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Investigation on Toughness Behaviour of High Performance Concrete using ABAQUS Software

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ABSTRACT: High performance concrete is a concrete mixture, which possesses high durability and high strength when compared to conventional concrete. This concrete contains one or more of cementitious materials such as fly ash, Metakaolin, Silica fume or ground granulated blast furnace slag, and usually a super plasticizer. Generally in High Performance Concrete, the micro steel fibres improve the durability of concrete by providing crack arresting mechanism and minimizing it's possible to cracking. Toughness enhancement is among the most important contributions of fibres to concrete. Toughness or energy absorption capacity is the area under a load deflection curve: This is especially important for structures subjected to large energy inputs such as earthquakes, blast loads, impact loads, and other dynamic loads. As the element is loaded, the fibre bridges the cracks. Such bridging action provides greater ultimate tensile strength and, more importantly larger toughness and better energy absorption, that is, it retains some degree of structural integrity and post cracking strength even when deformed to a considerable deflection. In this study, an Analytical investigation using ABAQUS software was undertaken to study the effect of micro steel fibres on the flexural toughness of high performance concrete. The tested specimens were divided into 3 groups based on content of micro steel fibres (0%, 1%, 1.5% and 2%).The results show that the flexural toughness indexes on the first crack and failure deflections were extensively enhanced by the addition of fibres. The improvement in post-cracking toughness could be due to the crack arresting effect of micro steel fibres because it continued to exhibit residual strength after the first crack creation.

KEYWORDS: High performance concrete, Durability, Fibre, Metakaolin, Finite element analysis

I. INTRODUCTION

Concrete is the most extensively used material for the construction of large infrastructural facilities. Although the compressive strength of concrete has been historically increasing, the commercial potential of high strength concrete became evident for the columns of high rise buildings in the 1970's in the United States. To improve the performance of concrete, numerous new technologies and products such as high strength concrete containing super plasticizer, fibre reinforced concrete, latex modified concrete, chemically bonded ceramics, macro-defect free cement products and epoxy coated reinforcing steel have been developed [1]. High performance concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete [2]. This concrete contains one or more of cementitious materials such as fly ash, Silica fume or ground granulated blast furnace slag and usually a super plasticizer. The term 'high performance' is somewhat pretentious because the essential feature of thisparticularly appropriate properties for the expected use of the structure such as high strength and low permeability. The use of some mineral and chemical admixtures like Silica fume and Super plasticizer enhance the strength, durability and workability qualities to a very high extent. Besides strength, there are other equally important criteria such as durability, workability and toughness [6].

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Effect of Metakaolin on strength of concrete: The compressive strength and flexural strength of concrete was increased with increase in replacement levels of metakaolin[4]. The micro steel fibres content by volume fractions considerably enhanced the mechanical properties of concrete in terms of compressive strength, splitting tensile strength and flexural strength. Also, the tested results show that the flexural toughness indexes and post-cracking toughness especially on the first crack and failure deflections were extensively enhanced by the addition of fibres. The improvement in post-cracking toughness could be due to the crack arresting effect of steel synthetic fibres because it continued to exhibit residual strength after the first crack creation and needed higher energy for the fibre pull out[11].The Influence of high-reactivity metakaolin and silica fume on the flexural toughness of high performance steel fibre-reinforced concrete was studied. Energy absorption or toughness of high- performance steel fibre-reinforced concrete increases with the introduction of high- reactivity metakaolin into the mix and also HRM is particularly effective in improving the post-peak energy absorption capacity of concrete with fibres, and unlike silica fume, no particular post-peak brittleness is seen to occur[3]. The compressive strength of concrete increases with increase in HRM content up to 7.5%. Thereafter there is slight decline in strength for 10%, 12% and 15% due excess amount of HRM which reduces the w/b ratio and delay pozzolanic activity. AvailableHRM reacts with calcium hydroxide which accelerates hydration of cement and forms C-S-H gel [8].

