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Propagation of Ultrasonic Waves in Self -Compacting -Concrete and Investigation of Distribution of Dynamic Modulus of Elasticity in Concrete

O. Lotfi Omran[1], I.M. Nikbin [2], A.R. Manssouri[3], A. Sadeghi Nik[4], S. Rabbanifar [1] and H. Fallahnejad[1]

[1]Master of Science student of Noushirvani University of Technology, Babol, Iran.
[2]Dept. of Civil Engineering, Islamic Azad University, Rasht Branch, Rasht, Iran.
[3]MSc. Iecturer of Alame Mohades Noori higher education institute, Iran.
[4]Young Researchers Club, Jouybar branch, Islamic Azad University, Jouybar, Iran.

ABSTRACT

Spatial distribution of mechanical properties in a structural element in full scale is a function of numerous variables. These variations can be due to segregation and bleeding while casting and placement of concrete. On the other hand alternation of engineering parameters can cast doubt on construction reliability. Therefore in investigation of these variables in a structural element seems inevitable .Using the technique of ultrasonic sound waves as a non-destructive assess some engineering properties of concrete element. Thus the aim of this paper is to study the degree of dispersion of dynamic modulus of elasticity in walls made of normal and light- weight SCC .The results show that the average of dynamic modulus of elasticity in walls made of SCC rises in direction of casting, but the rise for light- weight SCC is less than that of normal SCC. Also in walls dynamic modulus of elasticity of SCC rises, from up to down, less considerably than compressive strength.

KEYWORDS: reinforced -concrete wall-Dynamic modulus of elasticity, nondestructive ultrasonic test - self compacting concrete.

1. INTRODUCTION

In some cases determination of gradual changes in concrete strength such as strength loss due to freezing or chemical attacks is intended. Such investigations can be achieved through compression tests on standard specimens, but it is preferred to assess changes in quality of samples in- situ because standard specimens may not represent actual properties of concrete. It is because of lack of attention to real curing conditions, ignoring compaction degree of concrete in the structure, changes in the type and quantity of material from one batch to another and also lack of attention to concrete placement. On the other hand relationship between modulus of elasticity and compressive strength, changes in modulus of elasticity in a concrete element is a reliable clue to changes in concrete [1].

In this study we will investigate changes of dynamic modulus of elasticity of concrete in structural reinforced walls made of two types of SCC using Ultrasonic waves technique. Ultrasonic wares method, which is put forward based on calculation of pulse transition velocity, is one of the non-destructive methods by which some of the properties of concrete element in-situ can be assessed. Ultrasonic wave's velocity is a function of physical and mechanical characteristics, and is in relation with basic geometric properties of a uniform material. So it is necessary that for concrete as a non-uniform material specific measure are taken [2, 3, 4]. Concrete studied in this paper is normal and light - weight SCC which can compress under its own weight with no need to vibration. Its use brings advantages such as elimination of traditional compression procedure, reduction of the corresponding noise and work for as well as construction time [5, 6]. Considering the nature of normal and light-weight SCC their high flow ability, any cause changes in mechanical properties of concrete. Studies show that in elements made of normal light-weight concrete, light-weight aggregates, due to porosity and floating in fresh concrete, intend to more and segregate from other ingredients compared to normal concrete [7]. Chi etal also reported that properties and amount of light-weight aggregates in concrete are effective factors in compressive strength and modulus of elasticity [8]. Basically raising the yield stress, viscosity and density of cement paste are strategies concrete out to reduce the tendency of concrete to segregate. In order to do so using admixtures such as micro silica in fresh concrete is one of the fundamental methods .however segregation remains an unfavorable phenomena of high probability in light-weight concrete[9,10].

***Corresponding Author:** O. Lotfi Omran, Master of Science student of Noushirvani University of Technology, Babol, Iran.
Email: O.Lotfiomran@yahoo.com

2. Structural Element under Study

In this study, in order to investigate the distribution of dynamic modulus of elasticity of normal and light-weight SCC in a Structural Element ,two reinforced-concrete walls , one made of normal SCC and one made of light-weight SCC , are fabricated . Walls are reinforced using two meshes of bars 0/2@25.Altheugh the wall is not to be loaded, it is reinforced to show the effect of bars reinforcement on compaction.

