Size Effect on Shear Behavior of Reactive Powder Concrete Containing Steel Fibres and Silica Fume

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ABSTRACT: *To focus on a structural performance in response to intense shear loading, a series of direct shear specimens random oriented fibres in shear failure plane were tested using optimized composition of RPC A simple shear strength test setup is proposed which is found to provide reliable and consistent results. The experimental results show that RPC exhibits ductile failure mode, higher ultimate strength and slip capacity in addition to much improved structural integrity. This enhancement of performance, however, reduces with decrease in size of Specimen.*

Key Words*:* *RPC, Strain hardening, Ductility, Slip capacity.*

I. INTRODUCTION

Shear failure is generally brittle in concrete structures. Examples of concrete structural failure related to shear loading are bridge deck punching shear, corbel failure, anchor bolt pull out and segmental bridge shear key failure a motivation of the work presented here is to modify the brittle failure mode by taking advantage of unique material behavior of RPC. It is a fiber reinforced cement based material with designed microstructure such that composite undergoes pseudo strain hardening instead of softening when first crack strain is exceeded. As a result, RPC is characterized by ultimate tensile strain and fracture energies which can be higher than conventional cementitious materials. The present study is primarily concerned with the translation of pseudo strain hardening properties of RPC from material level to structural level.

A number of researchers have reported about the use of fibers as a replacement for shear reinforcement to enhance shear capacity of concrete beams in order to ensure a ductile final failure in flexure in RCC beams [3]. They emphasized testing of conventional reinforced beams to study the effect of shear span to effective depth ratio, fiber type, volume fraction and aspect ratio and the longitudinal steel content on shear capacity. But experience shows that two planes failing simultaneously in double shear for beam specimens never happens in reality and hence shear strength calculated in this manner could be erroneous. On the other hand, an attempt to get one failure plane in shear in beam and column specimen directly under compression testing machine invites undue eccentricity since one portion of the specimen needs to be held fixed with respect to the other part. Hence, there exists no standard, reliable and simple method to get direct shear strength. Sliding of one layer over the other layer with slip at common surface of contact gives realistic picture of direct shear. An attempt is made in the present paper to get direct shear strength of RPC material using a simplified and reliable test setup, both in conventional UTM under load control with large size specimen giving 2D effect of fiber orientation and MTS machine under displacement control with smaller size specimen giving 1D effect of randomly oriented fibres in shear failure plane.

Reactive Powder Concrete has higher durability, higher fatigue, and impact and abrasion resistances. With these unique properties, there is a potential for substantial reductions in cross-section dimensions reducing the weight of members which directly impact on substructure and erection cost. Further, for RPC beams without conventional shear reinforcement lower manpower and supervision cost are also a consideration when considering total long term costs. In term of structure performance, the inclusion of discrete fibers into the concrete matrix can arrest cracks and thereby control crack propagation.

II. MATERIAL COMPOSITION

TABLE: 1.0 OPTIMIZED COMPOSITION OF RPC

Mixture		RPC_1	RPC_2	$RPCF_3$	$RPCF_4$
Cement		1	1	1	1
Silica Fume		0.32	0.32	0.32	0.32
Quartz Sand		--	0.36	--	0.36
Sand	150 – 600µm	1.50	1.50	1.50	1.50
Super Plasticizer		0.035	0.032	0.032	0.032
Steel Fibers		--	--	0.20	0.20
Water/Cement		0.20	0.22	0.22	0.23
Compressive Strength (7-days) N/mm^2		**96**	**118**	**103**	**138**
Compressive Strength (28-days) N/mm^2		**106**	**129**	**114**	**151**
Flexural Strength (N/mm^2)		**13.5**	**19.0**	**17.5**	**29**

RPC_1 = RPC without Steel Fibers at normal Curing
RPC_2 = RPC with Steel Fibers at hot water Curing
$RPCF_1$ = RPC with Steel Fibers at normal Curing
$RPCF_2$ = RPC with Steel Fibers at hot water Curing

III. LITERATURE REVIEW

Bairagi and Modhera **[11, 12]** checked the feasibility and reliability of the test method proposed by them with the test method suggested by JSCE method. Results obtained by their proposed method were 10% higher than that of JSCE method. They concluded that by comparing the procedure of test methods and fabrication of test assemblies as well as the test specimen, their proposed method is simpler to handle compared to JSCE method.

During the performance of the test using the arrangement as suggested by Bairagi and Modhera, it was seen that the roller penetrates down in the specimen, not giving the correct picture of the failure. Also the results reported by them were on higher side compared to that of JSCE method in case of fiber reinforced concrete samples.

IV. SPECIMEN AND TEST SET-UP

In the present study the influence of steel fiber variation on Shear strength of RPC have been studied. Different size of L-shape moulds are used for the preparation of samples. Three different percentage of steel fiber (i.e. 0.0, 1.0, 2.0 & 3.0%) added in the RPC mixture and compare the shear strength of RPC. The variations in the shear strength gained from the different steel fiber variation are tabulated in the table.

