International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.2., Issue.4, 2014

RESEARCH ARTICLE

ISSN: 2321-7758

BEHAVIOUR OF STEEL FIBER REINFORCED POLYMER CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY METAKAOLIN

VINAYAK VIJAPUR[1], SATISH JYANOPANTHAR[2]

[1]Assistant Professor, Civil Engineering Department, Government Engineering College, Devagiri, HAVERI, Karnataka, India

[2]P.G. Student, M. Tech. (Structural Engineering), Civil Engineering Department, Government Engineering College, Devagiri, HAVERI, Karnataka, India

Article Received: 20/08/2014 | Article Revised on: 29/08/2014 | Article Accepted on:31/08/2014

VINAYAK VIJAPUR

SATISH C.JYANOPANTHAR

ABSTRACT

The increasing demand for producing durable construction materials is the outcome of the fast polluting environment. Supplementary cementitious materials prove to be effective to meet most of the requirements of durable concrete. Metakaolin is found to be greater to other supplementary materials like silica fume and fly ash. Due to its high pozzolanic activity, both strength and durability of concrete are enriched.

Steel fibre concretes are growing concern in construction industry owing to increased fatigue resistance and long term durability aspects of concrete. It is vital to improve the brittle properties of plain concrete by increasing the ductility and toughness of the concrete. Fibre addition provides increased tensile and compressive strengths, higher toughness, high energy absorption and durability.

Research studies also showed that the addition of styrene butadiene rubber latex-modified concrete has been widely used in the field of repair work patching, resurfacing works for damaged bridge decks, because of its ease of execution, excellent adhesion to the base concrete, high freeze-thaw resistance and resistance to chloride penetration.

In this work the behavior of Steel fiber reinforced polymer concrete with partial replacement of cement by metakaolin is studied. In the experimentation, cement is replaced by metakaolin by 30% and 40% (by weight of cement), with varying addition of Styrene Butadiene Rubber Latex Polymer (SBR latex) at 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5% and 5%. Steel fibres are also used at a dosage of 1%, (by volume fraction). The strength characteristics such as Compressive strength, Tensile strength, Flexural strength, Shear strength and Impact strength are studied. Workability characteristics as measured from slump, compaction factor, flow test and Vee-Bee degree are observed. Along with this, the near surface characteristics as measured from which percentage of water absorption and soroptivity have also been studied.

KEYWORDS: Steel fiber, Polymer, Metakaolin, Partial replacement, Fibre reinforced concrete.

INTRODUCTION

In order to improve the performance and durability of concrete, the allowance of polymer was introduced in the 1920 and optimized as regards the type and amount of the employed polymers. From the mechanical point of view, polymer latexes bridge micro cracks in the latex-modified mortar and concrete under stress by the formation of polymer films, which prevents cracking propagation. Moreover, it provides a strong calcium–silicate–hydrate (CSH) aggregate bond, leading to increased tensile strength and fracture toughness. On the other hand, the sealing effect due to the polymer films also provides a considerable increase in water proofness or water tightness, resistance to moisture or air permeation, chemical resistance and freeze–thaw durability. Recent research results revealed an increase in both flexural strength and tensile bond strength by the allowance of styrene–butadiene rubber (SBR) latex. The toughness was significantly improved.

Fibres are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produced greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibres actually reduce the strength of concrete. The amount of fibres added to the concrete mix is expressed as a percentage of total volume of the composite (concrete and fibres), termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibres with a non circular cross section are used as an equivalent diameter for the calculation of aspect ratio. An increase in the aspect ratio of the fibre usually segments the flexural strength and the toughness of the matrix. However, fibres which are too long tend to create workability problems. Some recent research indicated that using fibres in concrete have limited effect on the impact resistance of the materials.

Metakaolin is produced by heat treating kaolin, a natural, finely divided, alumina siliceous mineral. Heating to 650°C - 900°C alters its structure, producing a highly reactive supplementary cementitious material (SCM) that is widely available for use in concrete construction. Because it is produced under controlled conditions, its composition (typically 50% to 55% SiO_2 and 40% to 45% Al_2O_3), white appearance, and performance are relatively consistent. Due to its high surface area and high reactivity, relatively small addition of metakaolin (typically 10% or less by weight of cement) produce relatively large increases in strength, impermeability, and durability, while its light color gives it an aesthetic advantage over other SCMs. Metakaolin's reaction rate is rapid, significantly increasing compressive strength, even at early ages, which can allow for earlier release of formwork. Metakaolin concrete tends to exhibit a creamy texture, resulting in better finishability compared to other finely divided SCMs. This quality also improves pumpability.

