https://doi.org/10.1051/e3sconf/202130901048

Stress - strain behaviour of confined nano silica-based concrete

Kakara S J Kumar[1], *M V Seshagiri* Rao[2], *V Srinivasa* Reddy[3], *S* Shrihari[4]

[1]Research Scholar of Civil Engineering, JNTUH CEH, Hyderabad.
[2]Ex-Professor, JNTUH CEH and Professor, CVR College of Engineering, Hyderabad
[3]Professor, Department of Civil Engineering, GRIET, Hyderabad. Email id: vempada@gmail.com
[4] Professor, Department of Civil Engineering, VJIT, Hyderabad.

Abstract. In the present study, the stress-stain behaviour of confined concrete made with nano-silica (nano-SiO_2) were taken up. The stress-strain behaviour was studied for the M30 and M50 grades nano-silica (nano-SiO_2) concrete mixes confined with steel rebars. The confinement was given in the form of steel hoops in the cylinders, 3 hoops (0.8%), 4 hoops (1.1%), 5 hoops (1.3%) and 6 hoops (1.6%). The addition of nano-silica (nano-SiO_2) along with confinement of concrete with steel hoops enhanced the compressive strength, indicating further confinement effect in the concrete. It is observed that the addition of nano-silica (nano-SiO_2) is helpful in lower confinements only. Beyond 1.1% confinement, doesn't show any effect on compressive strengths. From the stress-strain behaviour of all types of concrete mixes, it is concluded that the ultimate load-carrying capacity and strains at peak stresses are more in nano-silica (nano-SiO_2) concrete with steel hoops for mixes up to 1.1% confinement. The addition of nano-silica (nano-SiO_2) to concrete has increased the ductility in both confined and unconfined states

1 Introduction

Concrete is a composite material consisting of many phases in micro and macro scale level. It is strong due to the heterogeneous nature acquired due to (1) interfacial transition zone between aggregate and matrix, (2) interaction between sand and paste matrix and (3) collaboration among CSH gel, large crystals of $Ca(OH)_2$, unhydrated cement particles and pores formed due to high w/c ratio. Interface between coarse aggregate, fine aggregate and cement paste is understood well with micro-observational studies but the phase between the unhydrated cement grains and CSH gel was not been explored effectively especially in concretes with high w/c ratio due to availability of high amount of unhydrated cement particles. To enable a uniform distribution of nano-SiO2 in paste, colloidal nano-SiO_2 (CNS) was used instead of nano-SiO_2 powder. The SiO_2 content of CNS was larger than 99% by weight, and the pH value was 11.

2 Methodology

In this phase of investigations, the stress-stain behaviour of nano-silica (nano-SiO_2) concrete *confined by steel rebars were taken up. The confinement was given in the form of steel hoops in the cylinders, 3 hoops (0.8%), 4 hoops (1.1%), 5 hoops (1.3%) and 6 hoops (1.6%) as shown in Fig 1. The tests were carried out on the standard cylindrical specimens of diameter 150mm and height 300mm. After casting, the cylinders were capped with cement mortar and cured for a period of 28 days in curing tanks. The specimens were then taken out and made surface dry. The samples were placed in a microprocessor strain controlled universal testing machine of 1000 kN capacity and tested under uni-axial compression as per IS 516:1959. The stress–strain behaviour as obtained was plotted.

* Corresponding author: kumarjyo2003@yahoo.com

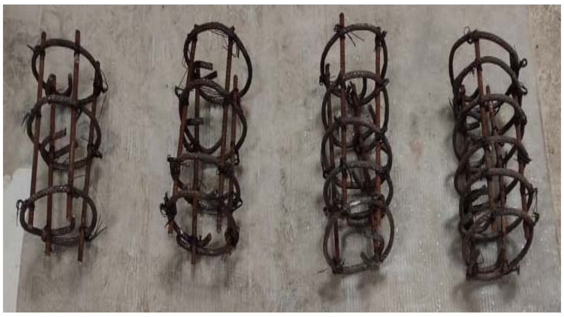

Fig.1. Cylinders with different Confinements

Table 1. Percentage of confinement by volume

		Volume of confinement percentage
C0	Confinement 0 hoops	0.00
C3	Confinement 3 hoops	0.80
C4	Confinement 4 hoops	1.1
C5	Confinement 5 hoops	1.3
C6	Confinement 6 hoops	1.6

