International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-3, Issue-8, August 2015

"Correlation of Compressive strength and Dynamic modulus of Elasticity for high strength SCC Mixes"

Priyanka P. Chavhan, Manoj R.Vyawahare

***Abstract*— The Self compacting concrete is one of the best form of high performances concrete which can be used in both reinforced and prestressed concrete structure. The mechanical properties of SCC are required to be investigated for the analysis of reinforced concrete structure and precast concrete structure. The modulus of elasticity is one of the key properties which is investigated and correlated with the compressive strength in this work. The method has been used to find out the dynamic modulus of elasticity of high strength SCC. Vary good correlation has been obtained between the compressive strength and dynamic modulus of elasticity.**

***Index Terms*— Self compacting concrete ; ultrasonic pulse velocity**

I. INTRODUCTION

A. *Introduction of Self Compacting Concrete*

Self-Compacting Concrete (SCC) is a highlyflow ableand non-segregating concrete that does not require vibration when cast, yetIt is capable of flowing through narrowOpenings or extremely congestedReinforcement. SCC is also known as Self-Consolidating Concrete, Self-Leveling Concrete and High-Fluidity Concrete.

Development of Self- Compacting Concreteis a desirable achievement in theConstruction industry in order to overcome Problems associated with cast-in-place Concrete. Self-Compacting Concrete is cast in such aManner that no additional inner or outerVibration is necessary for the compaction. ItFlows like honey and has a very smooth Surface after placing. With regard to its Composition, Self-Compacting Concrete Consist of the same components as conventionally vibrated concrete, i.e. Cement, aggregates and water, with theAddition of chemical and mineral admixturesin different proportions. Usually, the Chemical admixtures used are Super plasticizer and viscosity-modifying Agents, which change the rheological Properties of concrete. Mineral admixturesAre used as an extra fine material, and inSome cases, they replace cement.

B. *Development of Self Compacting Concrete*

The motive for development of Self-Compacting Concrete was the social problem on durability of concrete structuresthat arose around 1983 in Japan. Due to agradual reduction in the number of skilled Workers in the Japan s construction industry,a similar reduction in the quality of onstruction work took place. As a result ofThis fact, one solution for the achievement of Durable concrete structures independent of The quality of construction work was the use Of, which could be compacted into every Corner of a formwork, purely by means of its Own weight vibration giving an improved interface between the aggregate and hardened paste. A number of concrete properties may be related to the concrete compressive strength, the only concrete engineering property that is routinely specified and tested. In this investigation for compressive strength test, standard 100mm cube specimens were cast. The concrete cubes were tested by using Compression Testing Machine having capacity of 2000kn. Three standard cubes each for various mixes were tested to determine 28 days compressive strength.

Priyanka P. Chavhan, M.E. Student, Department of Civil Engineering, B.N. College of Engineering, Pusad, Maharashtra, India
Manoj R.Vyawahare, (Associate Professor) Department of Civil Engineering, B.N. College of Engineering, Pusad, Maharashtra, India

C. *Dynamic modulus of elasticity*

The stress strain relationship of concrete exhibits complexity particularly due to the peculiar behavior of gel structure and the manner in which the water is held in hardened concrete. The value of E is found out by actual loading of concrete i.e. the static modulus of elasticity does not truly represent the elastic behavior of concrete.Due to the phenomenon of creep the elastic modulus of elasticity will get affected more seriously at higher stress when the effect of creep is more pronounced. Attempts have been made to find out the modulus of elasticity from the data obtained by non-destructive testing of concrete. The modulus of elasticity can be determined by subjecting the concrete member to longitudinal vibration at their natural frequency. This method involves the determine of either resonant frequency through a specimen of concrete or pulse velocity travelling through the concrete The value of dynamic modulus of elasticity can also be computed from UPV method.

Ultrasonic Pulse velocity method

This can be sub divided into two parts

a) Mechanical sonic pulse velocity method which involves measurement of the time travel of longitudinal or compression waves generated by a single impact hammer blow or repeated blows.
b) Ultrasonic pulse velocity method, which involves measurement of the time of travel of electronically generator mechanical pulse through the concrete.

