ATLANTIS PRESS
Advances in Computer Science Research (ACSR), volume 73
7th International Conference on Education, Management, Information and Computer Science (ICEMC 2017)

Finite Element Analysis of Enhanced RAC Beam with Hybrid Fibers under Shearing

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Keywords: Hybrid Fibers; RAC beam; Shear in inclined section; ABAQUS

Abstract. This paper had studied the basic properties of an ordinary concrete beam and a RAC beam with 50% replacement ratio and a EC-RAC beam which contains 0.3% hybrid fiber respectively by 3 groups of 15 standard specimens, and three simply supported beams under shearing without web reinforcement was stimulated by finite element analysis software ABAQUS to compare the deflection, stirrup strain curves and ultimate shear capacity index correspondingly. The analysis shows that beam ultimate shear capacity is closer to test results, at the same time, with the influences of 50% replacement ratio and hybrid fibers, the mechanical properties of beams were worse than ordinary concrete beam in the plastic state, which cracks concrete ahead of time in inclined section and shears stirrup earlier and provides less effect to beams without web reinforcement in inclined section under shearing.

Introduction

The waste concrete has become an important part of construction wastes that can't be ignored under the increasing building wastes. So, recycling the waste concrete will save natural coarse aggregate like sand in concrete structure and reduce the exploitation of the original ecological sand and improve the ecological environment effectively, to some extent, it has great meanings to sustainable development in Chinese economy[1-2]. Now, scholars at home and abroad study mainly on recycled concrete (RAC) materials and influences to recycled concrete components by different coarse aggregate replacement ratios, however, few of them work on mechanical property to Enhanced Capabilities-Recycled Aggregate Concrete (EC-RAC) with different hybrid fibers [3-4]. This paper has made an enhanced RAC beam with 0.3% hybrid fibers which is mixed of three branches of anti ageing polypropylene fiber and modified polypropylene TANK fiber on the basis of an ordinary concrete beam, and fitted the constitutive equation of concrete by test .Also, the ordinary concrete beam , an RAC beam with 50% replacement ratio and an enhanced RAC beam with 0.3% hybrid fibers was stimulated and analyzed by finite element analysis software ABAQUS in inclined section under shearing , in order to study mechanical property of enhanced RAC beam with 0.3% hybrid fibers preliminary under shearing ,which providing some theoretical basis for projects and practical application.

Determination Materials of Test. This test has chosen Qinling Mountains brand 32.5 R-rated Portland cement, the natural sand and poly carboxylic Super-plasticizer. The continuously graded particle size of natural gravel coarse aggregate in ordinary concrete is from 5-31.5mm, the RAC coarse aggregates choose waste concrete blocks which are removed from a frame structure that has been in service for 15 years by screening artificially. And in addition, three branches of anti ageing polypropylene fiber and modified polypropylene TANK fiber are added to concrete, which are mixed with 3:7through material experiments. The material properties of two fibers is shown in Table 1.

Table 1 Material Properties of Two Fibers

Physical properties of materials	Types of fiber	
	Three branches of anti ageing polypropylene fiber	Modified polypropylene TANK fiber
Density [kg/cm3]	0.91	1.18
Tensile strength [MPa]	>350	472.3
Elastic modulus [MPa]	>4000	4804.6
Length [mm]	50	19
Elongation at break [%]	10-30	23.2
Anti-alkali strength [%]	≧40	≧50
Melting point [℃]	160	167
Anti-solarization strength [%]	≧50	≧50

According to the norms of 《Standard Test Method for Mechanical Properties of Ordinary Concrete》[5]（GBT50081-2002）,the test piece of cube and prism were made and compressive mechanical property index of concrete is shown in Table 2. At the same time, mechanical properties of steels were tested by universal testing machine, which is shown in Table 3.

