Impact Resistance Of Ultra-High Performance Concrete

R. SEENIVASAN
PG Student, Department of Civil Engineering,
PRIST University, Thanjavur, Tamil Nadu, India.

***Abstract*—This paper presents the cost effectiveness in design of concrete sturutes with high performance concrete. The testing program demonstrated that both types of panels could resist impact loads with energies up to 1900 J without complete failure. Both types of panels were not adversely affected by the extreme cold temperatures and in fact displayed increased effectiveness. The residual strength of UHPFRC panels was easily predicted based on the permanent midspan deflection caused by the impact test. The ambient temperature FRP strengthened SFRC panels had decreasing residual strengths as the amount of permanent deflection increased, while the cold temperature panels had the same residual strength despite having different amounts of permanent deflection. Both types of panels exhibited ductile behaviour, with the UHPFRC panels reaching maximum deflections of 100 mm and the FRP strengthened SFRC panels reaching maximum deflections of 120 mm.**

I. INTRODUCTION

Steel Fibre Reinforced Concrete (SFRC) is simply defined as normal strength concrete which contains randomly distributed steel fibres, such as those shown in Figure 2-1. These fibres are added to the mix prior to pouring and are intended to reinforce concrete, which on its own, is brittle and lacks tensile strength and ductility [6]. Much research has been done in this field over the past few decades to determine the key material properties and how it behaves within various structures.

Random fibre orientation in SFRC

There are many different types of steel fibres that can be used in this application, with variations in length, width, and shape, as shown in Figure 2-2. The most common types of steel fibres are those cut from sheets, slit sheet fibres, fibres extracted from steel melt, and mill cut fibres [6]. These fibres have a random distribution in the mix which leads to an increase to both the ultimate strength and the toughness or ductility of the concrete structural component [8]. These fibres increase the tensile capacity of the member as they bridge the cracks that form in the tension regions of the member as loads increase. It is recommended that the aspect ratio of the fibres, the ratio between fibre length and diameter, be less than 100 and it typically ranges from 20 to 100 [8]. If the aspect ratio is larger than 100, the fibres tend to clump within the mix, reducing workability and preventing a uniform distribution within the mix.

Steel fibres are typically used as secondary reinforcement in addition to reinforcing steel bars. In many applications, fibres are used to control cracking caused by fatigue, impact, shrinkage, or thermal stresses [8]. Steel fibres can be the sole source of reinforcement in members that do not require continuous reinforcement for the structural integrity or safety that it provides. In thin sections that are not required by code to have continuous reinforcement, such as non-structural blast wall panels, steel fibres can be used to reduce the section depth but still provide improved toughness, flexural strength, and impact and fatigue resistance.

Research done by Banthia [12] shows that the addition of steel fibres increases the ductility of the concrete member both under static and dynamic loading conditions. He also found that hooked end steel fibres were superior to straight polypropylene fibres. A dramatic increase in the peak loads and fracture energies were also noted by adding steel fibres to the mix. The failure method noted was primarily steel fibre pull-out, with increasing numbers of fractured fibres as impact energy was increased. The addition of fibres reduced spalling and helped preserve the integrity of beams subjected to impact loads.

Ultra high performance fibre reinforced concrete (UHPFRC) is a material that can be characterized by the

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

following ACI 239 definition, currently pending approval: “Ultra-High Performance Concrete (UHPC) is a cementitious, concrete material that has a minimum specified compressive strength of 150 MPa with specified durability, tensile ductility and toughness requirements; fibres are generally included to achieve specified requirements” [13]. The inclusion of steel fibres in some cases reduces the requirement for passive reinforcement such as normal steel reinforcing bars. The purpose of UHPFRC is to achieve high tensile strengths through the activation of the steel fibres within a matrix. This matrix still provides tensile strength even after first cracking due to the bond between the fibres and the concrete [14]. As this material is still relatively new and there are no existing North American design codes, CSA formed a working group in December of 2015 to develop a new annex on UHPC materials for their code, A23.1 [15].