Out of these two, the ultrasonic pulse method has gained considerable popularity all over the world.When Mechanical impulses are applied to a solid mass, three different kind of waves are generated. These are generally known as longitudinal waves, shear waves and surface waves. These three waves travel at different speeds. The longitudinal or compression waves travel about twice as fast as the other two types the shear or transverse waves are not so fast, the surface waves are the slowest.

The pulse can be generated either by hammer blows or by the use of an electro acoustic transducer. Electro acoustic transducer are preferred as they provide better control on the type and frequency of pulse generated. The instrument used is called " soniscope ".

Ultrasonic pulse velocity method consists of measuring the time of travel of an ultrasonic pulse, passing through the concrete to be tested the pulse generator circuit consist of electronic circuit for generating pulse and a transducer for transforming these electronic pulse into mechanical energy having vibration frequencies in the range of 15 to 50 kHz. The time travel between initial onset and the reception of the pulse is measured electronically the path length between transducer divided by the time of travel gives the average velocity of wave propagation.

D. *Objective of the investigation*

- The objective of the study presented here is to examine and correlatethe compressive strength and dynamic modulus of elasticity .
- To obtained a better understanding of dynamic test used to compute the dynamic young's modulus using UPV method for SCC.
- To better understand the relationship between the dynamic modulus of elasticity and compressive strength of SCC.

II. MATERIALS AND THEIR PROPERTIES

A. *Materials*

a) Cement

In this experimental study, Ordinary Portland Cement 53 grades, conforming to IS: 8112-1989 was used. The different laboratory tests conducted on cement to determine the physical and mechanical properties of the cement used are shown in Table-1

Table 1: Properties of Cement

Physical Property	Result
Normal Consistency	**29%**
Vicat initial setting time (minutes)	**75 min.**
Vicat final setting time (minutes)	**482 min.**
Specific gravity	**3.15**

b) Aggregates

Locally available natural sand with 4.75 mm maximum size conforming to class II- IS 383 was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 2 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table-2 was used as coarse aggregate. Table-2 gives the physical properties of the coarse and fine aggregates.

Table 2: Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.5	2.85
Fineness Modulus	2.8	7.44
Particle shape	Rounded	Angular

c) Water

Ordinary potable water available in the laboratory was used.

d) Fly Ash

Fly ash is a by-product obtained by burning coal at thermal power plants. For this study FA was obtained from Dirk India Company pvt. Ltd. Eklehra, Nashik. The physical properties of fly ash have been shown in Table-3 and chemical properties have been shown in Table-4.

Table 3: Physical Properties of Fly Ash:

Sr. No.	PhysicalProperties	Test Results
1	Colour	Grey
2	Specific Gravity	2.13

Table 4: Chemical Properties of Fly ash:

Sr. No.	ChemicalProperties	Test Results
1	Loss on ignition	4.17
2	Silica(SiO_2)	58.55
3	Iron Oxide(Fe_2O_3)	3.44
4	Alumina (Al_2O_3)	28.20
5	Calcium Oxide (Cao)	2.23
6	Magnesium Oxide (MgO)	0.32
7	Total Sulphur (SO_3)	0.07

e) Silica Fume:

Silica fume (SF) is obtained from Elkem Ind. Pvt. Ltd. Vashi Navi Mumbai. SF having specific gravity 2.2 as a filler material has been used. Chemical composition of SF is given in table-5.

Table 5: Chemical composition of Silica Fume:

Sr. No	Constituents	Quantity (%)
1	SiO_2	91.03
2	Al_2O_3	0.39
3	Fe_2O_3	2.11
4	CaO	1.5

f) Super plasticizers

Super plasticizers or high range water reducing admixture is an essential component of SCC. It is used to provide necessary workability. Glenium B233 (modified Poly carboxylic ether based) was obtained from BASF India Limited, Nagpur.