Table 2 Compressive Mechanical Property Index of Concrete

NO.	Compressive Strength of Cube[MPa]	Compressive Strength of Prism[MPa]	Elastic modulus[MPa]
B-1	34.7	31.4	4.09×10^4
B-2	33.2	30.9	3.24×10^4
B-3	34.7	20.9	3.71×10^4

Table 3 Mechanical Property Index of Steel

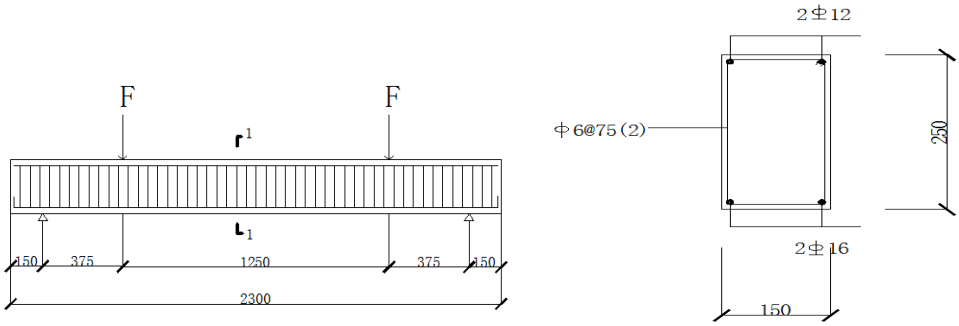
Reinforcement diameter [mm]	Yield strength [MPa]	Limit strength [MPa]	Elastic Module [MPa]
6	454	518	2.12×10^5
12	345	538	2.11×10^5
16	415	625	2.04×10^5

Model Design of Beams in Inclined Section under Shearing

In order to control the external variables, three beams were made and also shear span ratio and longitudinal reinforcement ratio are fixed to study the mechanical property influence to beams in inclined section under shearing through replacement ratio and hybrid fibers. The length of beam is 2300mm and cross section is 150mm ×250mm.Thickness of concrete cover designs 25mm, shear stirrups with Φ6@75 are designed along the lengthwise direction of the longitudinal reinforcement. At the same time ,two supports and load points are set150mm, 425mm away from the left and right of beam, experimental conditions of beam under shearing and size and reinforcement of beam in inclined under shearing are shown in Table 4 , Fig.1.

Table 4 Experimental Conditions of Beam Under Shearing

NO.	Longitudinal Reinforcement Ratio[%]	Shear Span Ratio	Replacement Ratio R [%]	Hybrid Fiber Content HF [%]
B-1	1.76	1.5	0	-
B-2	1.76	1.5	50	-
B-3	1.76	1.5	50	0.3



（a）beams in inclined section under shearing （b）1-1 profile section

Figure 1. Size and Reinforcement of Beam in Inclined Under Shearing

Finite Element Simulation of Beams by ABAQUS

Building Test Model. According to three structural types of reinforced concrete that ABAQUS provided: interface and unit separation type, displacement coordination separation type, integral form type[6], this chooses types of interface and unit separation to stimulate during to loading device, model concrete designs C3D8R type and reinforcement designs T3D2 truss type. Material properties are built according to the constitutive equation of concrete and reinforcement above and concrete damage model(CDP) is built to stimulate the process of stiffness degeneration constantly with the crack of concrete damage, also damage shaping factor is built due to document[7].

The bond between surface of concrete and reinforcement is done by Embedded command in ABAQUS to stimulate sliding contact between them. At the same time, the solid steel plates are set in load points and supports up and lower ends of model to decrease simulation accuracy under the influence of local stress concentration, also, steel plates are interconnected with concrete by Tie command in ABAQUS, in order to simulate the beam changes in different stages better. Final assembly drawing of reinforced concrete beam model and meshing drawing of beam model under shearing are shown in Fig. 2, Fig. 3.

