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Effect of W/C Ratio on Workability and Mechanical Properties of High Strength Self Compacting Concrete (M70 Grade)

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Abstract:- This paper presents the results of an experimental research on the workability and mechanical properties of self-compacting concrete. The work focused on concrete mixes having Water/Cement ratios of 0.23, 0.24, 0.25, 0.26 and 0.27, with a Packing Factor of 1.12. The Concrete mixes contains different proportions of GGBS, Super plasticizers, water binder ratios and constant proportions of Cement, Micro Silica, VMA, Coarse aggregate and Fine aggregate for different Water Cement ratios. The percentage of Micro Silica added is 7% for all mixes. The mix proportions are obtained on the basis of NAN-SU mix design. All the mixes contain Cement of 574 kg/m^3 but with different total binder content. The workability tests performed in this research were as per EFNARC. Based upon the experimental results, for water cement ratio 0.25 fresh and hardened state properties of high strength self-compacting concrete are moderate.

Keywords:- Self-Compacting Concrete, Workability, GGBS, Micro silica, Super plasticizer and VMA.

I. INTRODUCTION

Self-compacting concrete having advanced viscosity and workability properties can easily fill the moulds without the necessity of using vibrators. High volume of mineral powder is a necessity for a proper self-compacting concrete design. For this purpose, mineral admixtures such as limestone powder, Fly Ash, micro silica, rice husk ash and blast furnace slag can be used. In this study, the effect of water cement ratio on fresh and hardened properties of self -compacting concrete has been investigated.

It is worth noting that extensive investigations on the workability of self-compacting concrete have been made recently. Kayat et al. reported that the L-box, U-box, and J-ring tests can be used to evaluate the passing ability of self-compacting concrete and to a certain extent, the deformability and resistance to segregation. When combined with the slump flow test, the L-box test is very suitable for the quality control of on-site self-compacting concrete.

It is apparent that workability depends on a number of interacting factors such as water content, aggregate type and grading, fine aggregate to coarse aggregate ratio, packing factor, kind and dosage of super plasticizers, and the fineness of cement. The main factors on self-compacting concrete are the water and super plasticizer contents of the mix since by simply adding them the inter particle lubrication is increased.

In this research mix design used is based on NAN-SU method. His design is based on packing factor (PF) of aggregate. In this research PF and FA/CA used are 1.12 and 52/48 for different W/C ratios. Proportions of GGBS, Super plasticizers and water binder ratios are different and proportions of Cement, Micro Silica, VMA, Coarse aggregate and Fine aggregate are constant for different Water Cement ratios. The percentages of Micro Silica and VMA added are 7% and 0.3% for all mixes.

II. MATERIALS AND MIX PROPORTIONS

This part of the paper presents the specifications of the mixes used for obtaining the workability, compressive strength, split tensile strength and flexural strength of self-compacting concrete. Ordinary Portland Cement (OPC 53 grade), GGBS and Micro silica were used as cementitious materials. Natural river sand and crushed gravel with a nominal maximum size of 10 mm were used as the aggregates. Chemical admixtures used were GLENIUM B233 (a new generation based on modified poly carboxylic ether) as super plasticizer and Glenium Stream-2 as VMA.

Table 1: Mix proportions of concrete containing different water to cement ratios.

Mix Components	Concrete Mixes				
	M1 W/C=0.23	M2 W/C=0.24	M3 W/C=0.25	M4 W/C=0.26	M5 W/C=0.27
	Qty. (kg/m^3)	Qty. (kg/m^3)	Qty. (kg/m^3)	Qty. (kg/m^3)	Qty. (kg/m^3)
Cement	574	574	574	574	574
GGBS	54.57	45.65	36.73	27.82	18.9
Miro Silica	40.18	40.18	40.18	40.18	40.18
F.Aggregate	844.48	844.48	844.48	844.48	844.48
C.Aggregate	805.32	805.32	805.32	805.32	805.32
Water/Binder	140.83	143.65	146.83	150.01	153.18
Super Plasticisers	11.31	11.15	10.99	10.83	10.67
VMA	1.722	1.722	1.722	1.722	1.722