III. EXPERIMENTAL WORK

A. *Mix Design*

The mix proportion was done based on the method proposed by Nan Su et al.[3]. The mix designs were carried out for concrete grade 60. This method was preferred as it has the advantage of considering the strengths of the SCC mix. The final mixes were arrived after making some changes to meet the strength and self-compacting ability criteria. The details of mixes are given in table-6.

Table 6: Mixture proportion for 1m^3 of SCC

Specimen	Cement (kg/m^3)	Sand (kg/m^3)	Course aggregate (kg/m^3)	Fly ash (kg/m^3)	Silica fume (kg/m^3)	Water (kg.)	Super plasticizer (kg.)
S_0	437	1048	927.4	150	0	176	5.283
S_{10}	437	1048	927.4	135	15	176	5.413
S_{20}	437	1048	927.4	120	30	176	5.625
S_{30}	437	1048	927.4	105	45	176	5.895
S_{40}	437	1048	927.4	90	60	176	6.025
S_{50}	437	1048	927.4	75	75	176	6.231
S_{60}	437	1048	927.4	60	90	176	6.416
S_{70}	437	1048	927.4	45	105	176	6.538
S_{80}	437	1048	927.4	30	120	176	6.687
S_{90}	437	1048	927.4	15	135	176	6.819
S_{100}	437	1048	927.4	0	150	176	7.044

B. Batching ingredients:- The various ingredients required for SCC mix were taken by weight batching.

C. Mixing of ingredients:- All the ingredients taken by weight batching. Then in mixer all the ingredient are mix in dry condition. Then 70% of calculated amount of water was added to the dry mix and mixed it thoroughly. Then 30% of water was mix with superplasticizer and added in mixer.Then the mix was check for self compacting ability by different tests.

D. ***Self Compactability tests on mixes:-*** Various tests are conducted on the trial mixes to check for their acceptance and self Compactability properties. The tests included slump Flow test and V-funnel tests for checking the filling ability and L-box test for the passing ability. The mixes are checked for the SCC acceptance criteria suggested by EFNARC (2002) given in table no. 7.

Table 7: SCC - Acceptance Criteria

Method	Properties	Range of values
Flow value	Filling ability	650-800mm
V-funnel	Viscosity	6-12 sec
L-box	Passing ability	0.8-1.0

a) Slump Flow Test:

Slump flow &T500 time is a test to assess the flow ability & the flow rate of SCC in the absence of obstructions. It is based on the slump test described in EFNARC (2002). The result is an indication of the filling ability of SCC.

In this experimental work, the slump value of fresh concrete was obtained in the range of 680mm to 730mm. The result has been shown in Table-8.

b) L-Box

L- Box test is used to assess the passing ability of SCC to flow through tight openings including spaces between reinforcing bars & other obstructions without segregation of blocking. The passing ability is calculated from the following equation: PA=H2/H1. In this experimental work, the. L-Box value of fresh concrete was obtained in the range of 0.8cm to 0.94cm.The result has been shown in Table-8.

c) V- Funnel Test

The V-funnel test is used to assess the viscosity & filling ability of SCC. T_v is the V-funnel flow time. In this experimental work,The V- Funnel value of fresh concrete was obtained in the range of 8.65 to 11.35 sec.The result shows in Table-8.

E. ***Preparation of Cube and Cylinders:*** At a time 3 cylinders were cast the laboratory of size 15 cm diameter and 30 cm height. and three cubes were cast of size 10x 10x 10 cm. The casting of cylinder and cube was done as follows. First of all the moulds used for casting purpose were oiled from inside so that the concrete does not stick to the surface. Immediately after mixing, the concrete which fulfilled the acceptance criteria of SCC were filled in mould. The temperature of water and test room was as specified i.e. 27^0 C + 2^{0}C during the above operations.

