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Effect of fly ash and steel fibres on shrinkage properties of self-compacting concrete: A review

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Abstract: This paper provides a systematic literature review of publications relating to the effect of incorporating fly ash and steel fibres on the shrinkage of self-compacting concrete (SCC). It identifies various influencing aspects related to the use of fly ash and steel fibres such as replacement level of fly ash, class of fly ash, dosage of steel fibres, type and aspect ratio of steel fibres. It concludes with a look to the future, including research needs to be addressed.

I. INTRODUCTION

This Self-compacting concrete is considered as a concrete which can compact on its own due to its self-weight without any external vibration effort. Self-compacting concrete should be cohesive enough to be handled without bleeding or segregation. Recently this concrete has gained wide use in many countries for different applications. With the use of SCC, better working environment is provided by eliminating vibration noise. There are many advantages of using SCC, these include:

- Reducing construction time and labour cost;
- Eliminating external vibration effort;
- Reducing noise pollution;
- Ensuring good structural performance;
- Improving filling capacity of highly congested structural members [1].

SCC requires good workability which can be achieved by addition of super plasticizer to concrete mixture. However chemical admixtures are expensive and their use may increase the construction cost. The use of mineral admixture such as fly ash can increase the workability without increasing the construction cost. The use of fly ash is not only economical but also increases workability, strength and drying shrinkage [1-6]. Fly ash is an industrial by product hence its storage and disposal problem is also solved.

Shrinkage of concrete is defined as volume change in concrete. Volume changes are of considerable importance because in practice this movement is partly or wholly restrained, which can cause high tensile stresses [3]. Use of high volume of Portland cement in SCC increases heat of hydration which in turn leads to high rate of shrinkage. To reduce the shrinkage, fly ash in partial replacement of Portland cement can be followed.

Steel fibres were added to the mixture to counteract early age cracking of concrete (due to plastic and autogenous shrink-age) and delayed cracking due to restrained drying shrinkage [12]. Several authors have shown the effectiveness of addition of steel fibres in counteracting plastic and drying shrinkage [9-12]. By varying the amount of steel fibres in the concrete mix, mechanical behaviour also varies [10].

II. ROLE OF FLY ASH ON SHRINKAGE

N. Bouzoubaa et al. [1] experimented with 9 SCC mixtures and one control mixture, cementitious material was kept 400 kg/m^3 and water to powder ratio ranged from 0.35 to 0.45. Class F fly ash was used in the experiment and the replacement level of fly ash with cement was 40-60% by mass. Slump flow of the mixes was in the range of 500-700mm. 50% fly ash replacement mix proved effective in achieving satisfactory compressive strength of 35MPa at 28 days curing and also minimising drying shrinkage strains.

J.M.Khatib [2] studied the effect of fly ash on shrinkage property of SCC, fly ash was partially replaced with Portland cement from the range 0-80% by mass. Water to binder ratio was kept constant (0.36). Results showed that there is systematic reduction in shrinkage as the fly ash content in the mix increased. Shrinkage was reduced by 2/3rd compared with control mix for 80% fly ash replaced mix at 56 days curing. A linear relationship exists between 56 day shrinkage and fly ash content.

Cengiz Duran Atis [3] carried out the experiment with 50-70% fly ash replacement with Portland cement, water to binder ratio ranged from 0.28 to 0.34. Results showed that 50% replacement mix attained higher strength than nominal mix strength at 28 days, shrinkage reduced to 30% when compared to plain cement concrete mix. Effect of super plasticizer also plays a role in shrinkage, concrete mixture made with super plasticizer showed 50% higher shrinkage than the mixture made without super plasticizer.

Hassan El Chabib [4] studied the properties of self-consolidating concrete made with high volumes of supplementary cementitious materials. Concrete mixes was prepared with class C and class F fly ash, content

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varied up to 70% as partial replacement of Portland cement. Results of the experiment showed that usage of high content of fly ash enhanced workability and long term compressive strength. Concrete mix incorporating fly ash and ground granulated blast furnace slag (GGBS) proved effective in reducing shrinkage strains

Mehmet Gesoglu et al. [5] carried out the experiment with binary, ternary, and quaternary cementitious blends of fly ash, blast furnace slag and silica fume to check the properties of SCC. 3 different mixes of 20%, 40% and 60% fly ash replacement with cement was prepared. Water to powder ratio kept as 0.44, and total binder quantity was 450 kg/m^3. At 56 days drying shrinkage observed was 430µm/m for 20% fly ash replacement, 410µm/m for 40% fly ash replacement and 390µm/m for 60% fly ash replacement. Using fly ash in the preparation of SCC reduced free shrinkage of SCC while the other mineral admixture silica fume increased shrinkage.