III. WORKABILITY AND COMPRESSIVE STRENGTH

The strict definition of workability is the amount of useful internal work necessary to produce full compaction. The useful internal work is a physical property of concrete and is the work or energy required to overcome the internal friction between the individual particles of the mixture. Because of the very high workability of self-compacting concrete, it needs no external vibration and can spread into place, fill the framework and encapsulate reinforcement without any bleeding or segregation. In other words, to ensure that reinforcement can be encapsulated and that the framework can be filled completely, a favourable workability is essential for self-compacting concrete. Moreover, aggregate particles in self compacting concrete are required to have uniform distribution in the specimen and the minimum segregation risk should be maintained during the process of transportation and placement.

Because the strength of concrete is adversely and significantly affected by the presence of voids in the compacted mass, it is vital to achieve a maximum possible density. This requires a sufficient workability or virtually full compaction. It is obvious that the presence of voids in concrete reduces the density and greatly reduces the strength, which means the presence of 5 percent of voids can lower the strength by as much as 30 percent. This research compares the compressive strength, split tensile strength and flexural strength of self compacting concrete mixtures for different water cement ratios.

IV. RESULTS AND DISCUSSION

In this part of the paper, the experimental results of self-compacting concrete mixes related to compressive strength, split tensile strength, flexural strength and workability are discussed for different water cement ratios. The workability tests performed in this research were as per EFNARC methods. They are Slump flow, L-box, U-box and V-funnel.

A. Experimental Results

The results of workability tests on self-compacting concrete are shown in Table 2. It can be observed that as the W/C ratio increases the workability increases. The results of compressive strength, split tensile strength and flexural strength are shown in Table 3.It can be observed that the strengths are decreasing with increase in W/C ratio.

B. Fresh and hardened state properties of Self-compacting concrete

Slump Flow (SF) increases as the w/c ratio increases. When w/c increases from 0.23 to 0.27(17.4%) , slump flow increases from 650mm to 675mm(3.8%). (Figure 1)

T500, V-funnel, T5 and U-box values are decreasing as the w/c ratio increases. When w/c ratio increases from 0.23 to 0.27(17.4%), T500 time decreases from 4.74 sec to 3.97 sec (16.24%),V-funnel time decreases from 11.4sec to 9.77sec (14.3%), T5 time decreases from 14.60sec to 11.87sec(18.69%) and U-box value decreases from 13mm to 5mm (61.53%). It is observed that workability increases as the w/c ratio increases. (Figures 2, 3, 4 and 6)

L-box value increases as the w/c ratio increase. When w/c ratio increases from 0.23 to 0.27(17.4%), L-box ratio increases from 0.94 to 0.97(3.19%).It is observed that flow ability increases as the w/c ratio increases. (Figure 5)

Compressive strength decreases as the w/c ratio increases. When w/c ratio increases from 0.23 to 0.27(17.4%), 7days Compressive strength decreases from 60.44MPa to 51.88MPa (14.16%). Whereas 28days Compressive strength decreases from 83.42MPa to 81.43MPa (2.38%). (Figure 7)

Split tensile strength decreases as the w/c ratio increases. When w/c ratio increases from 0.23 to 0.27(17.4%), 7days Split tensile strength decreases from 3.66MPa to 3.27MPa (10.65%). Whereas 28days Split tensile strength decreases from4.367MPa to 3.97MPa (9.09%). (Figure 8)

Flexural strength decreases as the w/c ratio increases. When w/c ratio increases from 0.23 to 0.27(17.4%), 7days Flexural strength decreases from 5.72MPa to 5.15MPa (9.96%).Where as 28days Flexural strength decreases from 6.58MPa to 5.65MPa (14.13%). (Figure 9)

It is observed that Compressive strength and Split tensile strength decreases at higher rate for 7days strength when compared to 28days strength, where as the Flexural strength decreases at higher rate for 28days strength when compared to 7days strength.

