Stress-Strain behaviour of plain and fibre reinforced SCC mixes

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Abstract. The goal of this research is to better understand the stress-strain behaviour of plain and fibre reinforced M30 grade plain SCC mixtures. The experimental stress strain relationship of SCC revealed that all changes had a minor effect on the stress strain curve's first section. The stress-strain behaviour of M30 FRSCC mixtures has improved with the addition of fibres, resulting in lower stress values for the same stresses. At peak loads, all fibre reinforced SCC mixes, notably SFRSCC and HFRSCC mixes, showed an increase in strain values. Steel and hybrid fibres enhanced the post-peak stress-strain behaviour of SCC mixes compared to glass fibered SCC mixes. M30 grades' modulus of elasticity When compared to other FRSCC mixes, HFRSCC mixes created with optimal combinations of PF and s/a ratios have high values. By dispersing deformation energy through fibres, HFRSCC mixtures have a better capacity to prevent fracture growth. HFRSCC mixtures with high toughness moduli have better shock resistance. Because of the dense and compact microstructure, the modulus of elasticity (E) of HFRSCC mixes shows improved performance.

1 Introduction

European Federation of National Associations Representing for Concrete (EFNARC)(2002) has developed specifications and guidelines for the use of SCC that covers a number of topics ranging from material selection and mixture design to the significance of the testing methods. The main disadvantage of SCC is the high cost associated with the use of chemical admixtures and high volumes of Portland cement. SCC can be obtained by increasing the fine aggregate content; by limiting the maximum aggregate size; by increasing the powder content; by using viscosity modifying admixtures (VMA) and reducing the water-to-binder ratio through superplasticizer (SP).

2 Stress -strain studies

Stress-strain behaviour was investigated for plain, steel fibre reinforced (SFR), glass fibre reinforced (GFR), and hybrid fibre reinforced (HFR) M30

grade self-compacting concrete (SCC) mixes, and characteristics such as modulus of elasticity and toughness were determined. Validate experimental stress-strain results against theoretical stress-strain values calculated using the Seanz analytical model. The cylinders were tested at 28 days for stress strain behaviour under strain controlled uniaxial compression testing machine. The experimental stress-strain behaviour for all plain and SCC mixes was plotted.

The stress - strain behaviour of M30 grade PS CC, SFRSCC, GFRSCC and HFRSCC mixes was found to be almost similar. However, it is observed that the addition of fibres has improved the peak stress values for the same strains. Increase in strain values were observed at peak stresses in all fibre reinforced SCC mixes especially more in SFRSCC and HFRSCC mixes. Addition of steel and hybrid fibres improved the post-peak stress-strain behaviour in SCC mixes than glass fibre SCC mixes.

The inclusion of fibres causes the FRSCC to become more ductile by increasing the strain corresponding to peak stress. It can be shown that the SFRSCC and HFRSCC mixes have higher ultimate load-carrying

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capacity and strains at peak stresses than the GFRSCC mix. The inclusion of steel and glass fibres increases the strength-carrying capacity and allows for greater

strains to be handled during peak pressures, as can be observed.

Table 1. M30 grade PSCC, SFRSCC, GFRSCC, and HFRSCC stress-strain behaviour for the best combination of PF=1.12 and s/a=0.53

Plain SCC		GFRSCC		SFRSCC		HFRSCC	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
0.0001	3.01	0.0000	0.17	0.0002	6.43	0.0000	0.58
0.0003	6.18	0.0002	5.57	0.0003	10.91	0.0001	4.08
0.0004	9.86	0.0003	9.91	0.0004	15.19	0.0002	9.34
0.0006	13.37	0.0005	14.09	0.0006	19.09	0.0002	12.84
0.0008	17.55	0.0007	17.39	0.0008	24.35	0.0004	17.11
0.0010	22.39	0.0009	22.09	0.0010	27.66	0.0005	19.83
0.0012	25.57	0.0010	24.35	0.0011	30.00	0.0006	22.93
0.0015	29.08	0.0011	27.48	0.0012	33.51	0.0007	25.07
0.0016	32.42	0.0012	27.65	0.0014	36.62	0.0008	27.20
0.0018	34.27	0.0013	32.00	0.0015	38.96	0.0009	29.73
0.0021	35.11	0.0013	33.74	0.0017	38.57	0.0010	31.86
0.0023	34.96	0.0014	35.65	0.0019	36.43	0.0012	33.80
0.0025	33.80	0.0015	34.96	0.0021	32.73	0.0013	35.54
0.0027	30.48	0.0017	33.04	0.0022	29.42	0.0015	39.03
0.0029	27.50	0.0019	30.43	0.0023	28.64	0.0016	41.16
0.0031	23.67	0.0022	15.00	0.0025	24.94	0.0018	39.01
0.0032	21.01			0.0025	22.60	0.0019	35.30
0.0035	18.53			0.0026	19.68	0.0020	32.17
0.0036	16.03					0.0021	30.02
0.0038	15.54					0.0022	26.12
						0.0023	22.22

Fig.1. M30 grade PSCC, SFRSCC, GFRSCC, and HFRSCC stress-strain curves for the best combination of PF=1.12 and s/a=0.53

Table 2. M30 grade PSCC, SFRSCC, GFRSCC, and HFRSCC stress-strain behaviour for the best combination of PF=1.14 and $s/a=0.57$

