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Effect of Steel Fibers on the Engineering Performance of Concrete

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ABSTRACT

Steel fibers are used widely in concrete to boost the performance of concrete. There are many studies of using steel fibers in concrete or mortar mixes. This review study is a trial of giving some highlights for inclusion of those fibers especially in terms of using them with new types of concrete.

Key words: Steel fiber, ductility, toughness

INTRODUCTION

The main concern about concrete is its brittleness while its strength is being increased. The higher the strength of concrete, the lower is its ductility. This inverse relation between strength and ductility is a serious drawback when using concrete is of concern. A compromise between these two conflicting properties of concrete can be obtained by adding short fibers (Bayramov *et al.*, 2004). Therefore, it becomes a more significant problem to improve the ductility of concrete. The use of steel fiber reinforced concrete has steadily increased during the last three decades. Considerable developments have taken place in the field of steel fiber reinforced concrete as reported by Bentur and Mindess (1990). The field of application of steel fiber reinforced concrete may include highway and airfield pavements, hydraulic structures, tunnel linings etc. Additionally, the composite has potential for many more applications, specially, in the area of structural elements (ACI Committee 544, 1993). The addition of steel fibers significantly improves many of the engineering properties of mortar and concrete, notably impact strength and toughness. Flexural strength, fatigue strength, tensile strength and the ability to resist cracking and spalling are also enhanced (Nataraja *et al.*, 1999).

WORKABILITY AND FLOW ABILITY OF STEEL FIBER CONCRETE MIXES

The use of fibers is known to affect the workability and the flow characteristics of plain concrete essentially. Many researches investigated the effect of the aspect ratio and volume content on the flow ability of concrete (Noor *et al.*, 2006). The higher the aspect ratio is, the fewer fibers could be included to surpass the critical fiber content. For the same fiber content, better workability is achieved at lower aspect ratios (Kareem and Naranyanan, 1983).

A mix design method is proposed for fiber reinforced concrete. First, their assumption was that the most workable concrete would be achieved if its granular skeleton would be optimized. They found that the optimum aggregate proportions were independent of the volume and properties of the paste. After varying the ratio of the sand to aggregate by trial and error, an optimum content of sand was found to achieve the best workability. This ratio depended on the type and amount of fibers. Next, an adjustment of the water, cement and superplasticizer has to be performed to attain the desired workability. Usually, the cement content has to be adjusted if a higher sand content was applied. Because fibers are known to affect the workability of concrete, the question arises whether the fibers are detrimental to the workability of SCC. Steel fibers with a longer shape than aggregate of the same volume have the higher specific surfaces. The degree to which workability decreases depends on the type and content of fibers used, on the matrix in which they are embedded and the properties of the constituents of the matrix on their own. A high content of fibers is difficult to distribute uniformly; a good distribution, however, it's required to achieve optimum benefits of the fibers (Sedran and Larrad, 1999).

Grumewald and Walraven (2001) investigated an experimental study on the effect of four types of steel fibers at different contents on the workability of two Self Compacted Concrete (SCC) with different compositions. It was found that the flow behavior of fiber reinforced mixtures differs from that of plain SCC. The observations also indicated that when a homogenous distribution was achieved with critical fiber content, the formation of a stiff structure of the granular skeleton will make the flow under concretes' own weight almost impossible. It was found that a considerable amount of fibers allowed self-compacting behavior. However, the composition of the reference mix would have some influences on the maximum possible fiber content.

THE EFFECT OF STEEL FIBER ON COMPRESSIVE, SPLITTING TENSILE AND FLEXURAL STRENGTH OF CONCRETE

The compressive strength test is considered the most suitable method of evaluating the behavior of SFRC for underground construction at an early age, because in many cases (such as in tunnels) SFRC is mainly subjected to compression (Ding and Wolfgang, 2000). Many researchers believed that steel fibers do not have the significant influence on the compressive behavior of concrete due to the small volume of fibers in concrete mix (Armelin and Helene, 1995). In general, the effect of addition of steel fibers on compressive strength ranges from negligible to marginal and sometimes up to 25% as reported by Balaguru and Shah (1992).

Nagarkar *et al.* (1987) indicated that the compressive strength, splitting tensile and flexural strengths increase with increasing fibers content. The compressive, splitting tensile and flexural strength increased by 13-40% for fibrous concrete containing steel fibers with aspect ratio of 105 at 0.5% volume fraction. Dawood and Ramli (2010) had investigated the effect of steel fiber content with different percentages of steel fiber from (0-2%) on the flowable mortar. The results indicated that the compressive strength has increased by 21% as the steel fiber fractions was 1.25%. On the other hand, the flexural strength results recorded a significant increase of about 200% by the inclusion of steel fiber up to 1.75%. These results according to the authors are related to the improvement of mechanical bond between the cement paste and the steel fibers when the flow of mortar is adequately applied.

THE EFFECT OF STEEL FIBER ON TOUGHNESS AND IMPACT CAPACITY OF CONCRETE

Toughness is a measure of the ability of the material to absorb energy during deformation estimated using the area under the stress-strain curves (Balaguru and Shah, 1992; Dawood and Ramli, 2009a). The main contribution of steel fibers to concrete can mainly be observed after matrix cracking. If a proper design is made, after the matrix cracking, randomly distributed, short fibers in the matrix arrest microcracks, bridge these cracks, undergo a pull-out process and limit crack propagation (Banthia and Trottier, 1995; Kurihara *et al*., 2000). ASTM (1997) C-1018 proposed a method for evaluating the toughness indices and JSCE-SF4 (1984) recommends determining the flexural toughness factor.