F. ***Curing of Cube and cylinders:-*** The prepared cylinders and cube were kept at a temperature of 27^{0}C ± 2^{0}C in an atmosphere of at least 90% relative humidity for 24 hrs from the time of addition of water to dry ingredients.At the end of this period concrete cylinders and cubewere taken out of mould for curing purpose. The method of curing was by pounding. In this method after taking out from the moulds they were immediately submerged in clean and fresh water for curing and kept for28 days till they were taken out for testing purpose.

G. ***Testing of Compressive Strength of SCC Mixes :-*** The cube were removed from curing tank turn by turn after 28 days of curing and compressive strength test was performed of each set of cubes. Three standard cubes each for various mixes were tested to determine 28 days compressive strength. Table 9 Gives the compressive strength of different mixes.

H. ***Testing of cylinders:-*** The cylinders were tested for dynamic modulus of elasticity by UPV method after 28 days of curing.

Dynamic modulus of elasticity

By the direct transmission of ultrasonic pulse acrossthe length of cylinder and recording the time required the dynamic modulus of elasticity has been calculated for each specimen. From measurement of ultrasonic wave's velocity it is possible to calculate the elastic dynamic modulus Ed as follows

$E_d = v^2 Q * (1+n)*(1-2n)/(1-n)$

Where,

V =ultrasonic pulse velocity in km/s

Q = concrete density in kg / m^3

N = poison's ratio (for high strength concrete N = 0.15 ,

E_d = dynamic elastic modulus.

IV. TEST RESULTS

A. *Fresh Properties of SCC Mixes*

Various tests were conducted on the trial mixes to check for their acceptance and self compacting properties. The tests included slump flow test and V-funnel tests for checking the filling ability and L-box test for passing ability. The mixes were checked for the SCC acceptance criteria suggested by EFNARC (2002) given in table-7.

Table 8: SCC Test Results of SCC Mixes

Specimen	Slum flow (mm)	V-funnel (sec.)	L-box (cm)	Segregation	Remark
S_0	700	9.76	0.91	No	SCC
S_{10}	710	11.35	0.91	No	SCC
S_{20}	700	10.43	0.85	No	SCC
S_{30}	720	11.1	0.86	No	SCC
S_{40}	730	10.5	0.92	No	SCC
S_{50}	680	11.6	0.88	No	SCC
S_{60}	730	9.36	0.87	No	SCC
S_{70}	685	10.11	0.92	No	SCC
S_{80}	700	9.74	0.89	No	SCC
S_{90}	730	11.1	0.87	No	SCC
S_{100}	700	8.65	0.94	No	SCC

The result of the self compact ability tests are tabulated in table-8. All the mixes satisfied the acceptance criteria for self compacting concrete. Hence these mixes were chosen as the successful mixes.

Compressive Strength of SCC Mixes

It can be seen that SCC with 30% SF and 70% FA gives maximum compressive strength. Three standard cubes each for various mixes were tested to determine28 days compressive strength. The 28 days compressive strength increases from 40.68 to 101.92MPa . Table 7 Gives the compressive strength of cube the mixes

Dynamic modulus of elasticity(Ed)

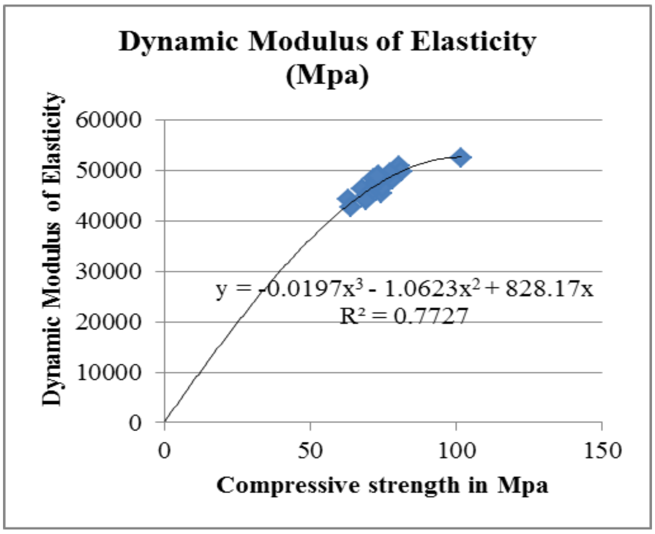
It can be observed that E_d for all specimens in the range of 35420 and 52487 Mpa. The correlation between compressive strength and dynamic modulus of elasticity has shown in following table and graph shows The correlation is represented by polynomial line with equation $\mathbf{y = -1.062x^2 + 828.1x}$. In this equation y represents the dynamic modulus of elasticity x represents the 28 days compressive strength**.** And the correlation can be considered as very good as the coefficient of correlation R^2 is near to 1 i.e. having value equal to 0.981