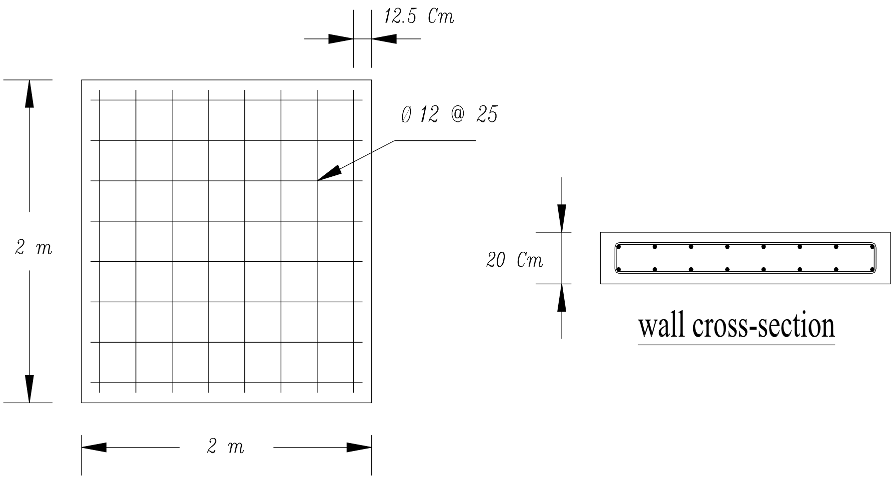


Figure1: Details of reinforcement for the walls

Mixtures of normal and light-weight SCC contain huge amounts of powder which give the fresh concrete required viscosity and flow ability. Science using large quantity of cement leads to rise of cost and production of high temperature, other types of powder such as lime stone powder is used instead. In this study design of mixture was obtained through trial and error and material at the site was used. The cement used is Portland of Neka factory with licallight-weight aggregates. lica is mixed with other materials in a dry environment. Aggregates are comprised of crushed gravel with maximum diameter of 10mm and stream-type sand. The powder and super plasticizer used were Chalous constructional powder and viscocrete respectively. Two mix designs are considered, one for normal SCC with compressive strength of 400 kg/cm2and one for light-weight SCC with compressive strength of 300kg/cm2. Amount of materials used per 1m3 of concrete in different mixes are depicted in table 1.

Table1: Mixture proportions

Mixture Type	Cement (kg/m^3)	Silica fume (kg/m^3)	Super plasticizer (kg/m^3)	Water (kg/m^3)	Limestone powder (kg/m^3)	Leca 0-3mm (kg/m^3)	Fine Agg. (kg/m^3)	Coarse Agg	
								5-10mm (kg/m^3)	10-20mm (kg/m^3)
SCC	350	38.5	8	181	270	-	873	469	384
L-SCC	440	30.8	9.8	198	290	245	382	250	-

Making concrete began by mixers of 0.153 volumes and in 6 steps. Mixing procedure of light-weight SCC was the same as normal concrete with only one difference that mix span SCC was one minute longer than light-weight SCC . After fabrication, properties of fresh concrete were investigated. Properties of fresh concrete are displayed in table 2.

Table2: Fresh properties

Mix Type	Slump flow		V-Funnel, (sec)	L-Box (h2 / h1)	Unit weight (kg/m3)
	T50 (sec)	D Final (cm)			
SCC	2.2	68	7.2	0.93	2373
L-SCC	3.8	69	8.1	0.91	1840

According to table2 it can be seen that result of slump flow test are slightly different from the allowable range .which has already been reported[11] .Based on this report SCC was successfully prepared with the least signs of segregation and with required time of 1s to reach the diameter of 500mm. While casting the reinforced wall, concrete was poured directly from above and with no external vibration into mould. Therefore concrete was allowed to more from a 2-meter height down through reinforcements. The mould is removed after 2 days and concrete is cured with wet sacks for two weeks and then is taken to free air.

