion best suitable for SCC without segregation and bleeding as per the guidelines of EFNARC [12, 47]. Thus a total of nine SCC mixes including control mix (M0) were designed. The MK was used to partially replaced cement in seven different proportions of 5% (M1), 7.5% (M2), 10% (M3), 12.5% (M4), 15% (M5), 17.5% (M6) and 20% (M7). The replacement of FA was kept fixed at 15% by weight of total binder and the fine aggregate was partially replaced by 20% WMP. To evaluate the influence of FA, control mix with 15% FA (M8) substitution with cement was also designed. The FA and WMP replacement levels were determined on the basis of studies forming a part of this research investigation. The total binder was kept at 498 kg/m^3 with 0.42 w/b ratio for all SCC mixes. The detailed mix proportions of SCC are tabulated in Table 4.

3.3 Determination of fresh properties of SCC

The filling ability, passing ability, flowability and segregation resistance of all SCC mixes were checked by different tests as per EFNARC

Table 4

Mix proportions

Mix Designation	Type of mix	w/b	Cement (kg/m^3)	Metakaolin (kg/m^3)	Fly Ash (kg/m^3)	Fine aggregate (kg/m^3)	Marble waste powder (kg/m^3)	Coarse aggregate (kg/m^3)	S.P. (%)	VMA (%)
M0	Control mix	0.42	498	-	-	960	-	700	1	0.25
M1	SCC5MK	0.42	398.40	24.90	74.7	768	192	700	1.05	0.35
M2	SCC7.5MK	0.42	385.95	37.35	74.7	768	192	700	1.1	0.40
M3	SCC10MK	0.42	373.50	49.80	74.7	768	192	700	1.25	0.45
M4	SCC12.5MK	0.42	361.05	62.25	74.7	768	192	700	1.30	0.45
M5	SCC15MK	0.42	348.60	74.70	74.7	768	192	700	1.35	0.50
M6	SCC17.5MK	0.42	336.15	87.15	74.7	768	192	700	1.40	0.55
M7	SCC20MK	0.42	323.70	99.60	74.7	768	192	700	1.45	0.60
M8	Control mix 15%FA	0.42	423.30	-	74.7	960	-	700	0.90	0.25

(a) Slump flow and T_{50} cm flow (b) L-Box (c) V-Funnel

Fig. 1 - Some of the fresh Properties tests of SCC.

guidelines [12]. In the absence of obstruction, slump flow test was performed to find out the flowability on a horizontal flat surface (Range= 650-800 mm), T_{50} cm slump flow (Range= 2-5 seconds) and V-funnel (Range= 6-12 seconds) were performed to assess the viscosity and segregation of all SCC mixes. L-box (blocking ratio) was carried out to find out the flowability and passing ability of SCC mixes. All the fresh properties tests are shown in Fig.1 (a), (b) and (c).

3.4. Mechanical properties of SCC

After performing the fresh concrete tests, the concrete mixture was put into the moulds without applying any external vibration for performing the hardened concrete tests. In order to determine the compressive strength, the mould cube size of 100 × 100 × 100 mm was used for casting, and the test was carried out as per IS 516-1959 (reaffirmed 1999) [48]. A small cylinder size of 100 × 200 mm was used to find split tensile strength as per ASTM C496/C496M-11 [49]. For finding flexural strength, the prism size of 100 × 100 × 500 mm was used and the test was carried out as per IS 516-1959 (reaffirmed 1999) [48]. The concrete samples were de-moulded after 24 hours and immersed in water in a curing tank up to testing date. The average reading of three samples for each mixture was taken at respective ages.

4. Experimental results and discussions

4.1 Fresh properties of SCC

The results in respect of fresh properties of the all SCC mixes are summarized in Table 5.