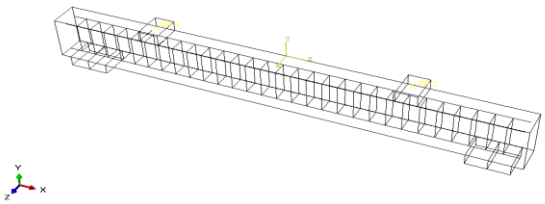


Figure 2. Assembly Drawing of reinforced Concrete Beam Mode

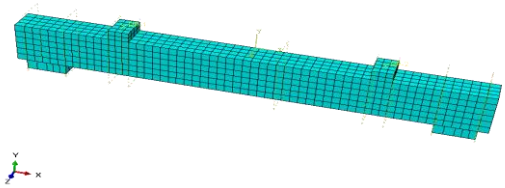


Figure 3. Meshing Drawing of Beam Model Under Shearing

ABAQUS provides three types of loading ,which is force loading , displacement loading and hybrid control loading, this paper chooses displacement loading type to make model convergent better in the condition of simplified simulation[8]. Two reference pointsRP-1, RP-2 are set on the top of steel plates mainly and Step-1 analysis step is set in two reference points to control deformation and displacement of model in Y direction. Stress Cloud Drawing of Beam Concrete and Stress Cloud Drawing of Steel Skeleton are shown in Fig.4, Fig.5 finally.

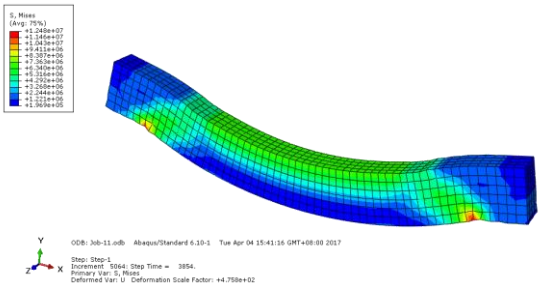


Figure 4. Stress Cloud Drawing of Beam Concrete

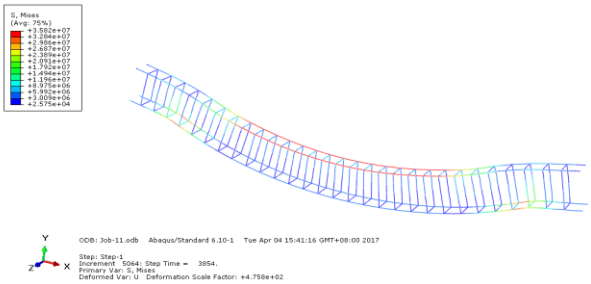


Figure 5. Stress Cloud Drawing of Steel Skeleton

Analysis of Load-Middle Deflection Curves. Load-middle deflection curves can be shown from Fig. 6 below by software simulation. Middle deflection of beamstoB-2 and B-3 is closer to original concrete beam when force is loading to 50kN, which indicates that concrete don't influenced by amount of replacement ratio and hybrid fibers, at this time , concrete shear mainly and stirrups contribute less. In the plastic stage, three beams deflection changes suddenly, however, little hybrid fibers don't influence greatly to beam in inclined section under shearing, load-middle deflection curve of EC-RAC beam almost coincide with RAC beam with 50% replacement ratio and the mechanical property is worse than ordinary concrete beam in general.

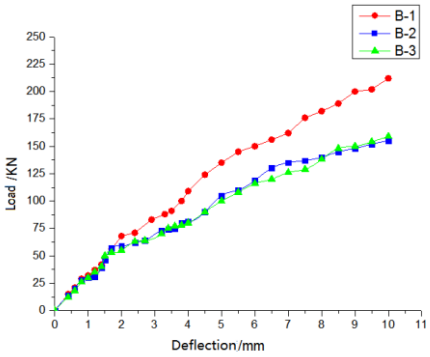


Figure 6. Load-Middle Deflection Curves

Analysis of Load-Stirrup Strain Curves. Load-stirrup Strain curves can be shown from Fig. 7 below by software simulation. In the elastic stage of early loading state, stirrup strain of three beams is closer to each other , however, stirrup strain of B-2 and B-3 beam increases slowly and less than B-1 ordinary concrete beam when load goes beyond40kN. Stirrup strain of B-3beam is the biggest

of all under same load, from that it indicates that hybrid fibers decrease cracking moment ,which cracks concrete in the shear ahead of time and makes stirrup bear shear earlier, providing less effect to simply supported beam in inclined section.