MATERIALS AND METHODOLOGY

MATERIALS

In this experimental work, ordinary Portland cement (OPC) 43 grade with cement content of 438 Kg /m^3 conforming to IS: 8112 – 1989 [7] was used. Natural sand confirming to IS 383-1970 of Zone II [8] and locally available crushed aggregates confirming to IS: 383-1970 [8] are used in this work and Water fit for drinking was used.

Concrete specimens with various percentages of the Styrene butadiene rubber (SBR) Latex Polymer (such as 0%, 0.5%,1% up to 5%) are used in combination with 1% of steel fibers(by volume fraction) with partial replacement of cement by metakaolin by 30% and 40% are prepared.

METHODOLOGY

A cement concrete Grade M30 with a proportion of 1:1.47:2.48 was prepared with a water cement ratio of 0.45.

The cement and metakaolin are weighed as per the calculated amount and blended uniformly, later mixed with weighed quantities of fine and coarse aggregates with required amount of water, steel fibres, SBR polymer and 0.5% -1% of super plasticizer in a batching tray. Filling each mould with concrete in 3 layers and compacting with 16 mm diameter rod with 25 blows and each each layer with vibrating. After 24 hours of filling concrete, specimens are demoulded and are kept for curing in water for 28 days.

Workability tests such as Slump cone test, Compaction factor test, Flow test and Vee-Bee Consistometer test are carried out on fresh concrete.

Near surface characteristic tests like water absorption test, soroptivity tests are also carried out on hardened concrete in this experimentation.

For compressive strength test, the cubes of size 150 mm x 150 mm x 150 mm were cast and tested under compression testing machine of 2000 kN the capacity as per IS: 516-1959 [7]. For splitting tensile strength test, the cylinders of 150 mm diameter and length 300 mm were cast and were tested under compression testing machine as per IS: 5816-1999 [10]. For the flexural strength test, beams of 100 mm x 100 mm x 500 mm size were cast and tested under flexural testing machine. Shear strength test using L shape, shear specimen as shown in the below figure were cast and tested on the compression testing machine of 2000 kN the capacity as per IS: 516-1959 [7]. Impact test on the specimen of sizes 150 mm dia. x 60 mm high cylinders were cast and tested on the impacting testing machine.

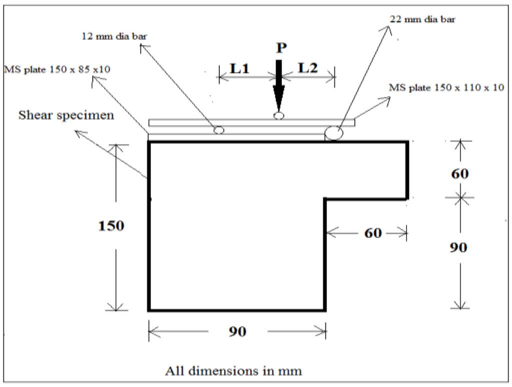


Table 1 shows the variation of slump values for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 2 shows the variation of compaction factor for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 3 shows the variation of Vee–Bee degree for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 4 shows the variation of flow for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 5 shows the variation of water absorption test results for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 6 shows the variation of soroptivity for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 7 shows the variation of compressive strength test results for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 8 shows the variation of tensile strength for different percentage variations of polymer with 30% and 40% replacement of cement by metkaolin.

Table 9 shows the variation of flexural strength for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 10 shows the variation of shear strength for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 11 shows the variation of impact strength for different percentage variation of polymer with 30% and 40% replacement of cement by metakaolin.

Table 1: Variation of slump values for 30% and 40% replacement of cement by metakaolin.