Table 5

Fresh SCC results

Mix Designation	Slump Flow (mm)	T_{50} cm (Sec)	V- funnel (Sec)	L-Box (h_2/h_1)
M0	690	4	7.5	0.87
M1	683	3.8	7.6	0.85
M2	688	3.7	7.0	0.84
M3	710	2.5	5.6	0.92
M4	705	2.8	5.7	0.90
M5	698	3.3	6.6	0.87
M6	670	3.8	7.3	0.89
M7	662	4.1	7.7	0.85
M8	713	2.4	5.5	0.93

4.1.1 Slump flow and T_{50} cm time

The test values of slump flow were between 662-713 mm for all SCC mixes. The results of all the SCC mixes fall under SF2 category of slump flow class (660-750 mm) as per the guidelines recommended by EFNARC [47]. The application of SF2 class of slump flow is suitable for construction of deep beams and columns etc. The perusal of the results indicates a gradual reduction in the slump flow values with the higher replacement percentages of MK. A significant inter-particle friction aggregates has been observed due to the larger surface area of MK. MK slightly reduces the workability due to its higher reactivity, irregular shape and higher surface area than OPC. These findings are similar to the findings reported by Khaleel and Razak (2014), Kannan and Ganesan (2014), Vejmelkova et al. (2011), Guneyisi and Gesoglu (2008) [50-53]. The enhancement of workability was achieved by increasing the required dosage of SP. This can be attributed to the liquefying and dispersing mechanism of SP by diminishing the quantity of entrapped water within the flocculated particles

[54]. While as, the use of FA enhances the slump flow value than control mix and dosage of SP was reduced to the required level to reduce the mix consistency. The T_{50} cm flow time was found to be in the range of 2.4 to 4.1 seconds. The results indicated an increase in the T_{50} cm flow time with the higher replacements percentages of MK. This is in accordance to the findings observed by the Guneyisi et al. (2009) [55] who used higher percentages of MK and found an increase in the T_{50} cm flow time.

4.1.2 V-funnel flow time

The test values were found to be in the range of 5.5 - 7.7 seconds for all SCC mixes. The results of all the SCC mixe
s fall under VF1 category of v-funnel time class (≤ 8 seconds) as per the guidelines recommended by EFNARC [47]. It is pertinent to mention here that the v-funnel time exceeding 25 seconds is not recommended as per the guidelines of EFNARC [47]. From the results a decrease in the v-funnel flow time was observed for the control mix with 15% FA (M8). The addition of VMA and the use of WMP as a filler material has also resulted in enhancement of viscosity. The relationship between V-funnel time and T_{50} cm time is found acceptable for all SCC mixes as reflected in Figure 2. The determination coefficient (R^2 = 0.98) showed it is very close to 1.0 considered as a strong relationship.

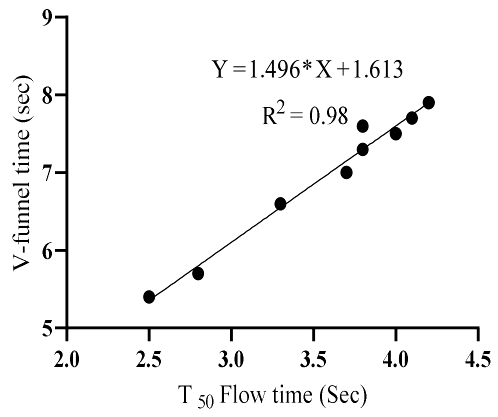


Fig 2 - V-Funnel vs. T50 cm.

4.1.3 L-box Test (Blocking Ratio)

The blocking ratio (h_2/h_1) of all SCC mixes were in the range of 0.84-0.93. All the SCC mixes were within the specified range as per the guidelines of EFNARC [47]. The incorporation of SCM's have affected the results positively.

4.2 Hardened concrete tests

The results obtained after evaluation of mechanical characteristics of the all SCC mixes are shown in Table 6.

Table 6

Mechanical Properties of SCC

Mix Designation	Compressive strength (MPa)				Split tensile strength (MPa)		Flexural strength (MPa)	
	7 days	28 days	56 days	90 days	28 days	90 days	28 days	90 days
M0	32.4	42.1	43.4	44.1	3.3	3.7	6.2	7.6
M1	34.1	44.8	45.3	46.0	3.4	3.8	6.8	8.3
M2	35.2	46.2	47.0	46.9	3.6	4.1	7.0	8.7
M3	37.0	48.8	49.4	50.1	3.7	4.3	7.8	9.3
M4	38.4	50.7	51.2	52.0	3.9	4.5	8.1	9.6
M5	34.8	45.7	46.3	47.0	3.7	4.2	7.0	8.0
M6	29.9	39.4	40.1	40.7	-	-	-	-
M7	28.1	37.1	37.9	38.5	-	-	-	-
M8	30.1	41.3	44.5	46.5	3.2	3.9	6.1	7.8