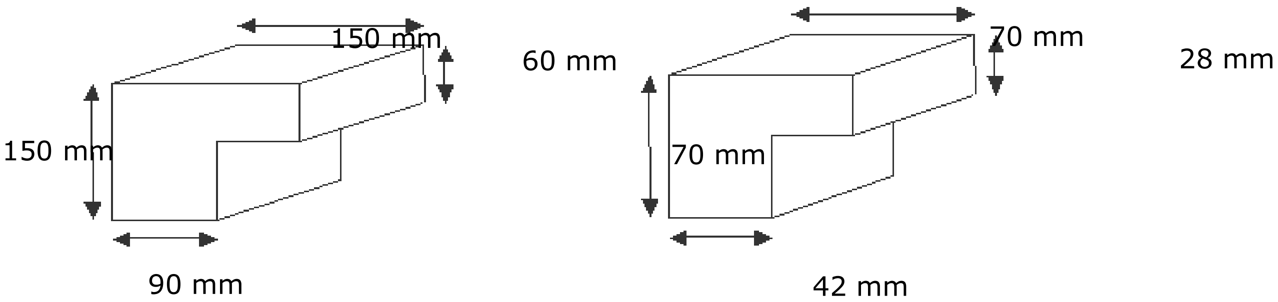

FIG.1.0: TWO TYPES OF L-SHAPED SPECIMENS

FIG.2.0: SHEAR TEST SET UP ON MTS

V. RESULTS AND DISCUSSION

Experimental results presented shows that the ultimate single shear strength for RPC with inclusion of fibers increases considerably with reference to plain RPC. With addition of fiber the specimens do not fail suddenly and the failure load is more than the first crack load. The quantity of fibers used in plain RPC do not significantly affect the first cracking load but a significantly influence on the rate of crack propagation and on the failure load. Typical shear strength variation with respect to fiber volume fraction and shear plane variations has been plotted in **FIG 3.0 & FIG 4.0.** It can be noted that the maximum increase in shear strength is found for 2% fiber volume fraction than 0%, 1%, 3% fiber volume.

For L shape shear specimen we had observed that shear strength increase for shear plane width 23mm than 28, 33, 37mm in 2% fiber volume in **FIG 4.0** and shear plane 28, 33, 37mm of 2% fiber volume shear strength increase in compare shear plane 28, 33, 37mm of 0%, 1%, 3% fiber volume.

By referring **fig.5 to fig.8** it is observed that the area below the curve is increases we increases fibre content as well as post peak performance is also enhanced to a large extant.