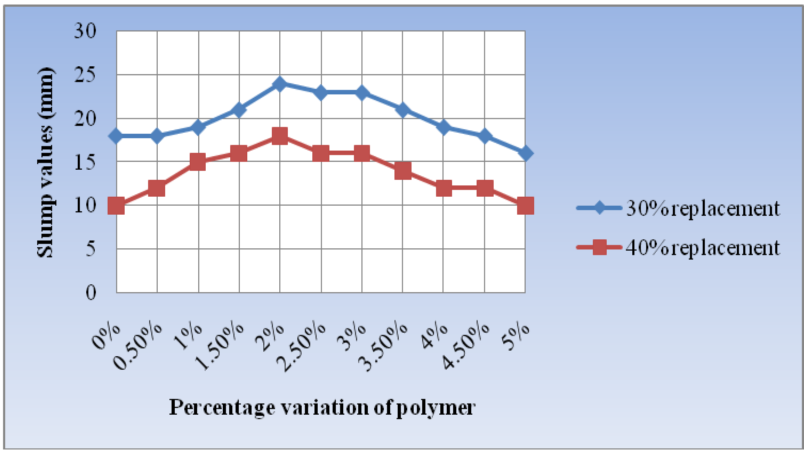


Table 2: Variation of Compaction factor values for 30% and 40% replacement of cement by metakaolin

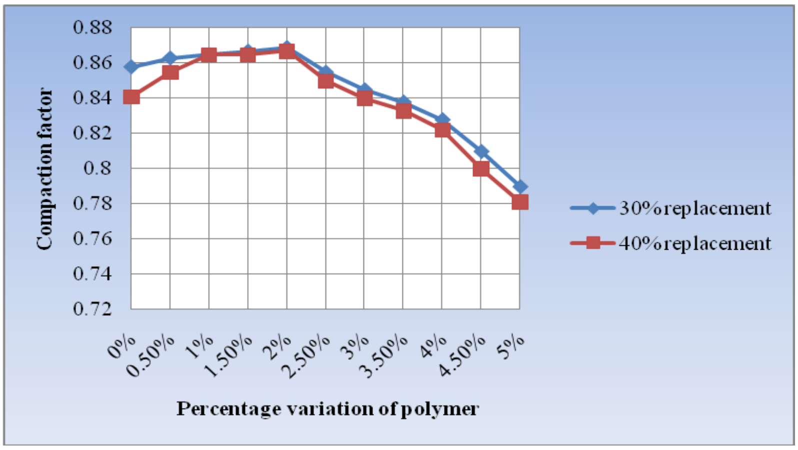


Table 3: Variation of Vee Bee values for 30% and 40% replacement of cement by metakaolin.

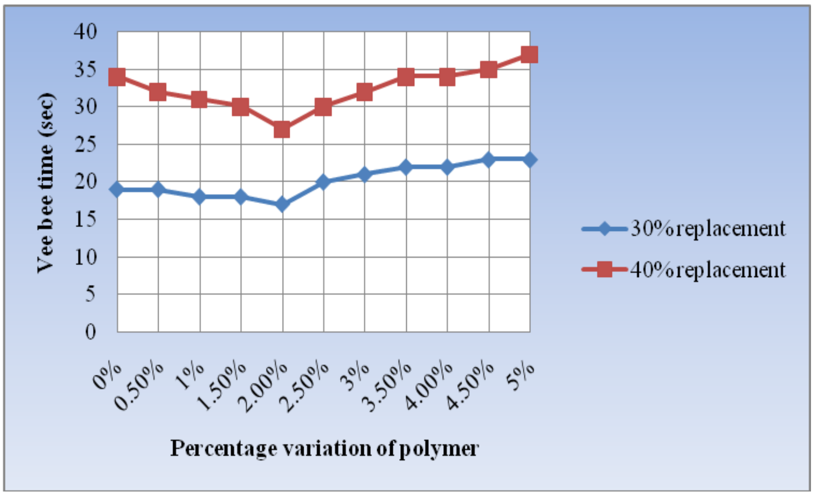


Table 4: Variation of Flow test values for 30% and 40% replacement of cement by metakaolin.

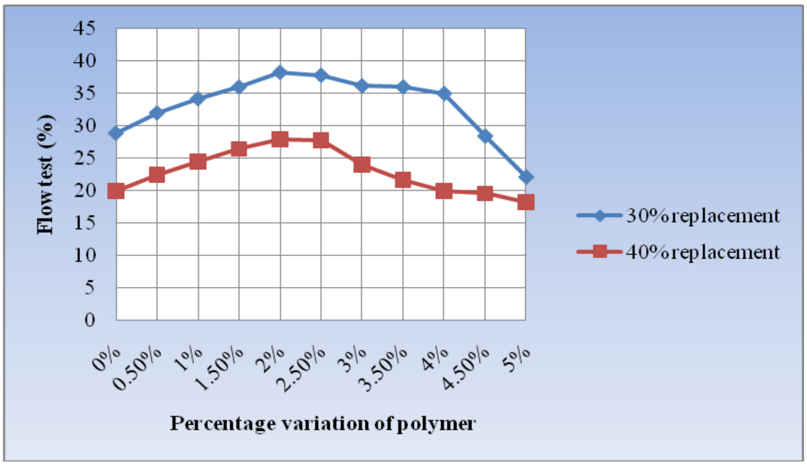


Table 5: Variation of Water absorption values for 30% and 40% replacement of cement by metakaolin.

