A Review On The Behaviour Of Self Compacting Concrete

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Abstract:

The present study is a review on self-compacting concrete (SCC) to know the behaviours its advantages and future use in conventional building techniques. The performance of fly ash and high-volume fly ash (HVFA) in SCC has been studied from different literature in terms of workability and strength. The study also focused on the used of natural and artificial fibres in SCC and its benefits. From the study its has been observed that partial replacement of cement up to 40% to 70% with Fly ash in SCC show some positive effect on concrete. Furthermore, the application of fly ash in high volume in SCC positively subsidizes in determining energy maintenance concern and elevation of SCC in developing and under developing countries.

Keywords: Self-Compacting Concrete (SCC), fly ash, high volume fly ash (HVFA),workability, fibres.

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Introduction:

Self-compactingconcrete (SCC), is one of the unusual kinds of concrete which can be placed and consolidated without any vibration under its own weight. This happed due to its outstanding deformability. Which can be moved without segregation or bleeding due to cohesive nature. Mainly plain concrete is brittle material with less tensile strength. Due to its complex structures, some internal micro-cracks occurring in fresh or hardened state which lead to failure in concrete (Barluenga and Olivares 2007, Aydin 2007, Ali et. Al 2013). SSC has many advantages compared to traditional concrete in terms of workability, better bonding between overfilled reinforcement and required less labour (Kashani and Ngo 2020).Primarily SSC basic ingredients are same as conventional concrete except it having high fines content at low water cement ratio and good aggregate grading including high range water reducing agent and viscosity modifying agents.The present of high fine contents increases the paste volume in SCC, which is the results of high shrinkage and creep (Ahmad and Umar 2018).

Now a days, many researchers are using artificial and natural fibres to reduce this micro-crack (Aydin 2007, Sukumar et. Al 2008, Kim et.al 2011, Dawood and Ramli 2012a, Dawood and Ramli 2012b).Fibres are spread homogeneously in the matrix, which avoidsthespread of matrix cracking. In safety and durability point of view, this addition changes large single cracks into a system of multiple smaller cracks (Brandt 2008,Pająk 2016).Fibre-reinforced SCC is an innovative building material that one of the positive additions in the advantages of SCC. This directed the accumulation of different types of fibres like polypropylene, glass, steel fibres etc in concrete mixture. According to Romualdi and Batson (1963), on 1950s and 1960s the idea of adding steel fibres is studied, where preparation of composite material from cementous material was investigated. To expand the tensile strength, compact the fragilityand to enhancing the performance of SCC under several load fibres were introduced (Evans 2001). However, adding of natural and synthetic fibres show better properties during fresh stage in concrete and reduced the initial cracking, but post cracking behaviours is less compared to steel fibres (Mastali et al. 2018).

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Through addition of fibres to SCC increases its advantages, but extreme use of fibres may reduce the workability (Ismail and Hassan 2017, A. A Li et al. 2021, Yang et al 2022).Thus, optimum percentage of fibres used in SCC in terms of volume or percentage is required to avoid the excessive fibres content (Hannawi et al. 2016, Zhang et al. 2018). On this point, some researchers (Akcay and Tasdemir 2012, Rambo et al. 2014) suggested 1.5% hybrid steel fibres in SCC not show any undesirable effects on workability. Pająk and Ponikiewski (2017), concluded addition of 2% hybrid steel fibre does not fulfil the condition for SCC and the value is less than 0.8. In this regard it is very much important to developed a suitable quantity of hybrid steel for the better development of the characteristics of SCC.

Significant of present study:

The combination of low and high volume of fly ash in SCC is a very important step and worldwide it has been already renovated. Mostly fly ash discarded as waste materials from industries, however thanks to researchers and government authorities who found out the benefits of use of fly ash as conventional building materials and a dependable solution for its consumptions. Thus, from past three to four decades fly ash has been used successfully mainly dumped from industries (Rutkowska et al. 2018, Khan and Ali 2019). From literature it has been observed that the till date many research on vibrated and non-vibrated concrete are made. However very limited studies have been done on high volume fly ash (HVFA) using hybrid fibres in SCC. Thus, the authors have put their efforts to investigate the effects of high-volume fly ash (HVFA) on SCC.