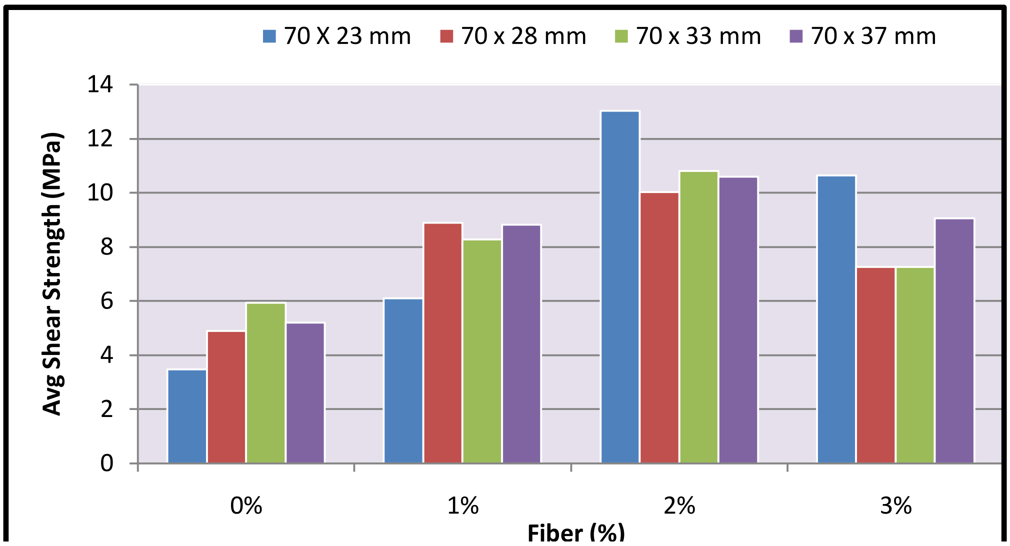

FIG.3.0: SHEAR STRENGTH OF RPC WITH STEEL FIBRE VARIATION

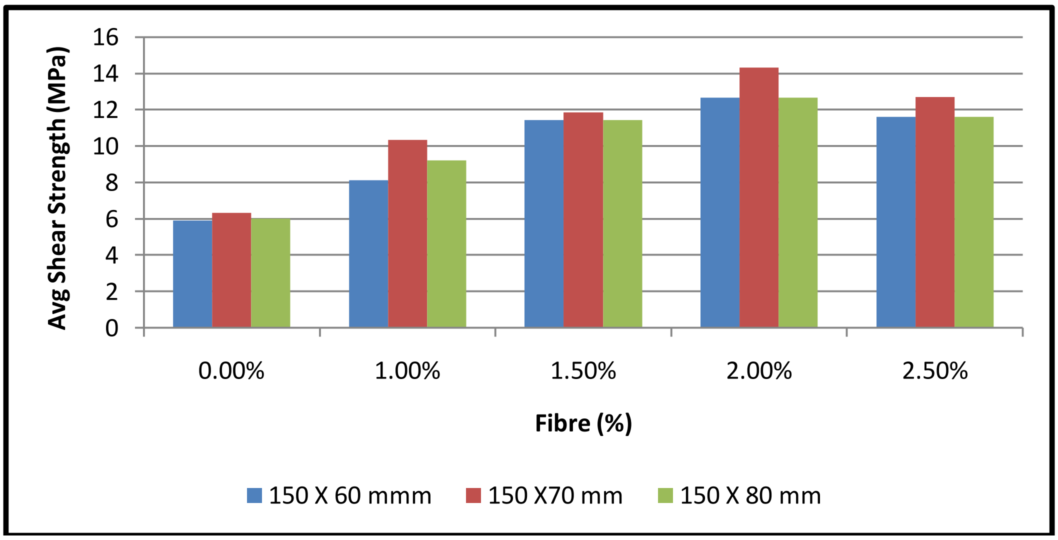

FIG: 4.0 SHEAR STRENGTH OF RPC WITH STEEL FIBRE VARIATIONS.