4.2.1 Compressive strength

The results of compressive strength of all SCC mixes at different intervals of time are depicted in Table 6. The results reveal that the use of MK in the SCC mixes enhanced the strength at an early age (7 days) as shown in Figure 3. The fast pozzolanic reaction of MK was mainly found to be responsible for the early strength of MK blended SCC [56]. The presence of calcium hydroxide in the hydrated Portland cement reduces the strength or durability properties of the concrete. MK reacts with $Ca(OH)_2$ and produces C-S-H gel, an additional binding compound which holds the concrete together and leads to the increase of compressive strength. The reactivity increases in concrete due to MK particles having larger surface area. The compressive strength of ternary blended SCC (OPC +MK + FA) has been observed to increase up-to 20.43% in M4 mix at 28 days as is reflected in Figure 2. This is due to the chemical and physical action of MK [57-59]. The compressive strength at 90 days of 52 MPa was maximum for M4 mix and thus considered as suitable replacement. The lowest compressive strength of 44.1 MPa at 90 days were observed for control mix (M0) whereas control mix with 15% FA (M8) exhibited slightly better compressive strength of 46.5 MPa than the control mix (M0). Similar findings were reported by Kavita et.al (2015), Kannan and Ganesan (2014), Guru et.al (2013) and Dinakar et.al (2013) [21, 22, 51, 60], who investigated the impact of MK and FA on the fresh and mechanical characteristics of SCC. MK replacement of 15% or above has decreased the strength probably due to the reduced workability in SCC which increases the required dosage of SP [61]. The use of 15% FA (M8) slightly decreases the strength at early age but enhances the compressive strength at later ages than normal concrete. This is attributed to the slow pozzolanic reaction of FA and its dilution effect [62].

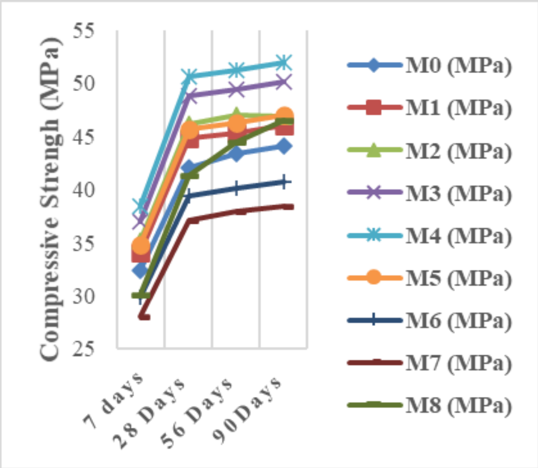


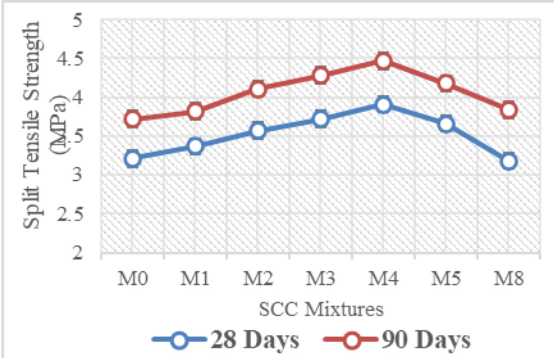
Fig. 3 - ompressive strength at different ages.