The relation between the strengths and water cement ratios are as given below.

$f_{ck} = -47.6 \left(\frac{w}{c}\right) + 94.466$

$f_t = -9.64 \left(\frac{w}{c}\right) + 6.5814$

$f_{cr} = -25.2 \left(\frac{w}{c}\right) + 12.418$

Where

f_{ck} = 28 days compressive strength in MPa.

f_t = 28 days split tensile strength in MPa.

f_{cr} = 28 days flexural strength in MPa.

$\frac{w}{c}$ = water cement ratio.

The relation between the flow values and water cement ratios are as given below.

S.F in mm = $630 \left(\frac{w}{c}\right) + 504.5$

T500 in sec = $-16.3 \left(\frac{w}{c}\right) + 8.315$

V-funnel in sec = $-42.6 \left(\frac{w}{c}\right) + 21.204$

T5 in sec = $-66.6 \left(\frac{w}{c}\right) + 30.054$

L-box ratio = $0.75 \left(\frac{w}{c}\right) + 0.7655$

U-box ratio = $-210 \left(\frac{w}{c}\right) + 61.1$

The relation between Compressive strength and Flexural strength is as given below. (Figure 10)

$f_{cr} = 0.5017 (f_{ck}) – 35.309$

The relation between Compressive strength and Split tensile strength is as given below. (Figure 11)

$f_t = 0.1972 (f_{ck}) – 12.113$

Table 2: Workability of the concrete mixes

Workability Tests	Concrete Mixes				
	M1 W/C=0.23	M2 W/C=0.24	M3 W/C=0.25	M4 W/C=0.26	M5 W/C=0.27
Slump flow (mm)	650x650	655x655	662x662	668x668	675x675
T 500(sec)	4.74	4.21	4.16	4.12	3.97

V-funnel(sec)	11.4	11.1	10.4	10.1	9.77
V-funnel T_5 min (sec)	14.60	14.11	13.53	12.91	11.87
L-box(h2/h1)	0.94	0.945	0.95	0.96	0.97
U-box (mm)	13	11	8	6	5

Table 3: Development of compressive strength, split tensile strength and flexural strength with age

Concrete Mix	Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)		Flexural strength (N/mm^2)	
	7days	28days	7days	28days	7days	28days
M1 W/C=0.23	60.44	83.42	3.66	4.367	5.72	6.58
M2 W/C=0.24	59.03	83.07	3.56	4.27	5.64	6.42
M3 W/C=0.25	54.21	82.62	3.39	4.15	5.32	6.18
M4 W/C=0.26	52.13	82.29	3.33	4.1	5.25	5.76
M5 W/C=0.27	51.88	81.43	3.27	3.97	5.15	5.65