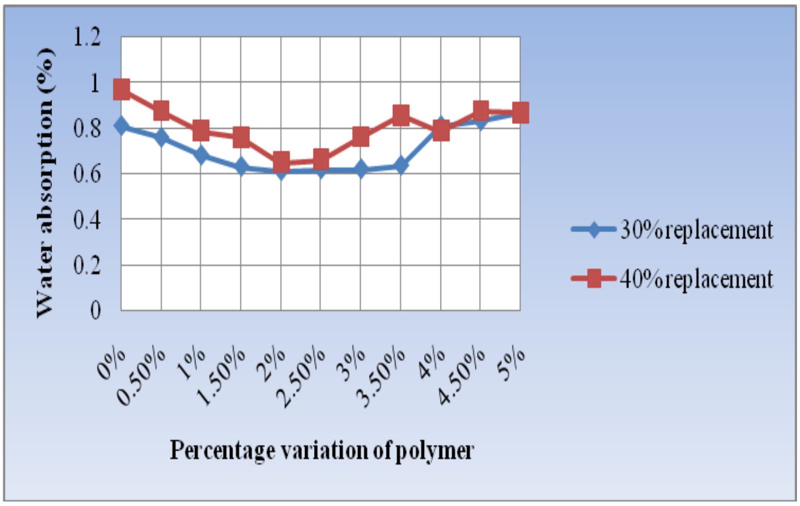


Table 6: Variation of Soroptivity values for 30% and 40% replacement of cement by metakaolin.

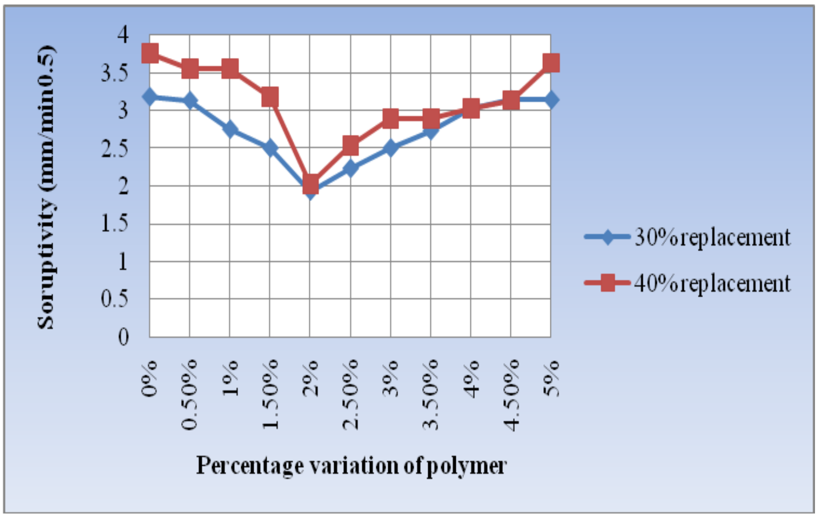


Table 7: Variation of compressive strength test results for different percentage variation the of polymer with 30% and 40% replacement of cement by metakaolin.

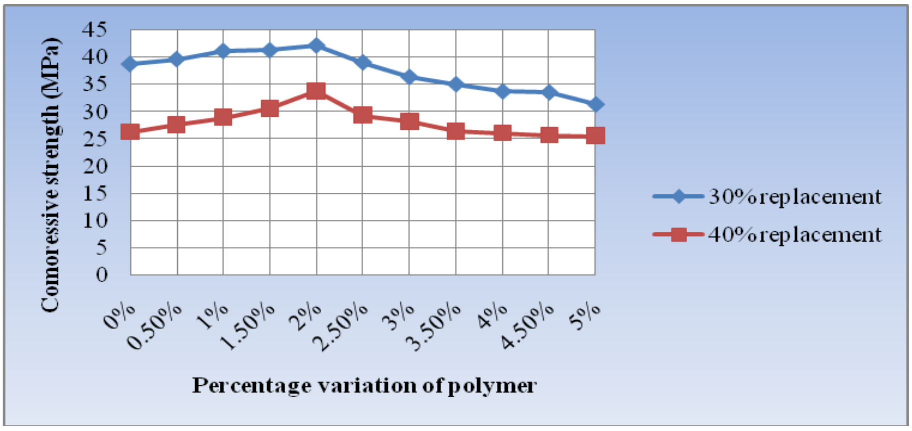


Table 8: Variation of tensile strength test results for different percentage variation of the polymer with 30% and 40% replacement of cement by metakaolin.