Table 2. Stress-strain values of M30 normal concrete confined with steel bars

M30SCC -C0		M30SCC -C3		M30SCC -C4		M30SCC -C5		M30SCC -C6	
Strain	Stress	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	0.00
0.0003	5.24	0.0000	1.17	0.0000	0.39	0.0000	2.16	0.0000	0.86
0.0004	9.43	0.0002	7.39	0.0003	5.50	0.0002	9.05	0.0000	0.00
0.0007	13.97	0.0004	12.45	0.0007	14.15	0.0005	15.95	0.0001	0.87
0.0009	17.82	0.0007	18.68	0.0011	21.22	0.0008	22.84	0.0003	5.63
0.0011	23.41	0.0010	24.53	0.0015	30.66	0.0011	33.62	0.0006	13.41
0.0013	25.15	0.0015	34.27	0.0017	39.30	0.0014	40.95	0.0009	24.21
0.0017	32.49	0.0018	42.45	0.0020	46.38	0.0018	49.14	0.0012	32.86
0.0021	39.13	0.0022	50.63	0.0025	53.06	0.0021	56.90	0.0015	42.79
0.0023	43.67	0.0026	59.20	0.0028	57.38	0.0024	60.34	0.0019	49.29
0.0026	48.91	0.0030	65.05	0.0031	64.85	0.0027	67.24	0.0022	56.65
0.0027	52.05	0.0031	67.39	0.0036	71.92	0.0030	75.86	0.0027	64.88
0.0029	56.94	0.0035	71.30	0.0039	74.28	0.0033	78.45	0.0030	72.24
0.0032	62.18	0.0038	74.04	0.0042	77.42	0.0036	80.60	0.0033	77.86
0.0035	64.28	0.0041	78.34	0.0045	80.57	0.0040	81.47	0.0036	81.77
0.0037	64.98	0.0042	81.46	0.0047	83.32	0.0043	83.19	0.0039	84.81
0.0041	70.22	0.0045	81.48	0.0050	84.50	0.0044	83.62	0.0043	87.86
0.0043	66.38	0.0048	80.73	0.0055	84.89	0.0049	87.07	0.0048	88.76
0.0044	62.53	0.0051	77.65	0.0058	77.82	0.0052	87.07	0.0051	90.52
0.0046	55.90	0.0051	72.62	0.0059	71.53	0.0055	87.07	0.0055	88.39
0.0047	49.26	0.0052	67.19	0.0060	64.06	0.0058	81.90	0.0058	84.54
		0.0053	63.70			0.0059	75.43	0.0062	76.82
						0.0060	67.24		