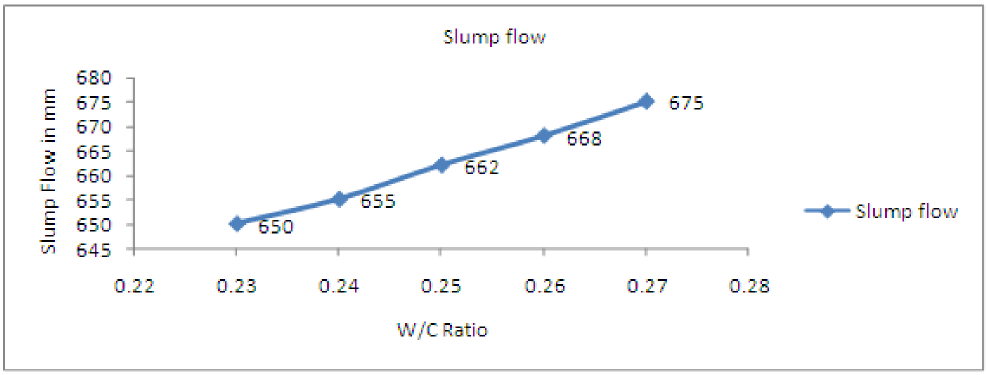

Figure 1: w/c ratio Vs slump flow

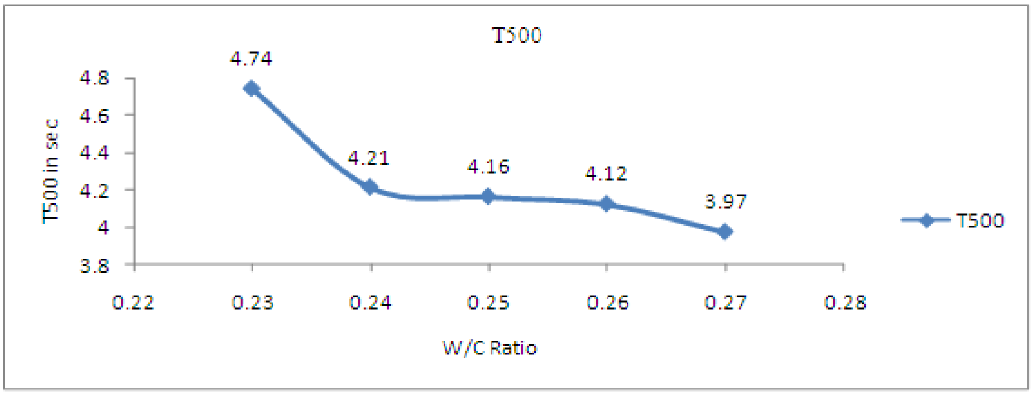

Figure 2: w/c Ratio Vs T500

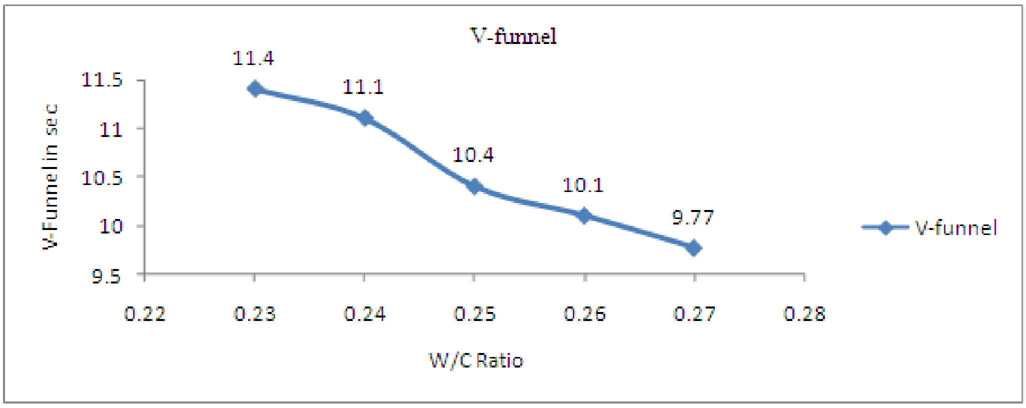

Figure 3: w/c Ratio Vs V-funnel

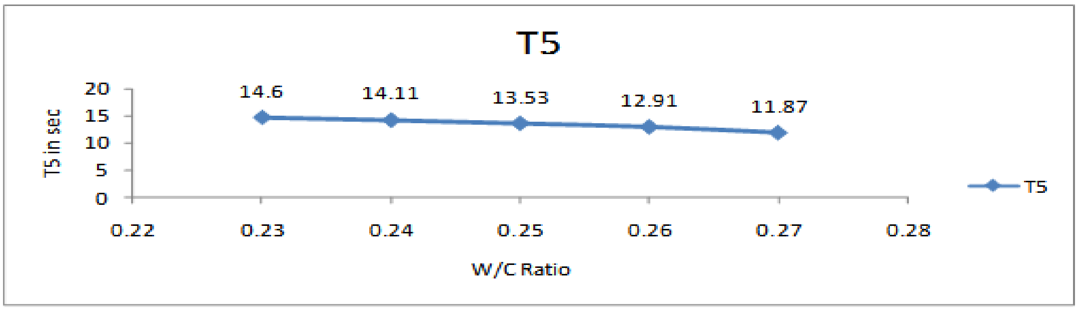

Figure 4: w/c Ratio Vs T5

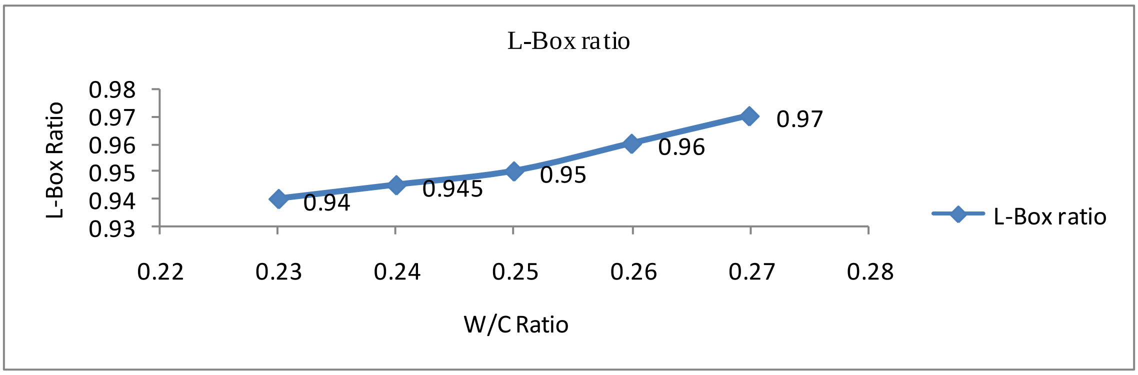

Figure 4: w/c Ratio Vs L-Box Ratio

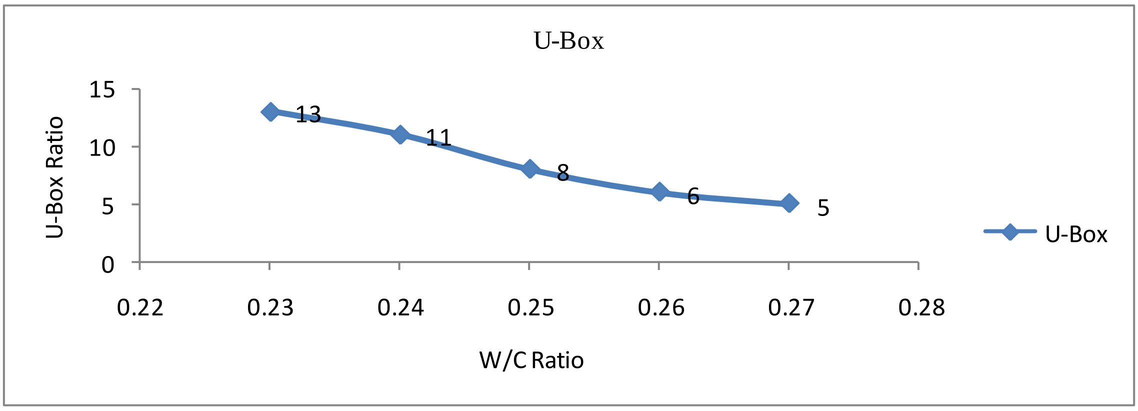

Figure 5: w/c Ratio Vs U-Box

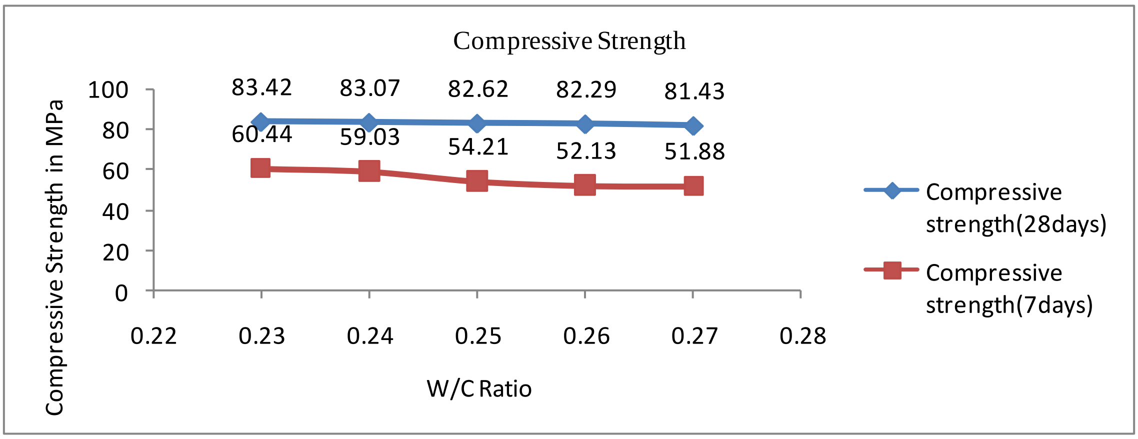