Steelfibresalters compressive strength, split tensile strength and flexural strength for a fibre volume of 2% at 28 days age. The experimental investigations show that it minimizes the tensile cracks and prevents the ingress of harmful chemical responsible for corrosion[10].the improvements in the fracture toughness of cement-based materials reinforced with a high volume fraction of carbon, steel and polypropylene micro-fibres. Tests on notched and un-notched beams were conducted which led not only to the engineering properties but also to Crack Growth Resistance Curves and Crack Opening Resistance Curves plotted in terms of the stress intensity factor, K at the crack tip. These K,-curves, indicate the exceptionally high fracture toughness of carbon fiber reinforced composites over the other composites and provide a valuable insight into the toughening mechanisms that exist in these composites [9].

Poisson's ratio, n, was found to be around n 5 0.13 for mature drying HPC with quartzite. Poisson's ratio, n, of a sealed mature HPC with quartzite was found to be about 0.14. Poisson's ratio, n, was found to be around n 5 0.16 for mature HPC with granite. Poisson's ratio, n, of young HPC exhibited low significance related to the maturity of HPC [12].

II. MATERIAL PROPERTIES

CEMENT

Cement is the most important ingredient in concrete. One of the important criteria for the selection of cement is its ability to produce improved microstructure in concrete. Cement of OPC of 53 Grade available in the market is used in this Investigation. The Cement is tested for various properties as per IS: 4031-1988 and found to be confirming to various specifications of IS: 12269-1987. The physical properties of cement are given below Table 1.

Table 1 Physical properties of cement of OPC of 53 Grade

Sl.No	Description	Values
1	Specific Gravity	3.15
2	Standard consistency	32%
3	Grade of cement	53
4	Setting time	
	(i) Initial setting time	70 mins
	(ii) Final setting time	290 mins

MANUFACTURED SAND

Manufactured sand is widely used around the world and technicians of major projects around the world insist on the compulsory use of manufactured sand because of its consistent gradation and zero impurity [5]. The term manufactured sand is used for aggregate materials less than 4.75 mm. By conducting sieve analysis, it is found that sand confirms to grading zone Il as per table 4 of IS 383-1970. The physical properties and sieve analysis for fine aggregate is given below Table 2.

Table 2 Physical Properties of aggregates

Sl.No	Description	Fine aggregate	Coarse aggregate
1	Specific Gravity	2.56	2.72
2	Water absorption	2.36%	1.80%
3	Bulk density	1860 kg/m^3	1633.8 kg/m^3
4	Fineness modulus	3.10	6.3

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COARSE AGGREGATE

The maximum size of coarse aggregate is generally limited to 20mm. Aggregate of size 10 to 12mm is desirable for structures having congested reinforcement. Well graded cubical or rounded aggregates are desirable. Aggregate should be having uniform quality with respect to shape and grading. Figure 3.2 shows the grading curve of coarse aggregate. The physical properties and sieve analysis for coarse aggregate are given in Table 2

SUPERPLASTICIZER

In present study, effectiveness of Sika Viscocrete (Super plasticizer) in improving the strength of concrete and workability at different dosages (1%, 1.2% & 1.5%) is studied. In low quantities super plasticizer have no bad impact on the properties of hardenedconcrete (up to 3%).

METAKAOLIN

Metakaolinis produced by heat treating Kaolin as one of the most abundant natural minerals to a temperature of 6000-8000° C. Kaolin is a fine white clay mineral that has been traditionally used. Metakaolin is produced under carefully controlled conditions and hence its composition, white appearance and performance are relatively consistent. It reacts rapidly with the calcium hydroxide in the cement paste, converting it into stable cementitious compounds thus refining the microstructure of concrete thereby reducing its permeation properties. Due to its high surface area and high reactivity, relatively small addition rates of metakaolin produce relatively large increase in strength, impermeability and durability while its light colour gives it an aesthetic advantage. The physical and chemical properties of metakaolin are given below Table 2.5

ALCCOFINE

It is a complementary cementitious material that adequately replaces the Silica fume used in high performance concrete and Alccofine 1203 is a micro fine based product of cement used for injection Grout in underground tunnels and soil stabilization. It has distinct characteristics to enhance 'performance of concrete' in fresh and hardened stages. It can be considered and used as practical substitute for Silica Fume as per the results obtained.