4.2.2 Split tensile strength

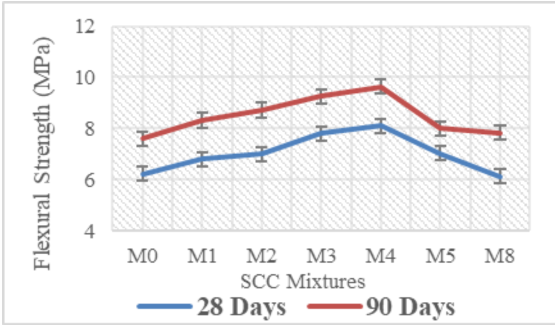
The split tensile strength test of all SCC mixes was carried out as per standard ASTM C496/C496M-11 [49] at different intervals of time and the results are shown in Table 6. In this study, there was an increase of 18.18% tensile strength for M4 mix and 12.12% tensile strength for M3 mix after 28 days with respect to control mix as shown in Figure 4 (a). The previous literature also suggests an increase of tensile strength (9.8%) after 28 days for concrete with 10% MK as replacement of cement [9]. From the results it is obvious that out of all SCC mixes, M4 mix exhibits the highest split tensile strength (18.18%). The tensile strength increases as a result of bridging of diametric splitting crack. The use of 15% FA (M8) as cement replacement slightly decreases the split tensile strength to 3.03% at 28 days but at later age (90 days) an increase of 5.41% as compared to control mix (M0) was observed. A Similar finding to this work has been observed by Gill and Siddique (2017), Hassan et.al (2012), R.Madandoust and S. Mousavi (2012) [9, 63, 64] who reported better results in split tensile was obtained with 10-15% MK substitution in SCC.

4.2.3 Flexural strength

The flexural strength test of all SCC mixes was carried out as per IS 516-1959 (reaffirmed 1999) [48] at different intervals of time and the results are shown in Table 6. In this study, the maximum flexural strength of 9.6 MPa was observed in M4 mix (12.5% MK) followed by a flexural strength of 9.3 MPa in M3 mix (10% MK) at 90 days with respect to control mix as shown in Figure 4 (b). The lowest flexural strength of 7.6 MPa was exhibited by control mix (M0). Similar findings were observed by Qian and Li (2001), Memduh and Sirin (2018), and Akcay et al. (2016) [61, 65, 66], who reported 15-35% enhancement in flexural strength with 20% MK substitution. A solid connection between compressive and split tensile strength has been found for all SCC blends as shown in Figure 5. The coefficient of determination (R^2 = 0.94) has been found which is very close to 1.0.



(a) Splitting Tensile Strength



(b) Flexural Strength

Fig. 4 - Splitting tensile strength (a) and flexural strength (b) of the concretes.

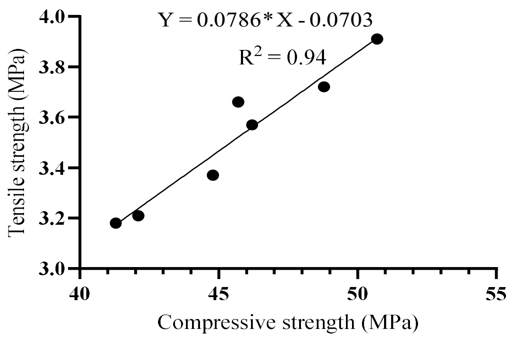


Fig. 5 - Compressive vs. splitting tensile strength.

5. Conclusion

This experimental investigation was carried out to determine the behaviour of SCC with the ternary blends of powders and incorporation of WMP as filler material. The fresh and mechanical properties of the SCC were assessed with following conclusions:

- All SCC mixes (M0 to M8) full-filled fresh property criteria detailed in the EFNARC (2002) and EFNARC (2005).

• The incorporation of MK in the SCC affected the workability but that can be taken care of by increasing the slight dosage of Poly Carboxylate Ether (PCE) based superplasticizer, use of FA as cement replacement and addition of WMP as filler material.

• The use of WMP as a non-pozzolanic filler material (partially replacement for fine aggregate) contributed positively in reducing of segregation and bleeding and its addition as a fine material in SCC has proved beneficial from economical, ecological and environmental point of view.

• Addition of MK and FA in ternary blends with cement effectively increased the hardened characteristics of SCC. The pozzolanic reaction of MK and FA blocks the pores resulting in densification in matrix, thereby increasing mechanical properties.

• The use of fly ash slightly improves hardened properties at later ages (56 and 90 days) due to its slow pozzolanic reaction.

• The utilization of MK and FA provided an excellent alternative for reduction of cement consumption, thus making the SCC an environmental friendly concrete.

Keeping in view the results of this study, it can be summarized that a compatible SCC could be produced by using ternary blends of cement, MK and FA with optimum percentage of MK at 10-12.5% and FA at 15% as cement replacements. WMP can be added as a filler material to harvest the maximum benefits of SCC.

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