Figure 6: w/c Ratio Vs Compressive strength

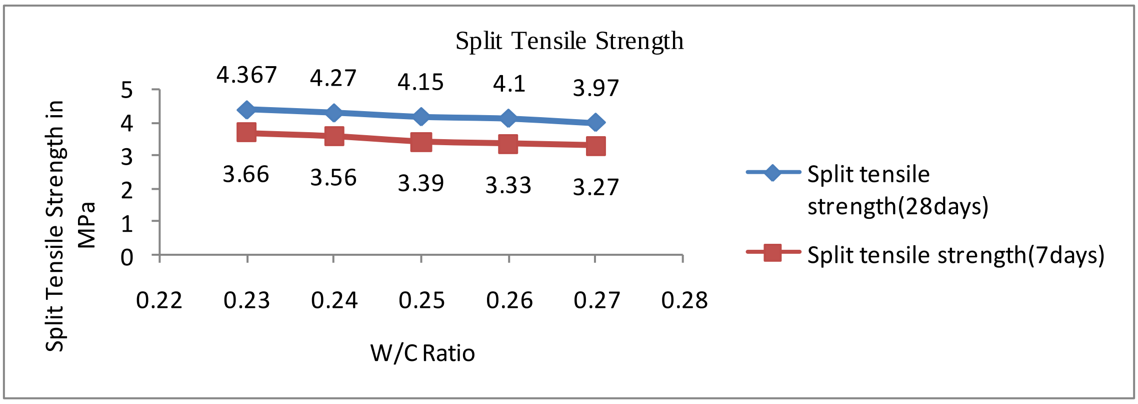

Figure 7: w/c Ratio Vs Split tensile strength

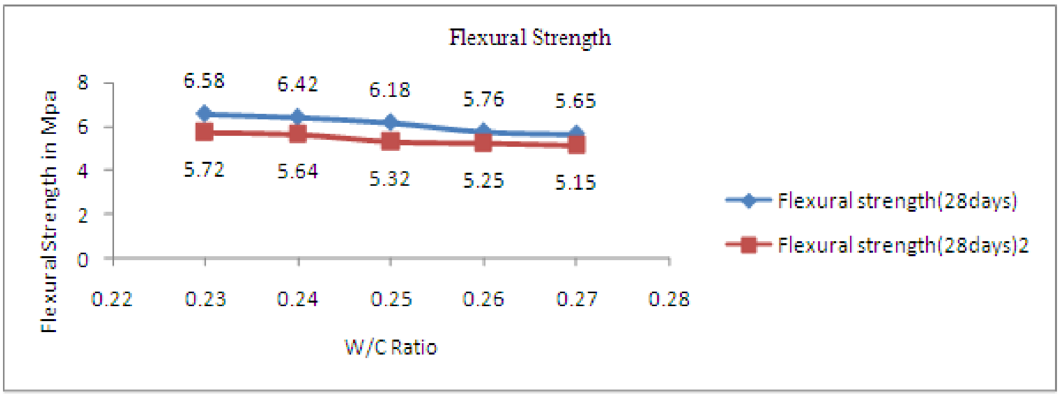

Figure 8: w/c Ratio Vs Flexural strength

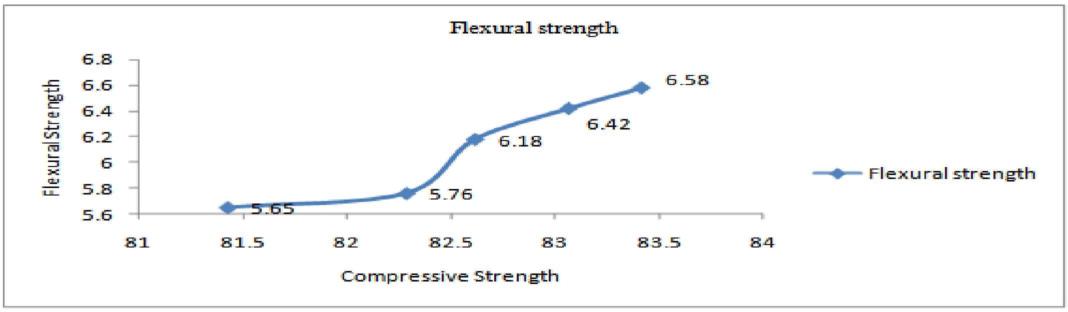

Figure 10: Compressive Strength Vs Flexural strength

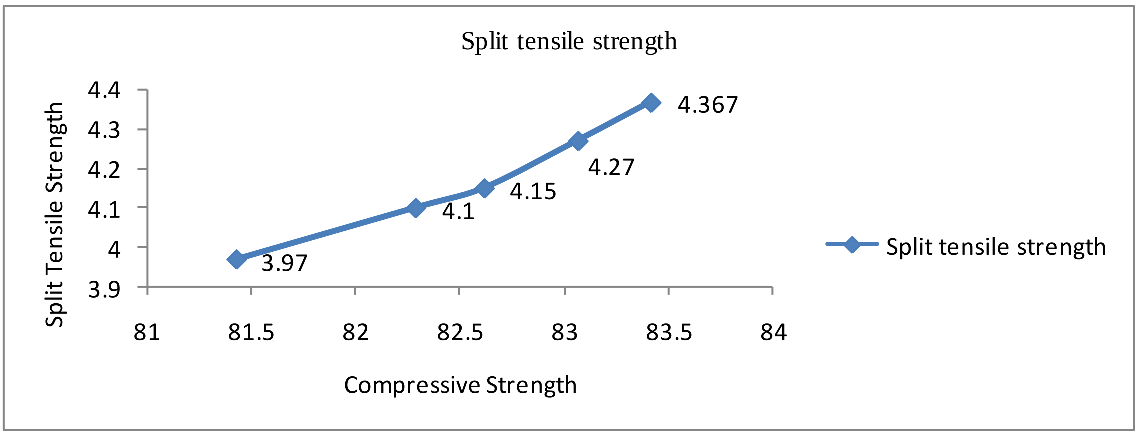

Figure 11: Compressive Strength Vs Split Tensile strength

IV. CONCLUSIONS

From the results presented in this paper using self compacting concrete with different w/c ratios for constant packing factor, the main conclusions are

1. Required minimum slump is achieved for a w/c ratio of 0.23 with optimum strength for M70 grade high strength self compacting concrete.
2. Required minimum strengths are achieved for a w/c ratio 0.27 with optimum slump for M70 grade high strength self compacting concrete.
3. For water cement ratio 0.25 fresh and hardened state properties of high strength self-compacting concrete are moderate.
4. These values are obtained for a Packing Factor of 1.12 with addition of 7% micro silica.

REFERENCES

[1]. Anne-Meike Poppe an Geert De Schutter. "Cement hydration in the presence of high filler contents". Cement and Concrete research 2005, Vol.35, pp 2290-2299.

[2]. Buia, V.K., Montgomeryb, D., Hinczak, I. and Turner, K. "Rapid testing method for segregation resistance of self-compacting concrete," *Cement and Concrete Research*, Vol.32, 2002, pp 1489-1496.