Henry H.C. Wong and Albert K.H. Kwan (Department of Civil Engineering, The University of Hong Kong, Hong Kong) (5) introduces the concept of packing density as a fundamental principle for designing HPC mixes. The concept is based on the belief that the performance of a concrete mix can be optimized by maximising the packing densities of the aggregate particles and the cementitious materials and presents a preliminary HPC design method, called three-tier system design.

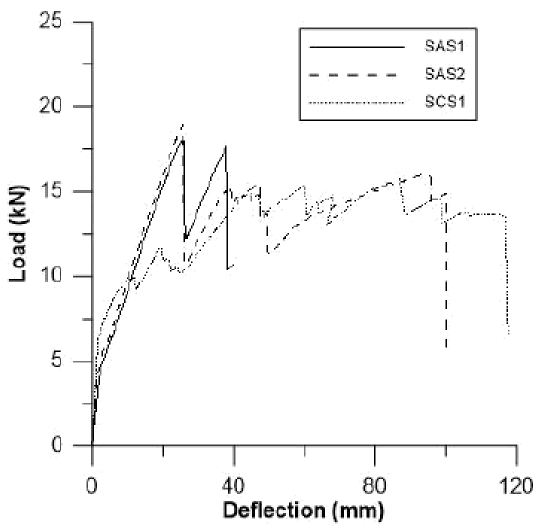
Papayianni, G. Tsohos, N. Oikonomou, P. Mavria(Department of Civil Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece) have established the influence of superplasticizer type and mix design parameters on the performance of them in concrete mixtures for cocrete of higher strength.

III. EXPERIMENTAL RESULTS

Three panels were tested quasi-statically using three-point flexural bending. Two ambient temperature panels and one cold temperature panel were tested. The ambient temperature panels displayed similar behaviour and data was only collected for one cold temperature test. All panels behaved in the same manner, with the FRP straps debonding and fracturing on the tension face of the panel before debonding on the compression face of the panel just before failure.

Eight panels were tested under impact loading, four panels were tested at ambient temperature and four panels were tested at extreme cold temperature. Each panel was subjected to impact loading from a different hammer drop height, ranging from 500mm to 1500mm. Cold temperature panels were tested at a temperature range of -50°C to -60°C, while ambient panels were tested at a temperature of approximately 20°C. Regardless of the drop height, all panels were very quick to crack due to the low strength of the concrete and the lack of standard steel reinforcement. At the lowest drop height, 500 mm, the FRP straps remained bonded to the concrete but as the drop height increased, the FRP straps began to debond. At the highest drop height, 1500 mm, the FRP straps completely debonded on the cold temperature panel but remained effective for the ambient temperature panel.

The load-deflection curves of the quasi-statically tested panels are shown in Figure. Each ambient temperature panel exhibited similar behaviour, with a distinct change in slope at first cracking of concrete and then a peak load of approximately 18 kN reached at a deflection of about 20 mm. Once the peak load was reached, the FRP straps began to debond at different locations on the panel, leading to drastic reductions in load-carrying capacity. After these rapid drops in capacity, the tension was redistributed to other parts of the FRP straps which allowed the load to increase again. Panel SAS2 was taken to its full deflection capacity and matched the behaviour of panel SAS1. For the cold temperature panels, panel SCS1 displayed a slightly different behaviour than those tested at ambient temperature, but still reached a similar plateau and had a higher maximum deflection. While the cold temperature panel also experienced drops in load-carrying capacity, these drops were not as significant as those experienced by the ambient temperature panels. The increased tensile strength of the SFRC at cold temperatures may allow the tension to be redistributed to other parts of the FRP straps quicker than the ambient temperature panels. It is assumed that all cold temperature panels will exhibit load-deflection behaviour like that of panel SCS1, depicted in Figure, but has not been verified experimentally.



Load-deflection behaviour of quasi-static panels

The load-deflection curves of the ambient temperature dynamic panels are shown in Figure. For each respective curve, the solid line represents an impact test, each graph designates which panel is represented, and the dashed line shows a comparison to a quasi-static load-deflection test. The

International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

loading data is sourced from the force transducers located on the reaction points of the panel. As seen in the graphs, there is an increase in deflection before there is a positive load recorded by the force transducers.