YilmazAkkaya et al. [6] studied autogenous and drying shrinkage of Portland cement, binary, ternary binder concrete. Fly ash, very fine fly ash and silica fume were used in the experiment. Results showed that incorporation of fly ash and very fine fly ash decreased autogenous shrinkage but increased drying shrinkage. Fly ash concrete mix did not gain the early strength but there was latter strength development, results proved that lower strength led to early cracking. 200µm/m was the observed autogenous shrinkage at 7 days.

B. Craeye et al. [7] studied the influence of the filler type on the autogenous shrinkage of self-compacting concrete, study was on the effect of filler type on cement hydration. 40% fly ash was replaced with cement where the water to binder ratio was 0.28. 190µm/m was the observed autogenous shrinkage at 7 days. PipatTermkhajornkit et al. [8] studied correlation between degree of hydration of fly ash and autogenous shrinkage. Results showed that degree of hydration of fly ash increases as its blain's surface area increases and it also leads to the increase of autogenous shrinkage. As Al_2O_3 content in cement or fly ash increases autogenous shrinkage also increased.

III. ROLE OF STEEL FIBRES ON SHRINKAGE

V. Corinaldesi et al. [9] produced thin precast elements with self-compacting concrete, steel fibres were added to the mixture of concrete at a dosage of 10% by mass of cement. Water to cement ratio was equal to 0.4. Steel fibres used in the experiment were straight with the length of 11mm and diameter of 0.4mm (Aspect ratio = 28). Addition of fibres to the concrete mix proved very effective in counteracting drying shrinkage of self-compacting concrete. 370µm/m was the observed drying shrinkage at 56 days.

Adel Kaikea et al. [10] studied the effect of mineral admixture and steel fibre volume content on the behaviour of concrete. Six concrete mixes of varying steel fibre content and mineral addition were prepared and tested, steel fibres used were corrugated of length 55mm and diameter 0.8mm (Aspect ratio=69) and its dosage was limited to 2%of total volume of concrete. Test results proved that by adding high fibre volume content in to the mix, the concrete obtained very good performance, compressive strength increased upto 30% for 2% steel fibre volume content mix when compared with no fibre mix. Fibres form a bridge between micro cracks, corrugated steel fibres are efficient in decreasing the width of the cracks. Shrinkage strains of concrete decreased significantly by increasing fibre volume content, 1% fibre content showed a 4-9% reduction in shrinkage whereas 2% fibre volume content showed 15-24% reduction in the shrinkage. Reduction of shrinkage strain also depends on shape of the steel fibre.

C. Bywalski et al. [11] studied the influence of steel fibres addition on mechanical and selected rheological properties of concrete. Four mixes were used for the study, steel fibres used were straight of length 13mm and diameter of 0.2mm, fibre volume content was 1,2 and 3%. Test results showed that deformations are smaller as the fibre content increased. The rate of total shrinkage depends on the contents of fibres and is decreased as the fibre content is increased. For each type of steel fibres , depending on their shape, length and aspect ratio there is optimum degree of structural reinforcement. Maxiumum fibre volume content was found to be 2% of total volume of concrete.

IV. CONCLUSION

The following conclusions were drawn from studying the various factors related to the inclusion of fly ash and steel fibres on shrinkage of SCC:

- The incorporation of increasing amount of fly ash leads to reduction in shrinkage strain in SCC. This decrease in shrinkage seems to have a linear reduction as the replacement level increases. When 80% of fly ash is replaced with cement, shrinkage reduced to two-third of the nominal mix.
- Class C fly ash causes greater shrinkage than class F fly ash because class F fly ash has lower Al_2O_3 content than class C fly ash.
- It is possible to control shrinkage of high volume fly ash SCC by reducing the dosage of super plasticizer and varying water to binder ratio.
- Although there is slow gain of early age strength of high volume fly ash SCC but there is high development of latter age strength and hence Target strength can be achieved. Some researchers proved 50% fly ash replacement is the optimum replacement in achieving higher strength.
- There is reduction in autogenous shrinkage as the fly ash content in SCC increased which is due to the less heat of hydration of cement,

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- All the literatures consistently proved that the addition of steel fibres in SCC counteracted drying shrinkage.
- As the fibre volume content increases, it reduces the shrinkage. 2% fibre volume content in the mix reduced shrinkage upto 24%.
- Steel fibres form a bridge between micro cracks and hence they resist in enlargement of the crack width.
- Corrugated steel fibres proved more effective than straight steel fibres due to the better bonding.

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