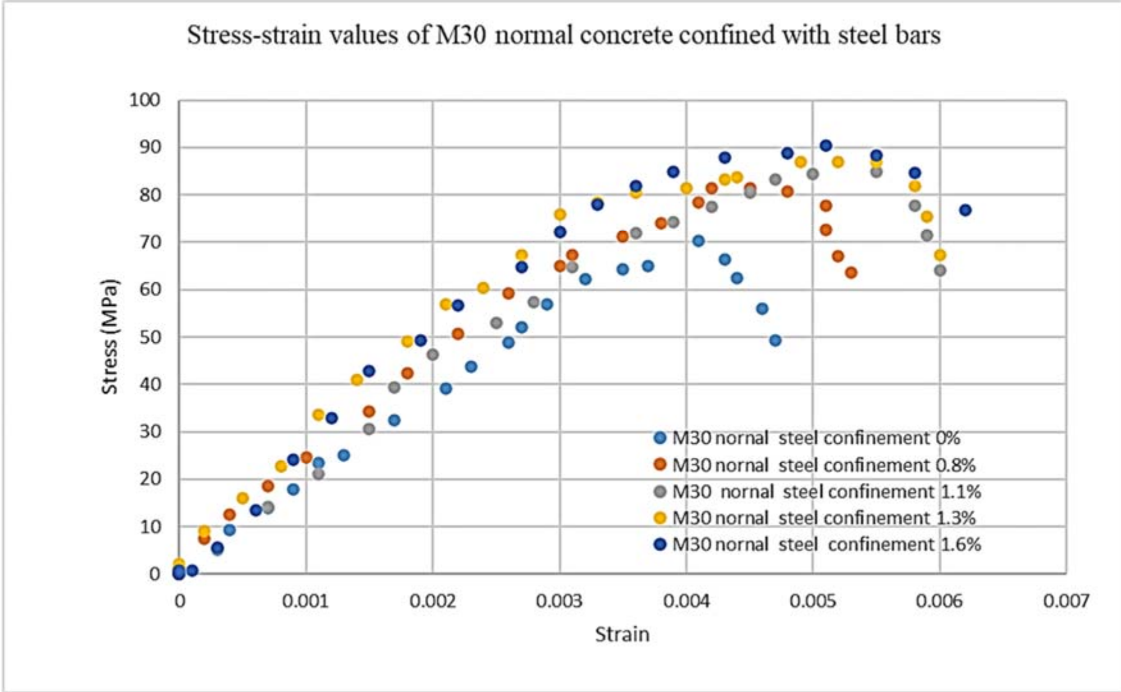

Fig.1. Stress-strain curves of M30 normal concrete confined with steel bars

Table3. Stress-strain values of M30 nano silica concrete confined with steel bars

M30SCC NS-C0		M30SCC NS-C3		M30SCC NS-C4		M30SCC NS-C5		M30SCC NS-C6	
Strain	Stress	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	0.00
0.0002	8.66	0.0003	7.27	0.0004	6.90	0.0004	7.79	0.0000	0.87
0.0004	13.85	0.0006	16.28	0.0006	19.47	0.0005	14.29	0.0003	7.42
0.0007	19.74	0.0010	24.94	0.0011	27.63	0.0006	21.21	0.0005	13.52
0.0009	25.97	0.0013	32.55	0.0017	39.71	0.0009	26.41	0.0007	20.49
0.0011	29.44	0.0015	37.06	0.0022	50.93	0.0011	31.60	0.0010	29.21
0.0014	34.63	0.0018	40.52	0.0027	62.14	0.0012	36.80	0.0011	37.05
0.0017	41.90	0.0020	45.71	0.0032	68.15	0.0015	41.99	0.0013	41.42
0.0021	46.75	0.0022	49.87	0.0037	74.14	0.0018	47.19	0.0016	45.79
0.0023	52.29	0.0024	54.72	0.0040	76.71	0.0020	51.95	0.0019	54.51
0.0025	54.72	0.0028	60.26	0.0043	80.13	0.0022	57.58	0.0021	58.87
0.0027	59.57	0.0032	64.42	0.0044	82.28	0.0026	62.34	0.0023	62.80
0.0031	64.42	0.0035	67.88	0.0047	84.41	0.0028	67.53	0.0026	68.92
0.0033	64.76	0.0039	73.42	0.0049	83.93	0.0032	71.86	0.0029	72.85
0.0035	68.57	0.0043	73.42	0.0052	79.54	0.0035	78.35	0.0031	77.66
0.0038	74.46	0.0046	67.19	0.0055	72.97	0.0038	80.95	0.0034	82.03
0.0043	69.61	0.0049	60.95	0.0058	65.53	0.0041	83.98	0.0041	86.87
0.0043	65.11	0.0050	55.76			0.0045	85.71	0.0043	88.63
0.0046	59.22	0.0051	49.52			0.0048	87.45	0.0046	90.82
0.0047	54.03					0.0050	86.15	0.0050	93.90
0.0050	51.95					0.0052	84.85	0.0053	95.66
						0.0055	83.98	0.0057	96.57
						0.0057	79.22	0.0059	90.50
						0.0059	72.29	0.0060	86.16
								0.0060	78.77