3. Ultrasonic test procedure

This method is based on determination of ultrasonic pulse wares velocity passing through objects. Ultrasonic pulses are generated implementing a sudden potential change from a transmitter to a converting pisoelectric crystal that emits vibrations at its own frequencies.Transmitter convertor is placed in touch with concrete and along the walls width and thus vibrations, after passing through the concrete, are received.

Pulse waves transition time through concrete is measured and then by deriding the pared distance by transition time, pulse waves transition velocity is obtained. Making a relation between pulse velocity and compressive strength of specimens, calibrated diagram is provided by which compressive strength of concrete can be determined in situ [12].

In this study ultrasonic test is carried out using Pandit Device at frequency of 54KHZ [13]. In order to conduct the test on reinforced concrete wall, a regular mesh consisting of steel bars at three levels shown in fig 2. These points are designed such that the effect of steel bars on ultrasonic waves velocity can be ignored .At the age of 28days at all points along the walls with of reinforced -concrete wall, ultrasonic test is carried out in the form of direct transition.

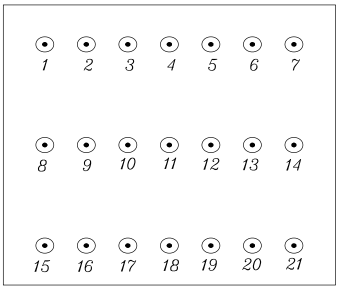


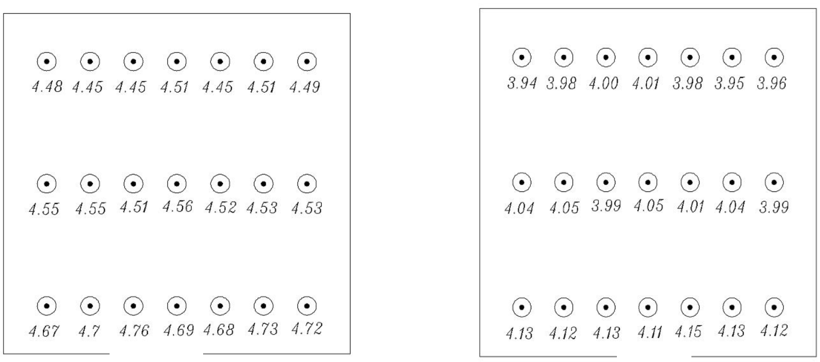
Figure 2: Test positions on walls.

4. Calculation of Dynamic modulus of elasticity

Based on researches a formula has been put forward by which, having ultrasonic wave's velocity and specific weight of concrete, dynamic modulus of elasticity can be obtained as follows[1].

$$E\,d = \rho V^2 \frac{(1+\theta)(1-2\theta)}{(1-\theta)}$$

Where Ed is Dynamic modulus of elasticity, p is specific weight of concrete (kg/m3), V is dynamic poison's ratio and V is velocity of ultrasonic waves. Calculation of dynamic poison's ratio has already been reported by researches which are 0.22 and 0.21 for normal and light - weight concrete respectively [14].



(a) (b)

Figure3: Ultrasonic pulse velocity measurements in different test points of the reinforced concrete walls: (a) self compacting concrete, (b) lightweight self compacting concrete (km/sec)

According to the results obtained from ultrasonic test in determined point of the wall and using eq (1) distribution of dynamic elasticity and its probable changes are investigated. The average velocity of ultrasonic waves and dynamic modulus of elasticity at three levels, 25,100 and 175 cm from the bottom of the wall, are depicted in table3.

Table 3: Estimated in-situ dynamic modulus and test results (28 days).

Level of walls	SCC		LW-SCC	
	E_D (Mpa)	Ultrasonic pulse velocity measurements (Km/s)	E_D (Mpa)	Ultrasonic pulse velocity measurements (Km/s)
Top	41.7	4.48	26	3.97
Middle	42.8	4.53	26.7	4.02
Bottom	46.1	4.71	28.1	4.12

Note: E_D =Dynamic Modulus

As expected, dynamic modulus of elasticity of both normal and light-weight concrete reduces from the bottom to the uppermost level. This reduction in height is the result of bleeding, segregation and also hydrostatic effects of concrete along the height of the reinforced -concrete wall. Relative changes in dynamic modulus of elasticity of normal and light-weight SCC and their compressive strength at different levels of the wall versus dynamic modulus of elasticity and compressive strength at the bottom lever are plotted in fig(4).