This is due to the attachment of the panels to the testing frame and the fact that as the panel displaces at the midspan, the panel initially pries away from the supports which leads to a negative initial reaction load before it registers as a positive reaction load. High-speed video shows the hammer impacting the panel, rebounding slightly and then continuing to impact the panel due to the kinetic energy of the hammer and is consistent with the multiple load peaks observed in Figure. Ambient temperature panels all displayed similar behaviour with similar peak loads from the hammer and increased maximum displacements as the drop height increased. The initial delay of load in the dynamic loaded panels is because the panel must deflect significantly and the inertia of the panel must be overcome before the reactions read a detectable load in the direction of the hammer's movement. The panels neither reached their maximum displacement as defined by the quasi-static tests nor completely failed.

CONCLUSIONS

1. Impact-tested panels that did not reach ultimate failure, i.e. complete debonding of FRP straps, all had similar residual strength (15 kN) despite having absorbed various levels of impact energy.
2. Ambient temperature panels tested using the impact hammer had decreasing residual strength based on the amount of residual deflection. Those panels tested at higher impact energies displayed higher residual deflections and lower residual strength.
3. The presence of fibres may reduce the amount of spalling and cracking in the panels but unlikely provided any significant additional strength because the overall capacity of the panels is controlled by the FRP straps.
4. The strength of these panels is attributed to the FRP straps which were applied using a wet layup procedure. Despite the best efforts, inconsistencies between each panel were inevitable with varying levels of concrete panel smoothness and different amounts of epoxy used for each strap.the failure of panel SCI4 but the predicted displacement of panel SAI4, also impacted from a drop height of 1500 mm, was only off by 2 mm from the actual displacement.

REFERENCES

[1] M. F. Green, L. A. Bisby, A. Z. Fam and V. K. Kodur, "FRP confined concrete columns: Behaviour under extreme conditions," Cement & Concrete Composites, no. 28, pp. 928-937, 2006.

[2] M. F. Green, A. J. Dent and L. A. Bisby, "Effect of freeze-thaw cycling on the behaviour of reinforced concrete beams strengthened in flexure with fibre reinforced polymer sheets," Canadian Journal of Civil Engineering, no. 30, pp. 1081-1088, 2003.

[3] L. J. Malvar, J. E. Crawford and K. B. Morrill, "Use of Composites to Resist Blast," Journal of Composites for Construction, vol. 11, no. 6, pp. 601-610, 2007.

[4] W. Elsaigh, "Steel Fiber Reinforced Concrete Ground Slabs; A Comparative Evaluation of Plain and Steel Fiber Reinforced Concrete Ground Slabs," University of Pretoria, Pretoria, 2001.

[5] M. V. Mohod, "Performance of Steel Fiber Reinforced Concrete," International Journal of Engineering and Science , vol. 1, no. 12, pp. 01-04, 2012.

[6] N. P. Banthia, "Impact Resistance of Concrete," PhD Dissertation, 1987.

[7] H. A. Toutanji and W. Gomez, "Durability characteristics of concrete beams externally bonded with FRP composite sheets," Cement and Concrete Composites, no. 19, pp. 351-358, 1997.

[8] C. Bakis, L. Bank, V. Brown, E. Cosenza, J. Davalos, J. Lesko, A. Machida, S. Rizkalla and T. Triantafillou, "Fiber-Reinforced Polymer Composites for Construction - State-of-the-Art Review," Journal of Composites for Construction, vol. 6, no. 2, pp. 73-87, 2002.

[9] A. Q. Bhatti, N. Kishi and K. H. Tan, "Impact resistance behaviour of RC slab strengthened with FRP sheet," Materials and Structures, vol. 44, pp. 1855-1864, 2011.

[10] D.-Y. Yoo, K.-H. Min, J.-Y. Lee and Y.-S. Yoon, "Enhancing impact resistance of concrete slabs strengthened with FRPs and steel fibres," in 6th International Conference on FRP Composites in Civil Engineering, Rome, 2012.

[11] O. Millon, A. Kleemann and A. Stolz, "Influence of the fiber reinforcement on the dynamic behaviour of UHPC," in First International Interactive Symposium on UHPC, Des Moines, Iowa, 2016.