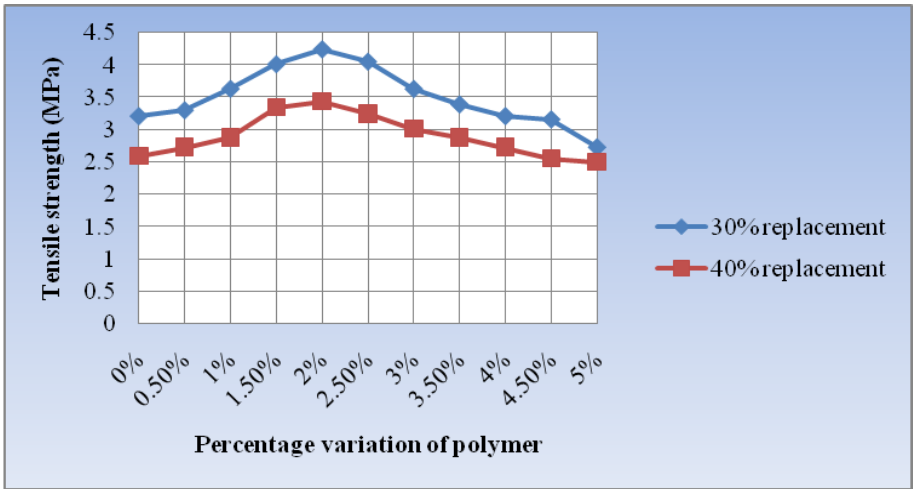


Table 9: Variation of flexural strength test results for different percentage variation of the polymer with 30% and 40% replacement of cement by metakaolin.

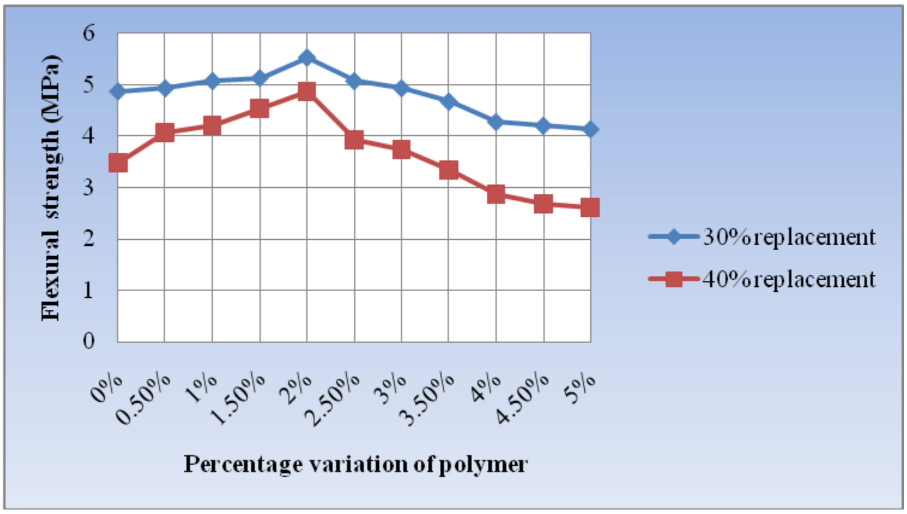


Table 10: Variation of shear strength test results for different percentage variation of the polymer with 30% and 40% replacement of cement by metakaolin.