To design and analyze structures using steel fiber reinforced concrete for compression, the stress-strain behavior of the material in compression is needed. While the compressive strength is used for the strength calculation of the structural components, the stress-strain curve is needed to evaluate the toughness of the material for consideration of ductility (Bayramov *et al*., 2004).

Nataraja *et al*. (1999), Banthia and Sappakittipakorn (2007) and Dawood and Ramli (2009b) studied the affect of steel fibers on toughness. It can be observed that the toughness improves with the increasing content of fibers, the reason being the ability of fibers in arresting cracks at both micro-and macro-levels. At micro-level, fibers inhibit the initiation of cracks, while at macro-cracks; fibers provide effective bridging and impart sources of toughness and ductility.

CONCLUSIONS

The study on the effect of steel fibers on different types of concrete can still be a promising work as there is always a need to overcome the problem of brittleness of concrete. The use of steel fibers has proven to be the best solution to overcome this problem. This review study, tried to focus on the most significant effect of adding steel fibers to the concrete mixes. The use of steel fibers according to many researchers may face drawback of inadequate workability or flow ability, therefore, the concrete mixes may include superplasticizer to solve this problem without affecting other properties, particularly strength and durability properties.

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REFERENCES

ACI Committee 544, 1993. Guide for specifying mixing, placing and finishing steel fiber reinforced concrete. ACI Mater. J., 90: 94-101.

Armelin, H.S. and P. Helene, 1995. Physical and mechanical properties of steel fiber reinforced dry-mix shotcrete. ACI Mater. J., 92: 258-267.

ASTM, 1997. Standard Test Method for Flexural Strength of Steel Fiber Reinforced Concrete (Using Beam with Third-Point Loading). ASTM C1018-97, Philadelphia.

Balaguru, N. and S.P. Shah, 1992. Fiber Reinforced Cement Composites. McGraw-Hill, New York, pp: 179-214.

Banthia, N. and J.F. Trottier, 1995. Concrete reinforced with deformed steel fibers. Part II: Toughness characterization. ACI Mater. J., 92: 146-154.

Banthia, N. and M. Sappakittipakorn, 2007. Toughness enhancement in steel fiber reinforced concrete through fiber hybridization. Cem. Conc. Res., 37: 1366-1372.

Bayramov F., C. Tas_demir and M.A. Tas_demir, 2004. Optimisation of steel fiber reinforced concretes by means of statical response surface method. Cem. Conc. Res., 26: 665-675.

Bentur, A. and S. Mindess, 1990. Fiber Reinforced Cementitious Composites. Elsevier Applied Science, London, UK.

Dawood, E.T. and M. Ramli, 2009a. Study the effect of using palm fiber on the properties of high strength flowable mortar. Proceedings of 34th Conference on our World in Concrete and Structures. Aug. 16-18, Singapore, pp: 93-100.

Dawood, E.T. and M. Ramli, 2009b. Use of flowable high strength mortar as a repair material for sustainable engineering construction. Proceedings of 1st International Conference of Rehabilitation and Maintanance in Civil Engineering, March 21-22, South Africa, pp:269-276.

Dawood, E.T. and M. Ramli, 2010. Development of high strength flowable mortar with hybrid fiber. Construction Building Mater., 24: 1043-1050.

Ding, Y. and K. Wolfgang, 2000. Compressive Stress-strain relationsahip of steel fiber reinforced concrete at early age. Cement Concrete Res., 30: 1573-1579.

Grumewald, S. and C.J. Walraven, 2001. Parameter study on the influence of steel fiber and coarse aggregate content on the fresh properties of self-compacting concrete. Cement Concrete Res., 31: 1793-1798.

JSCE-SF4, 1984. Method of tests for flexural strength and flexural toughness of steel fiber reinforced concrete. Concrete Lib. JSCE Japan Soci. Civil Eng. Tokyo, 3: 58-61.

Kareem, A.S.P. and R. Naranyanan, 1983. Factors influencing the workability of steel fiber reinforced concrete: Part 2. Concrete, 17: 432-444.

Kurihara, N., M. Kunieda, T. Kamada, Y. Uchida and K. Rokugo, 2000. Tension softening diagrams and evaluation of properties of steel fiber reinforced concrete. Eng. Fract Mech., 65: 235-245.

Nagarkar, P.K., S.K. Tambe and D.G. Pazare, 1987. Study of fiber reinforced concrete. Proceedings of the International Symposium of Fiber Reinforced Concrete, Dec. 16-19, Madras, India, pp: 130-138.

Nataraja, M.C., N. Dhang and A.P. Gupta, 1999. Stress-strain curves for steel fiber reinforced concrete under compression. Cement Concrete Composite, 21: 383-390.

Noor, A.M., R.S. Salihudin and R. Mahyuddin, 2006. Performance of high workability slag-cement mortar for ferrocement. Building Environ., 42: 2710-2717.

Sedran, F. and D. Larrad, 1999. Optimization of Self-Compacting Concrete. RILEM Symposium Stockholm, Rilem Publications, Cachan, pp: 321-32.