https://doi.org/10.1051/e3sconf/202130901048

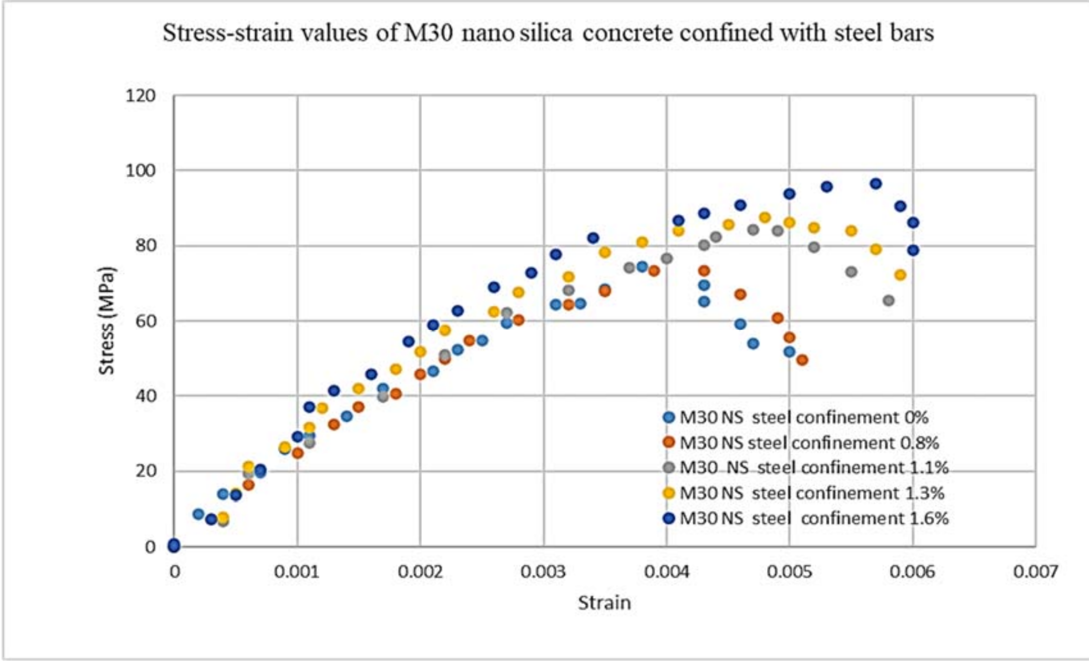

Fig.2. Stress-strain curves of M30 nano silica concrete confined with steel bars

Table 4. Stress-strain values of M50 normal concrete confined with steel bars

M50SCC -C0		M50SCC -C3		M50SCC -C4		M50SCC -C5		M50SCC -C6	
Strain	Stress	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	0.00
0.0003	6.99	0.0002	4.37	0.0003	6.01	0.0000	0.43	0.0002	5.74
0.0005	10.13	0.0005	11.35	0.0005	12.03	0.0003	6.44	0.0004	14.61
0.0006	15.02	0.0007	17.89	0.0007	18.48	0.0005	13.75	0.0007	20.87
0.0009	20.26	0.0010	23.56	0.0009	24.92	0.0007	19.77	0.0008	27.65
0.0011	24.80	0.0012	31.41	0.0012	30.50	0.0010	27.08	0.0011	35.48
0.0014	30.74	0.0014	36.21	0.0014	35.66	0.0012	32.23	0.0013	44.87
0.0016	34.59	0.0017	40.58	0.0016	43.83	0.0014	38.25	0.0016	52.70
0.0018	39.13	0.0019	47.55	0.0018	48.55	0.0016	45.12	0.0019	58.43
0.0021	44.37	0.0021	51.05	0.0021	55.00	0.0019	48.98	0.0022	63.65
0.0024	47.51	0.0024	55.42	0.0023	58.86	0.0022	56.28	0.0026	69.39
0.0026	52.05	0.0026	60.23	0.0026	64.01	0.0024	60.14	0.0029	73.04
0.0029	57.29	0.0029	65.90	0.0028	67.43	0.0027	64.86	0.0031	77.74
0.0031	60.09	0.0031	68.96	0.0031	73.01	0.0030	67.42	0.0035	82.96
0.0033	62.18	0.0034	72.90	0.0035	75.57	0.0032	70.85	0.0038	85.57
0.0037	66.38	0.0036	75.53	0.0038	78.99	0.0035	74.28	0.0040	88.70
0.0039	68.47	0.0040	80.34	0.0040	81.13	0.0038	77.70	0.0043	91.83
0.0045	76.16	0.0047	88.22	0.0043	83.69	0.0040	80.70	0.0047	93.91
0.0049	75.46	0.0052	86.97	0.0045	86.26	0.0041	83.71	0.0051	93.91
0.0052	71.62	0.0056	81.78	0.0049	89.24	0.0046	84.96	0.0053	95.48
0.0055	66.03	0.0059	68.77	0.0051	89.66	0.0049	86.23	0.0054	96.00
0.0058	62.18			0.0054	89.20	0.0051	88.80	0.0058	95.48
0.0059	56.24			0.0057	86.59	0.0056	87.90	0.0060	89.74
0.0061	51.70			0.0059	83.55	0.0057	83.57	0.0061	84.00
				0.0060	77.51	0.0059	78.39	0.0063	75.13
						0.0060	74.06		
						0.0061	67.16		