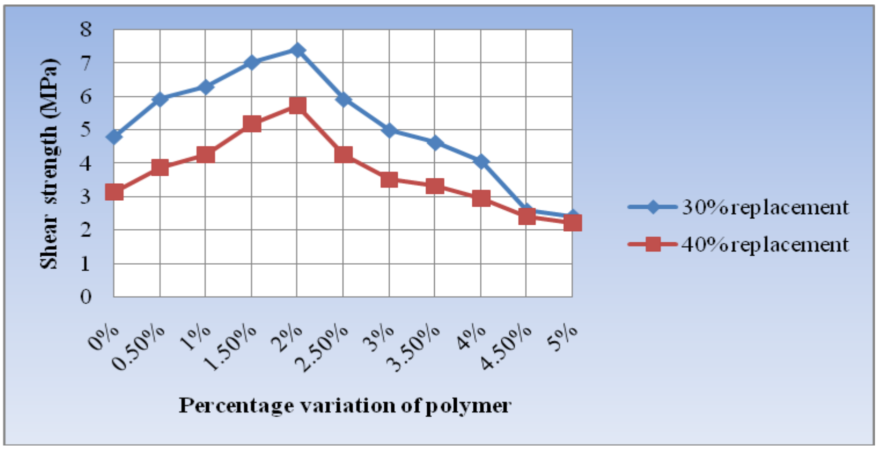
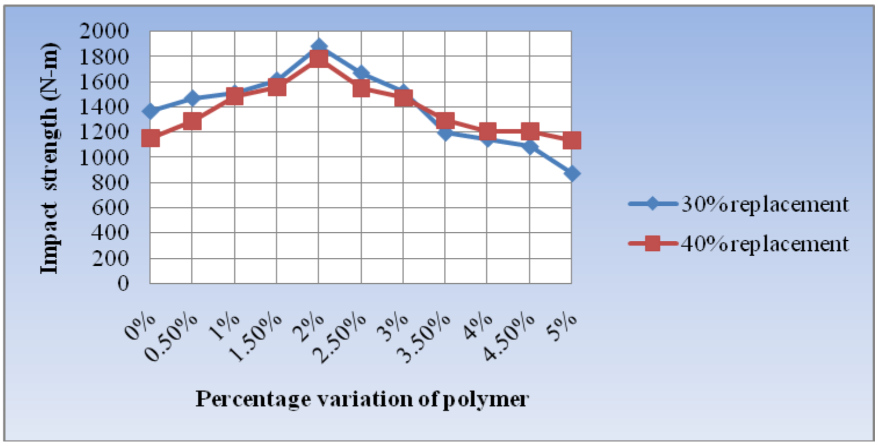


Table 11: Variation of impact strength test results for different percentage variation of the polymer with 30% and 40% replacement of cement by metakaolin.



It is observed that the workability as measured from slump, compaction factor, percentage flow and Vee-Bee degree go on increasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% addition of polymer, the workability decreases. Thus, the high workability is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher workability as compared to 40% replacement of cement by metakaolin.

It is observed that the water absorption values go on decreasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% addition of polymer, the water absorption increases. Thus, the lowest water absorption value is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows lower water absoption values as compared to 40% replacement of cement by metakaolin.

It is observed that the soroptivity values go on decreasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% addition of polymer, the soroptivity increases. Thus, the lower soroptivity value is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows lower soroptivity values as compared to 40% replacement of cement by metakaolin.

It is observed that the compressive strength goes on increasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% of polymer, the compressive strength decreases. Thus, the higher compressive strength is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher compressive strength as compared to 40% replacement of cement by metakaolin. The percentage increases in compressive strength are found to be 8.79% and 28.83% respectively for 30% and 40% replacement of cement by metakaolin.

It is observed that the tensile strength goes on increasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% of polymer, the tensile strength decreases. Thus, the higher tensile strength is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher tensile strength as compared to 40% replacement of cement by metakaolin. The percentage increases in tensile strength are found to be 32.09% and 32.82% respectively for 30% and 40% replacement of cement by metakaolin.

It is observed that the flexural strength goes on increasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% of polymer, the flexural strength decreases. Thus, the higher flexural strength is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher flexural strength as compared to 40% replacement of cement by metakaolin. The percentage increases in flexural strength are found to be 13.55% and 40.35% respectively for 30% and 40% replacement of cement by metakaolin.

It is observed that the shear strength goes on increasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% of polymer, the shear strength decreases. Thus, the higher shear strength is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher shear strength as compared to 40% replacement of cement by metakaolin. The percentage increases in shear strength are found to be 53.05% and 82.22% respectively for 30% and 40% replacement of cement by metakaolin.