Table 3Physical parameters of alccofine 1203

Specific Gravity	Bulk density	Practical size distribution (p)		
2.9	600-700	D10	D50	D90
		1-2	4-5	8-9

MICRO STEEL FIBRES

Steel fibres were used with a volume fraction of 0.5% with aspect ratio 100 is used in the mixes. Length-13 mmand Diameter - 0.16 mm

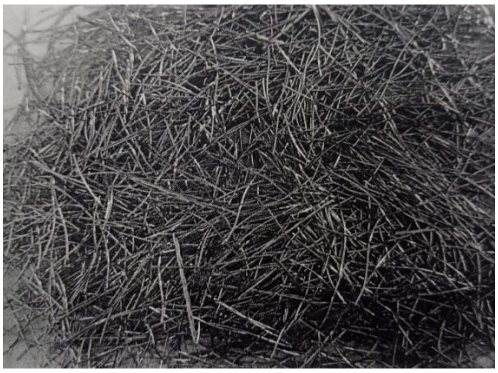

Figure 1 Brass coated micro steel fibres

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III. EXPERIMENTAL WORKS

Cubesand prisms were cast with varying percentages of alccofine and metakaolin.
Grade of Concrete = M60,Mix ratio: 1:1.32:2.227,w/c = 0.289,SP. percentage: 1.5,Cement = 512.89 kg/m³
FA = 680 kg/m³,CA=1142.4 kg/m³,Cement 512.89 kg/m, Water 142.30 kg/m³,micro steel fibres with 0%, 1%, 1.5% and 2%

Table 4 Trials for M60

Trials	Cement(%)	Metakaolin%	Alccofine(%)
T1	70	20	10
T2	70	10	20
T3	80	10	10
T4	70	15	15

These prisms were tested by four point loading systems. The load and displacement values are obtained from the test results. For the corresponding values graph is plotted between load and deflection. The area under the load deflection curve gives the toughness values. Cubes are tested in CTM and compressive strength values are obtained.

IV. FINITE ELEMENT ANALYSIS

The Finite Element Method (FEM) is a numerical analysis for obtaining approximate solutions to a wide variety of engineering problems. The finite element method is now accepted as the most powerful general technique for the numerical solution of a variety of engineering problems. The finite element program of ABAQUS 6.14-1 version is used to develop the finite element model of a 2 point loading system.To carry out Finite Element Analysis, meshing of the section plays a major role in getting accurate results. The whole assembly was meshed together using MESH module.Non-linear analysis of concrete sections was carried out using STATIC RIKS step in the STEP module.One end of prism was hinged at the base (U1=0; U2=0; U3=0), Other end of the prism was given roller support at the base (U1=0; U2=0:U3≠0)