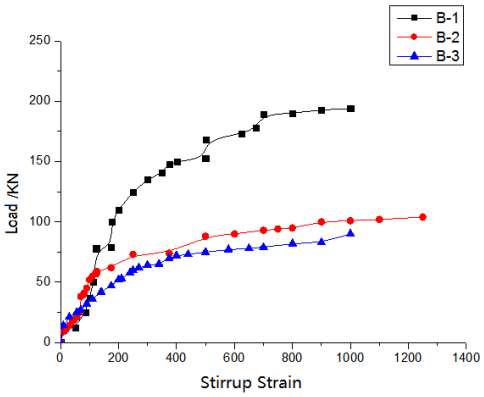


Figure 7. Load-Stirrup Strain Curves

Analysis of Cracking Moment and Limit Bearing Capacity. The limit shear capacity from the ABAQUS is simulated and compared with the experimental data, as shown in Table 5.

Table 5 Comparison of Ultimate Shear Capacity

NO.	Stimulation Value [kN]	Test Value [kN]	Stimulation/ Test Value	Average Deviation Rate
B-1	109.2	118.7	0.92	
B-2	80.5	90.5	0.89	9.7%
B-3	79.9	88.8	0.9	

According to Table 8, the limit shear capacity of the simulation value is less than the experimental value, and the overall deviation rate is about 9.7%, which verifies the correctness of the simulation. The dispersion of beam concrete with replacement ratio and the definition of the model damage factor are large that increases concrete rigidity and decreases simulation value of beam model when take both of that into account. At the same time, all of the shear capacity of B-1, B-2 and B-3 beams decreases which shows that the replacement ratio and the hybrid fibers can not improve the shear capacity reducing the limit shear capacity of the inclined section of beams.

Conclusions

In the elastic stage, the replacement ratio and the hybrid fibers does not affect the concrete, hybrid fibers on a small amount do not cause a greater impact on beam shear in inclined section and the deflection curve of recycled concrete beams is almost same with beam with 50% replacement ratio. In general, the mechanical properties of both are worse than ordinary concrete.

The replacement ratio and the hybrid fibers decrease cracking moment and limit shear bearing capacity of beam in inclined section without abdominal reinforcement, which cracks concrete in the shear ahead of time and makes stirrup bear shear earlier, deforming in the midspan of the beam largely and providing less effect to simply supported beam in inclined section.

References

[1] Z.P. Chen, C.H. Zhou, D.Y. Xu, J. Huang and B. Wu :CHINESE JOURNAL OF APPLIED MECHANICS, Vol. 36 (2017) No.2, p.180(In Chinese).

[2] Y.J. Fan: Experimental study on seismic performance of plain RAC and EC-RAC frame structures (Ph.D., Xi'an University Of Architecture and Technology, China 2013), p.30(In Chinese).

[3] W.L. Cao, Y.Q. Zhang, H.P. Yi and J.W. Zhang :The first national academic meeting on recycled concrete research and application (ShangHai, China, July 8, 2008).p.117(In Chinese).
[4] J.H. Zhou, T.B. Kang, F.C. Wang and Y.C. Shu: JOURNAL OF VIBRATION AND SHOCK, Vol. 36 (2017) No.2, p.235(In Chinese).
[5] Standard Test Method for Mechanical Properties of Plain Concrete(China Construction Industry Press, China,2003.) (In Chinese).
[6] S.L. Wang, Y.H. Du, B.S. Yu, Y.J. Fan and X.H. Chen: WORLD EARTHQUAKE ENGINEERING ,Vol. 31 (2015) No.2, p.28(In Chinese).
[7] X.L. Gao, Y.S. Zhang and J. Li: Structural Engineers, Vol. 29 (2013) No.6, p.19(In Chinese).
[8] Y.Z. Wang and C.G. Fu: ABAQUS structural engineering analysis and detailed examples(China Construction Industry Press, China, 2010) (In Chinese).