It is observed that the impact strength goes on increasing as the polymer percentage increases up to 2% in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. Beyond 2% of polymer, the impact strength decreases. Thus, the higher impact strength is obtained by adding 2% polymer in steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin. This is true for both 30% and 40% cement replacement by metakaolin. Also, it is observed that the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher impact strength as compared to 40% replacement of cement by metakaolin. The percentage increases in impact strength are found to be 37.5% and 53.85% respectively for 30% and 40% replacement of cement by metakaolin.

CONCLUSIONS

The following conclusions may be drawn based on the experimentations conducted on the behavior of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin.

1. The workability of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is higher at 2% addition of polymer into it. Beyond 2% addition, the workability starts decreasing and results in segregation. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher workability as compared to 40% replacement of cement by metakaolin.

2. The water absorption of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is lower at 2% addition of polymer into it. Beyond 2% addition, the water absorption values increases. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows lower water absorption values as compared to 40% replacement of cement by metakaolin.

3. The soroptivity of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is lower at 2% addition of polymer into it. Beyond 2% addition, the soroptivity values increases. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows lower soroptivity values as compared to 40% replacement of cement by metakaolin.

4. The compressive strength of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is higher at 2% addition of polymer into it. Beyond 2% addition, the compressive strength starts decreasing. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher compressive strength, as compared to 40% replacement of cement by metakaolin.

5. The tensile strength of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is higher at 2% addition of polymer into it. Beyond 2% addition, the tensile strength starts decreasing. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher tensile strength, as compared to 40% replacement of cement by metakaolin.

6. The flexural strength of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is higher at 2% addition of polymer into it. Beyond 2% addition, the flexural strength starts decreasing. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher flexural strength, as compared to 40% replacement of cement by metakaolin.

7. The shear strength of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is higher at 2% addition of polymer into it. Beyond 2% addition, the shear strength starts decreasing. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher shear strength, as compared to 40% replacement of cement by metakaolin.

8.The impact strength of steel fibre reinforced polymer concrete with partial replacement of cement by metakaolin is higher at 2% addition of polymer into it. Beyond 2% addition, the impact strength starts decreasing. Also, the steel fibre reinforced polymer concrete with 30% replacement of cement by metakaolin shows higher impact strength, as compared to 40% replacement of cement by metakaolin.

ACKNOWLEDGEMENT

The authors would like to thank Dr. Jagadish G. Kori, Head of the Civil Engineering Department, teaching and non-teaching staff of Government Engineering College, Devagiri, Haveri for giving all the encouragement needed which kept the enthusiasm alive.

REFERENCES

[1]. Amir M. Alani and Morteza Aboutalebi (2013), "Mechanical properties of fibre reinforced concrete A comparative experimental study" World Academy of Science, Engineering and Technology pp. 208-213

[2]. Faisal Fouad Wafa, (1990), "Properties and Applications of Fiber Reinforced Concrete", JKAU: Eng.Sci., Vol.2 pp. 49-63

[3]. IS: 8112 – 1989, "43 Grade ordinary Portland cement—Specifications" (First revision), BIS, New Delhi, May 1990.
[4]. IS: 383 – 1970, "Specifications for coarse and fine aggregate from natural sources for concrete" (Second revision), BIS, New Delhi. April 1971.
[5]. IS: 516 – 1959, "Methods of tests for strength of concrete", edition 1.2, BIS, New Delhi, reaffirmed 1999.
[6]. IS: 5816 – 1999, "Splitting tensile strength of concrete – Method of test" (First revision), BIS, New Delhi, July 1999.
[7]. Khatib J.M., Negim E.M. and Gjonbalaj E. (2012) "High Volume Metakaolin as Cement Replacement in Mortar" World Journal of Chemistry 7 (1): IDOSI Publications, 07-1 ISSN 1817-3128 pp 07-10
[8]. Marinela Barbuta and Maria Harja (2008), "Properties of fibre reinforced polymer concrete"
[9]. Ramakrishna R.V.S. and Ravindra V. (2012), "Fibre reinforced polymer materials in rehabilitation of concrete structures" International Journal of Engineering Science & Advanced Technology ISSN: 2250–3676 Volume-2, Issue-2 pp.241 – 244.
[10]. Vaishali. G. Ghorpade, K.Munirathnam and H. Sudarsana Rao. (2013), "Effect of natural rubber latex on strength and workability of fibre reinforced high- performance concrete with metakaolin admixture" International Journal of Engineering Research and Applications (IJERA) Vol.3 Issue 3. pp.827-831.