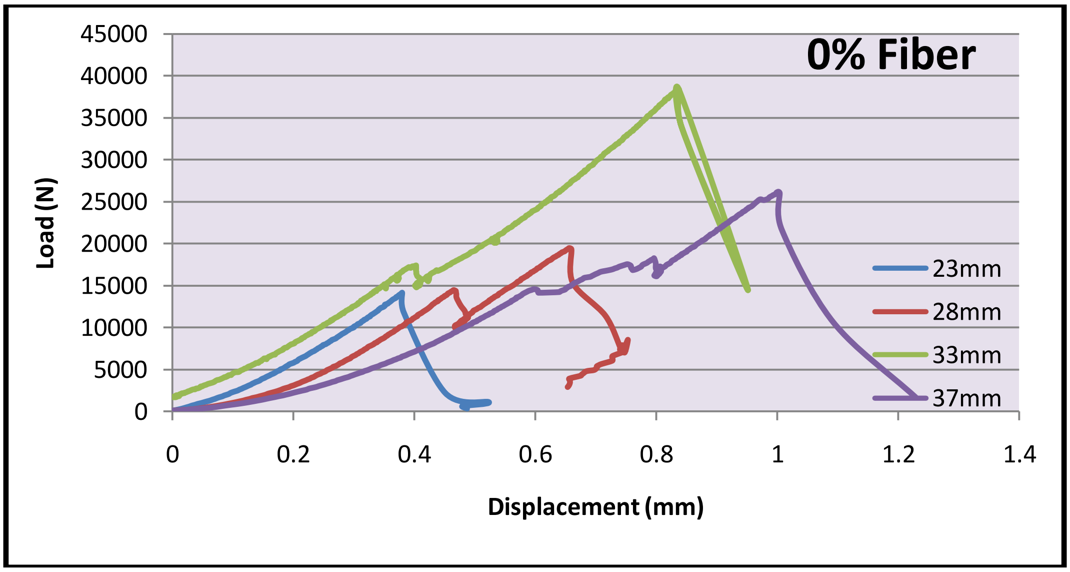

FIG.5.0: EFFECT OF 0.0% STEEL FIBER IN DIFFERENT SHEAR DEPTH

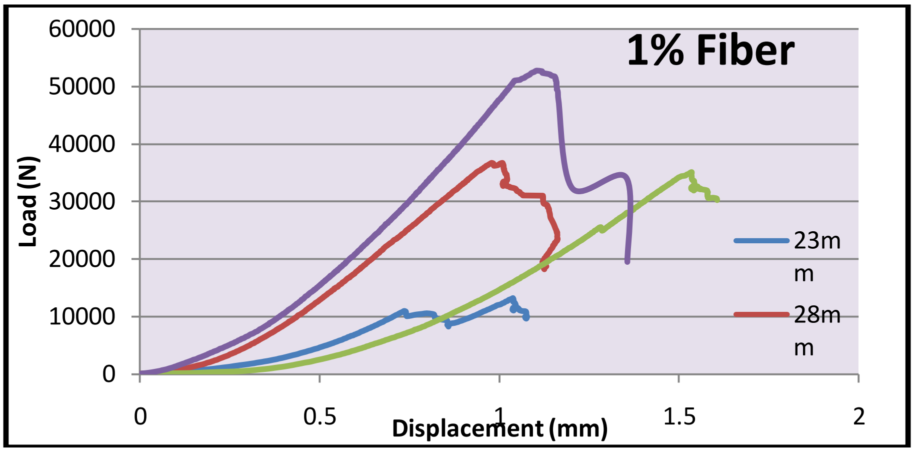

FIG.6.0: EFFECT OF 1.0% STEEL FIBER IN DIFFERENT SHEAR DEPTH

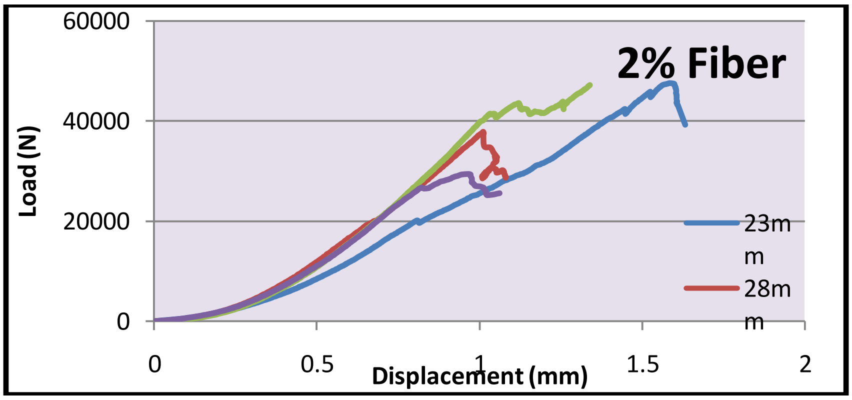

FIG.7.0: EFFECT OF 2.0% STEEL FIBER IN DIFFERENT SHEAR DEPTH

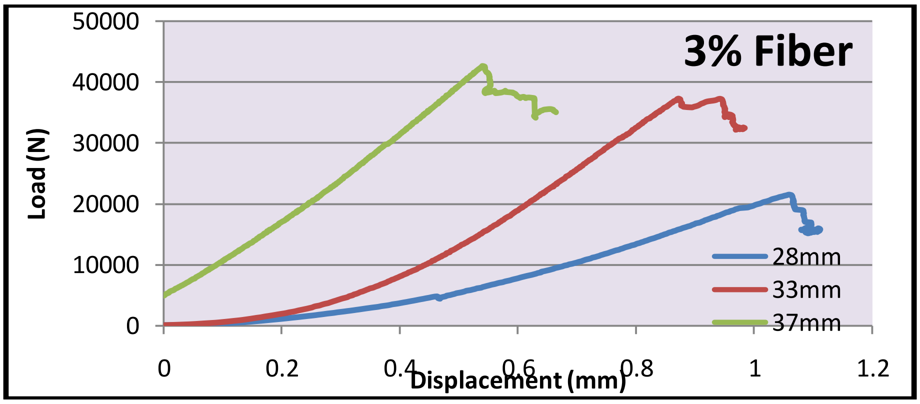

FIG.8.0: EFFECT OF 3.0% STEEL FIBER IN DIFFERENT SHEAR DEPTH

VI. CONCLUSIONS

- The proposed direct shear test is not only simple but also most suitable for the RPC composite. It indicates more realistic and efficient sliding mechanism in shear. Steel tends to enhance the shear strength much better than orientation effect could be closely seen as the shear strength of the smaller specimen and bigger specimens for all the matrices, deformation characteristics in shear could be evaluated better by testing the specimens in displacement control instead of load control.
- Maximum shear strength obtained in SF-RPC is quite high then ordinary concrete However, results of SF-RPC are much scattered as most of the specimens failed by fracture control after a formation of first crack, steel fibres being very strong and stiff in shear make it possible to resist large amount of load if fibres are available in the resisting plane.
- Due to presence of fibres ductile failure is observed .In fact crack get arrested by fibres does not get fractured but pulling out of fibres from matrix is observed.
- Experimental results shows that higher the thickness of shearing plane higher the value of shearing strength. However, optimum value results can be obtained at 60 to 75 mm depth.

- RPC specimens achieved much higher load carrying capacity and slip capacity in shear and were gradually damaged by ductile yielding. This phenomenon is due to ductile nature of RPC material and results of which confirms switching of failure mode from brittle concrete fracture to ductile yielding of RPC material with improved structural integrity. Such advantageous translation of structural shear response can effectively improve seismic resistance of building frames

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