Historical Background of self-compacting concreter (SCC):

In order to attain durable concrete structure by improving its quality, first self-compacting concrete (SCC) was introduced in Japan in 1986 (Corinaldesi and Moriconi 2004). It is observed that the use of SCC proposition economical benefits over conventional concrete construction which included quick construction, removed the noise during vibration and unskilled labour required for the placing and finishing of the concrete (Goodier 2003). In between 1989 to 1991 first independent research work published on SCC, which focused on the high performance and super-workable concretes and their fresh properties such as filling capacity, flowability and resistance to segregation (Yonezawa 1989, Tangtermsirikul et al. 1991).In 1990s, benefits and use of SCC spread all over the countries like Europe, France, Germany, Switzerland, Italy, Belgium, Spain etc. Fig. 1 shows the SCC bridge construction in Swedish in earlies of 1990s

Fig. 1: SCC Bridge Construction in Swedish (Billberg 1999).

In India used of SCC also observed in many projects like Kaiga Nuclear Power Project (Karnataka), Kota Atomic Power project (Rajasthan), Delhi Metro Project, Tarapore Atomic Power Project, Gosikhurd Project, Purna Dam Project, Lower Wardha Project etc. (SCC Handbook 2019).

Now a days worldwide use of SCC is observed in many industries and many research is also going on to take maximum benefits from concrete structures.

Fly ash:

The key waste materials from thermal plants mainly produced fly ash which is the ignition of coal. Mainly in concrete fly ash used as a partial replacement of plain concrete. To reduce the carbon emissions caused in terms of CO_2 from cement industry and refining the workable behaviour of concrete are the major use of fly ash (Celik et al. 2014, Siddique 2014, Kim 2015, Señas et al. 2016, Baite et al. 2016, Kurda et al. 2017, Xie et al. 2019). The major ingredients for fly ash are silicate glass and contains silica, alumina, iron and calcium and magnesium, sulphur, sodium, potassium and carbon. According to ASTM C618-12, precisely fly ash mainly considered as Class F or Class C, which is depend upon the chemical composition. Table 1 and Table 2 represent the physical and chemical properties of fly ash respectively investigate by different researchers.

Table 1: Physical properties of fly ash

Authors	Properties		
	Specific gravity	Surface area (m^2 /gm)	Fineness (cm^2 /gm)
Bouzoubaâ and Lachemi (2001)	2.08	-	3060
Nehdi et al. (2003)	2.08	280	-
Sukumar et al. (2008)	2.12	-	4280
Şahmaran et al. (2008)	2.25	-	2870
Şahmaran et al. (2009)	2.08	-	2890
Bingöl and Tohumcu (2013)	2.10	1.34	-
Afiniwala et al. (2013)	2.16	-	2810
Nguyen et al. (2018)	2.17	-	2630

Table 2: Chemical properties of fly ash

Authors	Compound								
	Silica (SiO_2)	Iron oxide (Fe_2O_3)	Alumina (Al_2O_3)	Calcium oxide (CaO)	Magnesium oxide (MgO)	Total sulphur (SO_3)	Sodium oxide (Na_2O)	Potassium oxide (K_2O)	Loss on ignition
Nehdi et al. (2003)	48.90	14.90	23.30	3.80	0.70	0.20	0.60	1.70	0.30
Sukumar et al. (2008)	57.90	2.69	33.54	0.65	0.49	0.13	0.46	0.87	1.05
Liu (2010)	50.50	7.20	25.00	3.90	1.90	0.90	-	-	6.10
Celik et al. (2014)	62.00	4.90	18.90	5.98	1.99	-	2.41	1.14	1.30
Anjos et al. (2015)	48.61	7.91	23.79	3.06	2.07	0.40	0.78	3.78	2.64
Silva and De Brito (2015)	54.70	5.40	24.70	2.63	1.01	1.38	0.89	1.12	5.10
Nguyen et al. (2018)	58.33	3.49	26.23	5.72	1.26	-	0.27	0.48	2.76