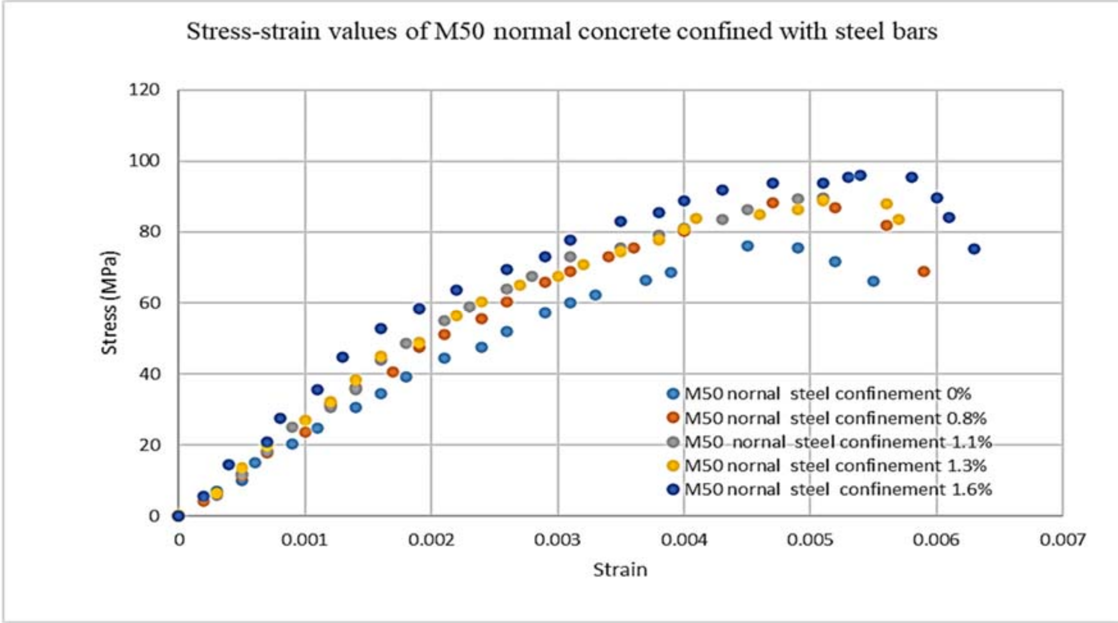

Fig.3. Stress-strain curves of M30 normal concrete confined with steel bars

Table 5. Stress-strain values of M50 nano silica concrete confined with steel bars