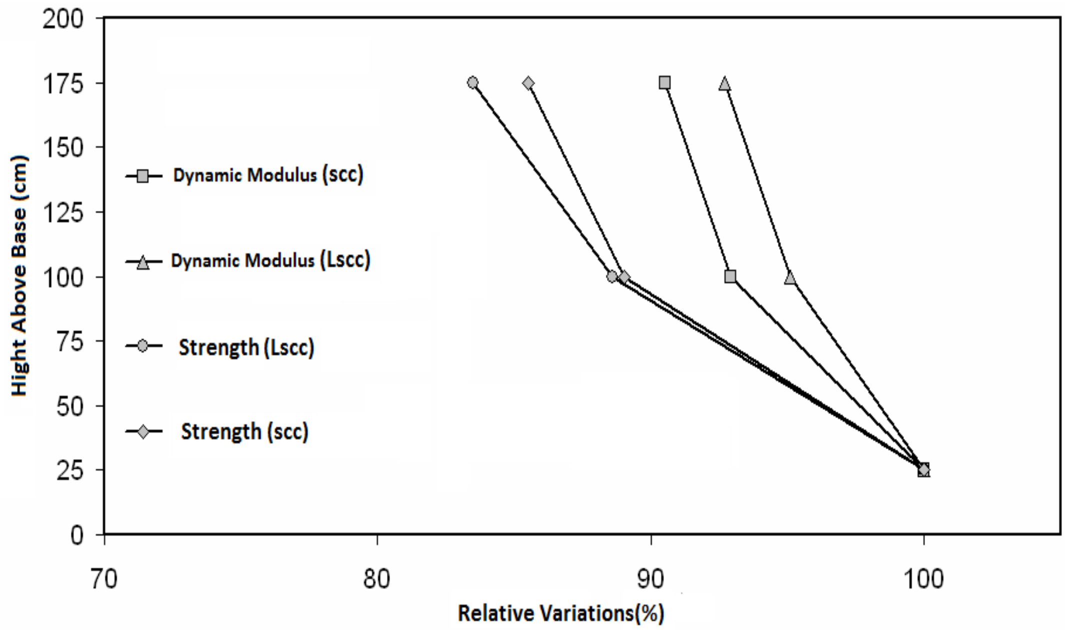


Figure 4: In situ dynamic modulus and strength variations across height of walls.

According to fig (4) it can be observed that there has been a decrease of 9.5% and 7.1% in dynamic modulus of elasticity of normal SCC at the top and mid elevation compared to the base respectively. As for the light-weight SCC results indicate that there has been a 7.3% and 4.9% at the top and mid elevation compared to the base respectively. Comparing the result it could be observed that rate of dynamic modulus of elasticity changes along height of wall made of light-weight SCC is 20% less than that of SCC however it is reported by Astyrakakis [15] that dynamic modulus of elasticity is slabs made of normal and light- weight concrete show no sign of change along height .It seems that low height of slab compared to the wall under study herein, accounts for the change in results.

Furthermore, according to fig4 for SCC rate of dynamic modulus of elasticity growth along the height of wall, from up to down, is less considerable than compressive strength changes [16, 17]. In this research investigation of dynamic modulus of elasticity change rate of concrete along the length of wall in normal and light - weight SCC is also intended. Studying diversion of dynamic modulus of elasticity from the average along the light-weight concrete wall at any level is about 1%. This indicates that location of the point under study along the wall and also its elevation makes no difference in the results.

5. Conclusion

1-the average dynamic modulus of elasticity decreases from the base level to upper levels such that dynamic modulus of elasticity at the uppermost level of normal SCC and light-weight SCC was 90.5% and 92% of the value at the bottom respectively.
2- Rate of changes of dynamic modulus of elasticity along the height of light - weight SCC wall is 20% less than that of normal SCC.
3-In SCC increase rate of dynamic modulus of elasticity along the height from up to down is less than that of compressive strength.
4- Diversion of dynamic modulus of elasticity from the average along the wall made of light-weight concrete at any level is about 1%.

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