[3]. Celik Ozyildirim, Stephen Lane D, "Measurement of properties of fresh self compacting concrete " Final report, Europian Union Growth Contact No. G6RD-CT-2001-00580,Sepetember 2005 pp 1489 - 1496.

[4]. Collepardi.M., "Self –compacting concrete: What is new? " Poceeding of the seventh CANMET/ACI Conference on Superplasticisers and other chemical dmixtures in concrete, Berlin(Germany), 2003, pp. 1-16.

[5]. Domone, P.L. "A review of the hardened mechanical properties of self-compacting concrete," *Cementand Concrete Composites*, 29, 2007, 1-12.

[6]. European Project Group, *Specification and guidelines for self-compacting concrete*, United Kingdom,

[7]. EFNARC, 2002.

[8]. Felekoglu, B. "Investigation on mechanical and physical properties of SCC," *M.Sc. Thesis in Civil Engineering*, Dokus Eylul University, Izmir, 2003. [12] Felekoglu, B., Turkel, S. and Baradan, B. "Effect of water/cement ratio on the fresh and hardened properties of self-compacting concrete," *Building and Environment*, 42, 2007, 1795-1802.

[9]. Felekoglu, B. and Sarikahya, H. "Effect of chemical structure of polycarboxylate-based superplasticizers on workability retention of self-compacting concrete," *Construction and Building Materials*, 22, 2008, 1792-1980.

[10]. Gibbs JC, Zhu W. "Strength of hardened self compacting concrete". In the 1st International RILEM Symposium on Self-compacting concrete, 1999. Skarendahl.A. Petersson.O.,editors, RILEM Publications S.A.R.L., PP 199-209.

[11]. Gomes.P.C.C, Ravindra Gettu et al., "Experimental optimisation of High Strength Self Compacting Concrete", proceedings of the second international conference on Self Compacting Concrete, Tokyo, October 2001.

[12]. Hemant Sood, Khitoliya R.K. and Pathak .S., " Incorporating European Standards for testing self compacting concrete in Indian conditions". International Journal of Recent Trends in Engineering May 2009, Vol.1, No.6, pp 41-45.

[13]. Khatri, R.P. and Sirivivatnanon, V. "Effect of different supplementary cementitious materials on mechanical properties of high performance concrete," *Cement and Concrete Research*, 25, 1, 1995, 209-220.

[14]. Lachemia M., Hossiana K.M.A, Lambrosa V., Nkinamubanzib and Bouzoubaa N. "Performance of new viscosity modifying admixtures in enhancing the rheological properties of cement paste". Cement and concrete research, 2004, Vol.34, pp 185-193.

[15]. Nan Su, Kung –Chung Hsub and His-Wen Chai. " A simple mix design method for self compacting concrete". Cement and Concrete Research, 2001, Vol.31, pp 1799-1807.

[16]. Su, N. and Miao,B. "A new method for mix design of medium strength flowing concrete with low cement content," *Cement and Concrete Composites*, 25, 2003, 215-222.

[17]. Okamura, H. and Ouchi, M**.** "Self-compacting concrete: development, present use and future," *Proceedings of the First International RILEM Symposioum* , 1999, 3-14.

[18]. Okamura, H. and Ouchi, M. "Self-compacting concrete". Journal of advanced concrete technology, 2003, Vol.1, No.1, pp 5-15

[19]. Ravindra Krishna M. " Strength and durability behaviour of super plasticized high strength concrete using combination of mineral admixtures", PhD thesis of JNTUH, 2005.

[20]. Subramanian, S. and Chattopadhyay D. "Experiments for mix proportioning of Self – compacting concrete", The Indian Concrete Journal, 2002, pp.13-20.

[21]. S. Venkateswara Rao, M. V. Seshagiri Rao and P. Ratihish Kumar. "Effect of size of aggregate and fines on standard and high **strength** self-compacting concrete", Applied science research, 6(5): 433-442, 2010.