M50SCC NS-C0		M50SCC NS-C3		M50SCC NS-C4		M50SCC NS-C5		M50SCC NS-C6	
Strain	Stress	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	0.00
0.0001	0.70	0.0001	3.17	0.0002	5.64	0.0002	6.89	0.0002	7.29
0.0002	5.56	0.0003	9.50	0.0004	13.44	0.0004	15.94	0.0005	15.08
0.0005	11.81	0.0006	15.22	0.0008	18.63	0.0006	22.41	0.0007	22.37
0.0007	18.40	0.0008	22.42	0.0009	26.45	0.0009	29.29	0.0010	29.65
0.0010	22.23	0.0010	27.59	0.0011	32.95	0.0011	33.57	0.0011	37.46
0.0012	26.75	0.0013	32.44	0.0014	38.14	0.0014	38.73	0.0014	43.70
0.0014	33.34	0.0015	39.43	0.0016	45.51	0.0017	45.16	0.0017	49.93
0.0017	38.21	0.0017	44.68	0.0018	51.15	0.0019	50.75	0.0021	59.29
0.0019	42.04	0.0020	49.62	0.0021	57.21	0.0023	58.06	0.0024	69.17
0.0022	47.25	0.0023	55.26	0.0024	63.27	0.0025	62.79	0.0028	73.84
0.0024	49.69	0.0026	59.29	0.0028	68.89	0.0027	67.94	0.0031	79.02
0.0026	53.86	0.0029	63.32	0.0031	72.77	0.0029	73.09	0.0035	87.33
0.0029	57.69	0.0032	67.39	0.0035	77.09	0.0033	78.66	0.0039	90.43
0.0032	61.17	0.0035	71.73	0.0038	82.29	0.0036	82.94	0.0044	93.51
0.0034	64.30	0.0038	74.58	0.0041	84.86	0.0039	86.34	0.0049	93.99
0.0037	68.83	0.0041	77.05	0.0044	85.27	0.0043	87.58	0.0052	96.05
0.0040	70.92	0.0043	78.96	0.0047	86.99	0.0049	88.79	0.0056	98.10
0.0041	73.70	0.0046	81.85	0.0050	90.00	0.0051	89.18	0.0060	95.98
0.0045	75.46	0.0049	82.50	0.0054	89.54	0.0053	90.88	0.0064	89.68
0.0048	76.17	0.0052	80.67	0.0056	85.17	0.0058	89.49	0.0067	83.92
0.0053	74.48	0.0055	77.65	0.0058	80.81	0.0061	86.42	0.0070	77.11
0.0055	69.65	0.0058	72.39	0.0060	75.14	0.0064	79.01		
0.0057	64.12	0.0029	32.06			0.0065	72.49		
0.0060	57.90	0.0030	28.95			0.0066	65.98		

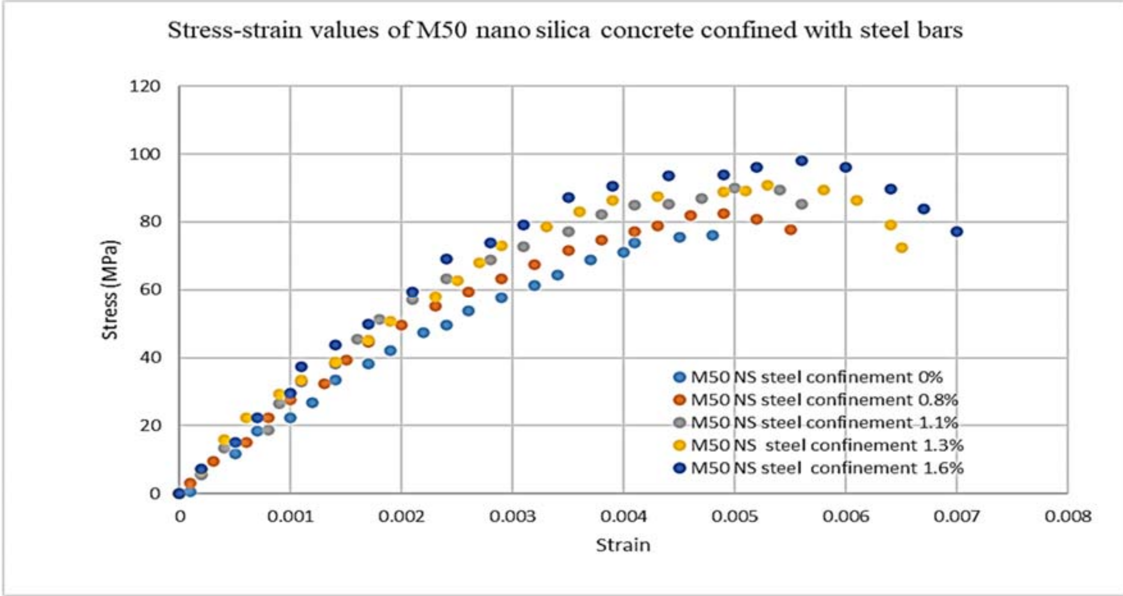

Fig.4. Stress-strain curves of M30 normal concrete confined with steel bars

3 Conclusions

1. The addition of nano silica along with confinement with steel hoops enhanced the compressive strength, indicating further confinement effect in the concrete.
2. It is observed that the addition of nano silica is helpful in lower confinements only. Beyond 1.1% confinement, doesn't show any effect on compressive strengths.
3. From the stress-strain behaviour of normal and nano silica-based concrete in M30 and M50 grade concretes, it is concluded that the ultimate load-carrying capacity and strains at peak stresses are more in nano silica mixes up to 1.1% confinement.
4. The addition of nano silica to concrete has increased the ductility in both confined and unconfined states.