Plain SCC		GFRSCC		SFRSCC		HFRSCC	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
0.0000	0.17	0.0001	3.52	0.0000	0.65	0.0001	3.88
0.0000	0.34	0.0003	6.46	0.0001	4.33	0.0003	9.28
0.0001	4.48	0.0005	10.37	0.0002	8.44	0.0005	13.59
0.0003	8.97	0.0010	16.83	0.0003	11.47	0.0006	18.13
0.0005	12.59	0.0012	20.74	0.0004	14.07	0.0007	22.01
0.0007	16.72	0.0016	24.85	0.0005	16.67	0.0010	25.02
0.0008	20.52	0.0018	28.37	0.0006	19.05	0.0010	28.48
0.0010	23.62	0.0021	32.48	0.0007	21.65	0.0013	32.57
0.0012	27.24	0.0024	35.41	0.0009	25.32	0.0014	35.59
0.0013	29.48	0.0025	35.80	0.0010	29.87	0.0016	37.95
0.0016	34.48	0.0028	40.11	0.0011	32.90	0.0018	40.96
0.0017	36.90	0.0031	40.11	0.0013	35.28	0.0020	43.54
0.0019	36.90	0.0034	38.93	0.0014	38.10	0.0020	44.19
0.0021	34.66	0.0038	35.41	0.0016	41.99	0.0022	43.74
0.0022	31.38	0.0040	31.89	0.0016	42.86	0.0024	42.43
0.0023	28.28	0.0042	28.76	0.0018	40.04	0.0026	39.16
0.0025	25.86	0.0044	25.83	0.0019	34.63	0.0028	35.03
0.0025	24.14	0.0045	24.07	0.0021	29.00	0.0029	32.42
0.0026	22.07			0.0022	22.08	0.0030	30.68
				0.0023	16.67		
				0.0024	12.55

Fig.2. M30 grade PSCC, SFRSCC, GFRSCC, and HFRSCC stress-strain curves for the best combination of PF=1.14 and $s/a=0.57$

3 Modulus of Elasticity and Toughness

The secant modulus of elasticity and toughness of M30 grade PSCC, SFRSCC, GFRSCC, and HFRSCC mixes for optimal PF and s/a ratio combinations are shown in table 3.

Table3. M30 grade PSCC, SFRSCC, GFRSCC, HFRSCC mixes' modulus of elasticity and toughness for optimal PF and s/a ratio combinations

Mix type	Optimum PFs and s/a ratios	Secant modulus of Elasticity (GPa)	Toughness (MPa)
M30PSCC	PF=1.12 and s/a=0.53	31.4	0.04025
M30SFRSCC		37.5	0.05805
M30GFRSCC		34.4	0.04440
M30HFRSCC		38.8	0.05903
M30PSCC	PF=1.14 and s/a=0.57	31.8	0.04124
M30SFRSCC		38.2	0.06007
M30GFRSCC		35.7	0.04536
M30HFRSCC		38.9	0.06109

Fig.1. Modulus of Elasticity and Toughness of M30 grade PSCC, SFRSCC, GFRSCC, HFRSCC mixes for optimum combinations of PF and s/a ratio

The modulus of elasticity describes the material's elastic behaviour, whereas toughness describes a material's capacity to resist fracture development by dispersing deformation energy. The slope of the stress-strain curve may be used to calculate modulus of elasticity, whereas the area (i.e., the integral) beneath the stress-strain curve can be used to measure toughness (the amount of energy absorbed by the specimen under loading). Due to its improved ability to resist fracture propagation by dispersing deformation energy through fibres, M30 grade fibre reinforced SCC mixes have a higher toughness or energy absorption capacity than equivalent grades of

plain SCC mixes. Fibre reinforced SCC mixtures with high toughness moduli provide better shock resistance. The modulus of elasticity (E) of fibre reinforced SCC mixes is found to be higher in all classes, suggesting improved performance due to the dense and compact microstructure of fibre reinforced SCC mixes.

4 Conclusions

The following conclusions are reached based on the findings provided in this study work and significant discoveries during the experimental investigations:

1. Based on the Nan Su mix design principles and subjected to the EFNARC flow standards, M30 grade plain SCC mixes are designed with various combinations of packing factors (PF) (ranging from 1.12 to 1.18) and fine to total aggregate ratios (s/a) (0.50, 0.53, and 0.57).
2. The PF & s/a combinations 1.12 & 0.53 and 1.14 & 0.57 were found to be the most effective, resulting in the highest compressive strengths, which can be related to the high particle packing densities achieved in SCC mixtures.
3. These optimum combinations of packing factors and s/a ratio is further used in the development of the fibre reinforced SCC mixes of grade M30.
4. The experimental stress strain relationship of SCC revealed that all changes had a minor effect on the stress strain curve's first section. The stress-strain behaviour of M30 FRSCC mixtures has improved with the addition of fibres, resulting in lower stress values for the same stresses. At peak loads, all fibre reinforced SCC mixes, notably SFRSCC and HFRSCC mixes, showed an increase in strain values. Steel and hybrid fibres enhanced the post-peak stress-strain behaviour of SCC mixes compared to glass fibered SCC mixes.
5. M30 grades' modulus of elasticity When compared to other FRSCC mixes, HFRSCC mixes created with optimal combinations of PF and s/a ratios have high values.
6. By dispersing deformation energy through fibres, HFRSCC mixtures have a better capacity to prevent fracture growth. HFRSCC mixtures with high toughness moduli have better shock resistance. Because of the dense and compact microstructure, the modulus of elasticity (E) of HFRSCC mixes shows improved performance.

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