The self compacting concrete has uniform consistence and hence the values of compressive strength and dynamic modules can be correlated. The even distribution of matrix due to uniformity in concrete mass is possible in SCC than in normally vibrated concrete. That is why the results are so consistent. It

can be seen that the 28 days compressive strength of all the mixes ranged between 63.21 to 101.92 Mpa.

Table 9: Result of Fck and Ed

specimen	Comp Strength 'f_{ck}' (Mpa)	Dynamic Modulus of Elasticity (Mpa)
S0-A	101.92	52487
S0-B	71.73	48298
S10-A	80.38	50744
S10-B	86.82	49204
S20-A	75.4	47658
S30-A	81.29	49629
S30-B	74.56	45314
S30-C	65.6	39873
S40-A	75.01	46557
S40-C	72.45	47206
S50-A	70.92	46212
S50-B	67.83	46317
S60-A	78.35	48154
S60-B	70.36	45409
S70-A	69.65	44985
S70-B	77.61	49387
S80-A	63.21	44302
S80-C	64.01	42634
S90-A	73.45	48927
S90-B	91.47	44125
S100-B	73.13	48714
S100-C	69.17	43969



V. CONCLUSIONS

- Dynamic modulus of elasticity can also be correlated to compressive strength of high strength SCC.
- The UPV test can be effectively used to determine dynamic modulus of elasticity of high strength SCC.
- The UPV method used to determine dynamic modulus of elasticity can indirectly give the compressive strength of high strength SCC using the correlation.

REFERENCES

[1]Rahul Sikka and ArvindDewangan, "Determination Of compressive strength difference between conventional , concrete and recycled

[2]Rahul Sikka and ArvindDewangan, "Determination Of compressive strength difference between conventional , concrete and recycled

[3]M.S. Shetty, "*Concrete Technology*", S. Chand and Company ltd. 572-606

[4]Nan, Su., Kung-Chung, H., His-Wen, C., "*A simple mix design method for self-compacting concrete*", Cement and Concrete Research 31 (2001) 1799–1807

[5]Heba A. Mohamad, "*Effect of FA and SF in SSC on compressive strength and in SSC under different curing conditions"* Ain Shams Engineering Journal (2011) 2. 79-86.

[6]Ravikumar M.S. Selvamony. C. Kannan S.U. Basil; Gnanappa S. "Self compacting concrete ", International Journal on design and Manufacturing Technologies vol. 5 January 2011

[7]Hansen, W., Static and dynamic modulus of concrete as affected by mix composition and compressivestrength, ACI Spec. Publ. SP 95, American Concrete Institute 1986, 115.

[8]Malhotra, V.M. and Berwanger, C., Correlations of Age and Strength with Values Obtained byDynamic Tests on Concrete, Mines Branch Investigation Rep. IR 70-40, Department of Energy,Mines and Resources, Ottawa, June 1970.

[9]MOCKOVČIAKOVÁ et al, "Study of The Relation Between The Static And Dynamic Moduli of Rocks"

[10] Xavier J.; Jesus, A.; Morais, J.; Pinto, J. CITAB/UTAD, Vila Real, Portugal On the "determination

[11] of the modulus of elasticity of Wood b directions dynamic moduli of elasticity with Transformations into anatomical"