References

1. T.Srinivas and M. Abinay Raj, Int. J. of Eng.and Adv. Tech. (IJEAT), ISSN: 2249 – 8958, Volume-8 Issue-6 (2019)
2. T.srinivas and P. Manoj Anand, Int. J. of Innov. Tech. and Explor. Eng.g (IJITEE), ISSN: 2278-3075, Volume-8 Issue-12 (2019)
3. T.Srinivas and G. Sukesh Reddy, Int. J. of Eng.and Adv. Tech. (IJEAT), ISSN: 2249 – 8958, Volume-9 Issue-1 (2019)
4. T.Srinivas and R. N. Koushik, Int. J. of Innov. Tech. and Explor. Eng.g (IJITEE), ISSN: 2278-3075, Volume-8 Issue-12 (2019), PP 112-117.
5. K. Sai Gopi, Dr. T. Srinivas and S. P. Raju V, E3S Web of Conferences ICMED 184, 01084GRIET, 28-29 February, https://doi.org/10.1051/e3sconf/202018401108 4(2020)
6. Jagannadha Kumar, M.V., Jagannadha Rao, K., Dean Kumar, B., Srinivasa Reddy, V., Int. J. of Civil Eng. and Tech., 9(7), pp. 1133-1141 (2018)
7. Ganta, J.K., Seshagiri Rao, M.V., Mousavi, S.S., Srinivasa Reddy, V., Bhojaraju, C., Structures 28, pp. 956-972 (2020)
8. Srinivas Rao J, S K Tummala, Kuthuri N R, Indonesia Journal of Electrical Engg. & Computer Science, **21** (723), 2020
9. Naidu, K.S.S.T., Rao, M.V.S., Reddy, V.S., Int. J. of Innov. Tech. and Explor. Eng.g (IJITEE), 8(9 Special Issue 2), pp. 641-642 (2019)
10. Chandana Priya, C., Seshagiri Rao, M.V., Srinivasa Reddy, V., Int. J. of Civil Eng. and Tech., 9(11), pp. 2218-2225 (2018)
11. K. Satyanarayana, M.V. Kumar, and N. Sateesh, *Materials Today: Proceedings*, **5(2)**, 5343 (2018).
12. Satya Sai Trimurty Naidu, K., Seshagiri Rao, M.V., Srinivasa Reddy, V., Int. J. of Civil Eng. and Tech., 9(11), pp. 2383-2393 (2018)
13. Supriya, Y., Srinivasa Reddy, V., Seshagiri Rao, M.V., Shrihari, S., Int. J. of Rec. Tech. and Engi., 8(3), pp. 5381-5385 (2019)
14. B. J. Varghese, P. B. Bobba and M. Kavitha, 2016 IEEE 7th Power India International Conference (PIICON), 2016, pp. 1-6
15. Kotkunde, N., Krishna, G., Shenoy, S.K., Gupta, A.K., Singh, S.K. International Journal of Material Forming, 10 (2), pp. 255-266 (2017)

16. Govardhan, D., Kumar, A.C.S., Murti, K.G.K., Madhusudhan Reddy, G. Materials and Design, 36, pp. 206-214. (2012)
17. Kumar, P., Singhal, A., Mehta, S., Mittal, A. Journal of Real-Time Image Processing, 11 (1), pp. 93-109. (2016)
18. Raghunadha Reddy, T., Vishnu Vardhan, B., Vijayapal Reddy, P. International Journal of Applied Engineering Research, 11 (5), pp. 3092-3102 (2016)
19. Hussaini, S.M., Krishna, G., Gupta, A.K., Singh, S.K. Journal of Manufacturing Processes, 18, pp. 151-158 (2015)
20. Karthik Rao, R., Bobba, P.B., Suresh Kumar, T., Kosaraju, S. Materials Today: Proceedings, 26, pp. 3085-3089, 2019