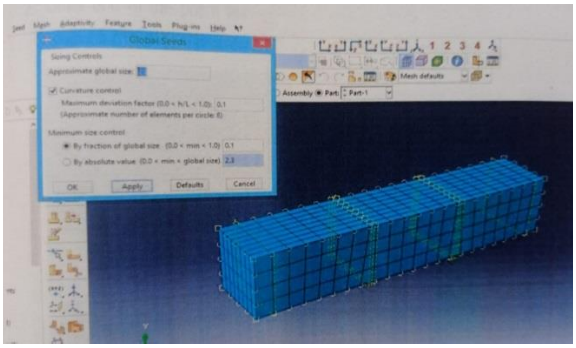

Fig. 2 Meshing of prism

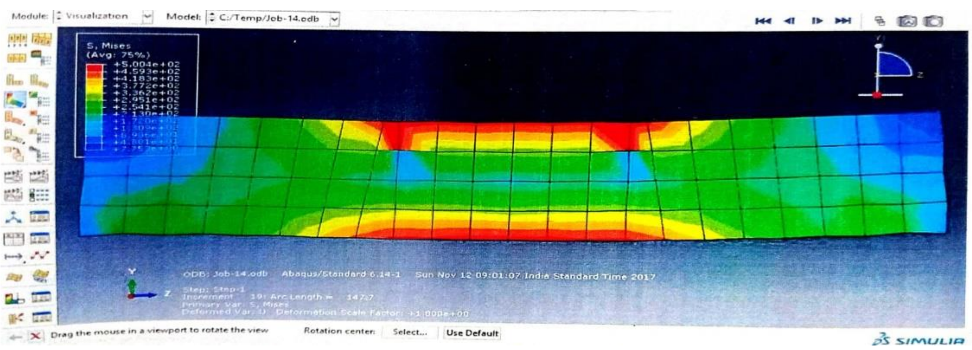

Figure 3 Stress contour of prism

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V. RESULTS AND DISCUSSION

Prism sections were geometrically created and properties were assigned to the sections. A two point loading system and simply supported end conditions were also modelled in the ABAQUS software. The longitudinally stiffened sections were placed on the supports and two point loading system was applied from L/3 distance from each end. From the results it is evident that the micro steel fibres considerably enhanced the flexural toughness indexes and post- cracking toughness especially on the first crack. Failure deflections were extensively enhanced by the addition of fibres.The toughness or energy absorption is defined as the area under the load- deflection curve up to a specific deflection levels and was calculated.Toughness index is the ratio of the area under load deflection curve up to limited deflection value, to the area up to the deflection established at first crack. Residual strength factor represents the amount of strength retained at the post cracking stage within a specific intervals as a percentage of the first crack strength. It is a measure to sustainability of prisms within a specific loading stage. The general formula for estimating the residual strength factor between two indices R1,2 100*(I_2 - I_1)

Table 5 Toughness index & Residual strength

Fibre volume fraction%	**0**	**1**	**1.5**	**2**
Peak load kN	22	25	33	35
Deflection mm	0.55	0.8	1	0.8
Stiffness kN/mm	40	31.25	33	43.75

VI. CONCLUSIONS

Based on the analytical results the following conclusion can be drawn: The micro steel fibres content volume fractions considerably enhanced the flexural toughness indexes and post-cracking toughness especially on the first crack. Failure deflections were extensively enhanced by the addition of fibres. The improvement in post cracking toughness could be due to the crack arresting effect of micro steel fibres because it continued to exhibit residual strength after the first crack creation and needed higher energy for the fibre pull out.Values of toughness indices, residual strength factors, and first-crack strength may be used for comparing the performance of various fibre-reinforced concretes during the mixture proportioning process or in research and development work. They may also be used to monitor concrete quality, to verify compliance with construction specifications, or to evaluate the quality of concrete already in service.

REFERENCES

[1] AM Neville& J.J. Brooks, "Concrete Technology" International Student edition 1999, ISBN 981-35-840-, Addison Wesley Longman Ltd.

[2] AM Neville, Properties of concrete" fourth and final edition 1996, ISBN 981-4053-56-2, Education Asia Pvt Ltd.

[3] T. Shanmugapriya, R. N. Uma, "Optimization Of Partial Replacement Of M-Sand By Natural Sand In High Performance Concrete With Silica Fume", International Journal of Engineering Sciences & Emerging Technologies, June 2012. ISSN: 2231-6604

[4] B. B. Patil, P. D. Kumbhar, "Strength and Durability Properties of High Performance Concrete incorporating High Reactivity Metakaolin", International Journal of Modern Engineering Research (IJMER).

[5] Dr.S.Elavenil, B. Vijaya, "Manufactured Sand, A Solution And An Alternative To River Sand And In Concrete Manufacturing" DR. M.G.R.Educational& Research Institute University,Chennai, India

[6] Ms. Shetty, Concrete Technology" fourth edition, ISBN 81-219-0348-3. S CHAND & Company Ltd.

[7] BIS 456 2000 Plain and reinforced concrete code of practice" Fourth revision, BIS, New Delhi.

[8] Rixon.M.R., Chemical admixtures for concrete" edition 1996 E & F.N. Span Ltd.

[9] N. Banthia& J. Shengb, "Fracture Toughness of Micro-Fiber Reinforced Cement Composites", Graduate Student, Department of Civil Engineering. Lava1 University, Ste-Foy, Quebec, GIK 7P4, Canada.

[10] P Muthupriya", Dr.K.Subramanian", Dr.B.G.Vishnuram"Investigation On Behaviour Of Highperformance Reinforced Concrete Columns With Metakaolin And Fly Ash As Admixture"

[11] Rajai Z. Al-Rousan"Flexural Toughness Characteristics of Steel Synthetic Fibers-Concrete" e-ISSN: 0975-4024, / International Journal of Engineering and Technology (IJET)

[12] WojciechPiasta, Jacek GóraWaldemarBudzyn"Stress-strain relationships and modulus of elasticity of rocks and of ordinary and high performance concretes", Construction and Building Materials 153 (2017) 728-739.