In SCC used of fly ash reduced the quantity of superplasticizer to get the desired slump, which is one of the major benefits of fly ash (Kurda et al. 2017, Jianhe et al. 2019). According to many researchers fly ash consider one of the eco-friendly and low embodied energy construction material (Kurda et al. 2017, Khodair 2017).

High Volume Fly Ash (HVFA):

In High volume fly ash (HVFA) concrete contains more than 50% fly ash by weight in cement. From many literatures (Bouzoubaâ and Lachemi 2001, Mahmoud et al. 2013, Afiniwalaet al. 2013, Kristiawan and Aditya 2015, Anjos et al. 2015, De et al. 2019) it has been observed that the, workability of HVFA grounded by SCC mainly affectedby types of aggregate, particle size, textural features and behaviours of binder.Above all, among several parameters one of the significant one to estimate the concrete performance is compressive strength. On the other words it can say compressive strength is interlinked with the superiority of concrete. From the literature is has been showed that the combination of fly ash as replacement of plain concrete show some undesirable effects on the compressive strength of SCC during curing periods. Where as some researchers discovered that a partial replacement of plain concrete with fly ash upto 35% to 80% show suitable results in case of SCC (Nehdi et al. 2003, Sukumar et al. 2008, Liu 2010, Afiniwala et al. 2013, Mahmoud et al. 2013, Bingöl and Tohumcu 2013, Arivalagan 2013, Celik et al. 2014, Anjos et al. 2015, Silva et al. 2015). Initially due to non-reactivity of fly ash the compressive strength values are found low, but after completion of the curing periods its improved the compressive strength (Şahmaran et al. 2008, Liu 2010). Thus, it proves that proper curing is very much important to get the maximum strength after using fly ash as replacement of plain cement. As concrete is very weak in tension, thus pre-assessment of tensile strength of concrete is very important. Like compressive strength, tensile strength of SCC with HVFA is also increasing with proper curing also. The combination of fly ash improves the tensile strength in most SCC mixes due to its water reducing capacity (Naganathan et al. 2012).Moreover, 40% to 70% replacement and in HVFA based SCC mixes improve the tensile strength significantly with the increases of curing periods. Based on the literature reviews it has been observed that the value of cement addition expands the tensile strength in HVFA based SCC. Thus, partial replacement of cement with HVFA has a significant effect on both compressive as well as tensile strength also.

Critical Comment:

Based on the literature review done on SCC it the following comments can be made:

- Mainly on vibrated and non-vibrated concrete work have been done on SCC for the conventional building making.
- Partial replacement of cement with HVFA in SCC up to 40% to 70% show better results with high curing.
- Compressive and tensile strength are not the conclusive factor for the general performance of HVFA on SCC.
- Use of SCC with hybrid fibre reinforced is not yet investigated properly with HVFA.
- The application of fly ash in high volume in SCC positively subsidizes in determining energy maintenance concern and elevation of SCC in developing and under developing countries.

Conclusions:

The present study mainly focused on the use of SCC using different materials like fly ash as a partial replacement of cement for sustainable development. The behaviour of SCC in terms of fly ash and HVFA has been studied. SCC with the partial replacement of plain concrete has achieves the essential conditions of workability efficiently. Compressive and tensile strength of SCC has been reduced at the initial stage of with combination of fly ash but upsurges at the final stage. The use of natural and artificial fibres and gypsum are show advantages in enhancing the strength of SCC.

In future it is required to do further study on high volume fly ash (HVFA) using hybrid fibres in SCC. Whereas, it is important to find the suitable proportion of hybrid fibres for the reinforcing of SCC for improved flow properties.

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