The Effect of Time on the Workability of Different Fresh Concrete Mixtures in Different Management Conditions

[1]Joseph Chukwuka Okah[*] and [2]Okore Godwin
[1]Department of Building Technology,
Rivers State College of Arts and Science,
Port Harcourt, Nigeria
[2]Department of Civil Engineering,
Abia State Polytechnic,
Aba, Nigeria
*Corresponding author Email: **engineerjoeciv@yahoo.com**

ABSTRACT

Workability can be defined as the amount of useful internal work necessary to produce full compaction. Consistency, mobility and compactability define workability. Factors such as constituent materials and environmental conditions affect workability. Research works has been done on the factors while field work continues to be starved of knowledge of the effect of time after mixing on workability. To this end, this paper presents an investigation into the effect of time on the workability of different fresh concrete mixtures handled differently. To achieve this, a slump test, compacting factor test and the modified Vebe consistometer test was carried out under ambient conditions of 29-30^{0}C temperature, 95% relative humidity and less windy condition with 250kg, 350kg, 415kg, 545kg and 560 kg of cement and max. aggregate size of 40mm at w/c ratio of 0.45. The results (curves) show that in 1hr times the loss of workability of the un-agitated mixes was remarkable while the agitated concrete still retains an appreciable workability after 1hr but tends to lose its workability totally in 2½hrs time. It showed that the % loss of workability of un-agitated MX1, MX2, MX3, MX4 and MX5 dropped by 75%, 70%,75%, 66.7% and 68.2% after 1hr against the 43.8%, 40%, 40%, 38% and 40.9% of the agitated concretes respectively by slump test. Also, the workability tends to increase as the cement-aggregate ratio increases. The three results showed a similar trend even if no relationship existed between them.

KEYWORDS: *Workability; Slump; Compacting factor; Vebe time; Agitated; Un-agitated; Mix ratio*

INTRODUCTION: The characteristics of fresh concrete which defines workability are consistency, mobility, and compactability. Consistency is a measure of fluidity while mobility is the ability of fresh concrete to flow into a formwork. Compactability is the ease with which entrapped air, voids and segregation can be eliminated from a mix. For a fresh concrete to be stable, it must maintain its uniformity which also depends on its consistency and cohesiveness. Workability in concrete practice offers an insight on plastic behavior of fresh concrete. This explains why a lot of research has been done on the effects of factors like water-cement ratio, aggregate size, shape and grading, admixture, ambient condition etc. on workability. Marar and Eren, (2011) writes that as cement content increases, compacting factor increases and also, a decreasing aggregate/cement ratio increase the compacting ratio. ACI, 238.1 (2008), explains also, that the higher the water-cement ratio, the more workable is the mix. Workability is also enhanced by the use of super plasticizers (ACI 238.1, 2008, Duggal, 2012). A well graded aggregate also helps in reducing voids making cement paste available for better lubrication (ACI 238.1, 2008). However, Kaplan, (2015) and Donzar et al, (2002) pointed out that angular and flaky aggregate reduces workability because they have greater surface area and more voids which reduces the available paste for lubrication. Pereira et al (2012) also showed that concrete with super plasticizers produced a superior workability to that without admixtures. Abdullah, (2001) writes that increased temperature increases the rate of hydration and evaporation with attendant loss of workability. This paper presents an experimental investigation into the effect of time delayed after concrete mixture of different constituent proportions under different management conditions.

2.0 MATERIALS AND METHOD

2.01 Materials

The cement used for this investigation in the laboratory was the Ordinary Portland Cement of class 45.2R according to BS 4550. The fine aggregate was the locally available alluvial sand with specific gravity of 2.6. The grading of the aggregate was according to BS 882 (1992). Drinkable water from tap was used for all the mixes. The W/C ratio used was 0.45. No chemical admixture or plasticizer was added. The experimental investigation was carried out under suitable ambient conditions of 29-30^{0}C temperature, 95% relative humidity and less windy condition.

2.02 Mixing Procedure

Table 1: Sieve analysis of the fine aggregate

S/No	Sieve size (mm)	% passing
1	5.00	100
2	2.36	90.4
3	1.18	62.5
4	0.60	41.4
5	0.30	21.2
6	0.15	5

Table 2: Sieve analysis of the coarse aggregate

S/No	Sieve size (mm)	% passing
1	40	100
2	20	95.2
3	10	22.4
4	5	5.0

A laboratory tilting concrete mixer was used as follows:

- Coarse aggregates, fine aggregates and cement were mixed for two minutes
- Water was added in thirty seconds and mixing continued for another two minutes
- Mixing was stopped for one minutes

- Testing was delayed for eight minutes

The last step was done to allow for the absorption of water by dry aggregates

2.03 Mix Proportions

Table3: Mix Proportion of concrete

Mix Tag	Mix ratio	Mix proportions in kg/m^3			
		Cement	Sand	Coarse aggregate	Water
MX1	1:3:6	250	720	1400	98
MX2	1:2:4	350	676	1302	138
MX3	1:1½:3	415	620	1240	162
MX4	1:1:2	545	565	1132	210
MX5	-	560	530	1005	220

2.10. Test Methods

Two samples of concretes were prepared under same condition, one agitated before test while the other remained un-agitated or undisturbed. The tests for the workability of the different concretes were carried out after ¼hr, ½hr, 1hr and 2½hrs time of mixing.

2.11. Slump Test

The test primarily measures the consistency of fresh concrete, hence detecting changes in the workability of concrete. It consists of a 300mm high frustum metal cone of internal diameter, 200mm at the base and 100mm at the top. The procedure was basically done by filling the frustum with fresh concrete in 3 layers of equal volume with each layer compacted with 25 strokes of a tamping rod. Thereafter, the frustum was removed and the concrete subsided. The slump or subsidence was measured as the difference between the top of the frustum and the subsided concrete according to BS 1881-102, EN 12350-2 (2000).

2.12. Compacting factor Test

This test measures the degree of compaction impacted on concrete for a standard workdone which is a reliable assessment of the workability of the concrete. The apparatus consists of upper and lower hoppers mounted on two sittings and a cylinder with a base sitting. The test was performed by placing the fresh concrete in the upper hopper A to its mouth with a hand trowel. The concrete was allowed to fall into the lower hopper B by opening the bottom trap door. Concretes stuck at the sides of the hopper A were pushed down into the lower hopper B with a steel rod. Again, the concrete in hopper B was allowed to fall into the cylinder beneath and weighed. The value recorded as W_1. The cylinder was filled with fresh concrete in layers of

50mm compacted by 100%. The cylinder was wiped off, weighed and recorded as W_2. The compaction factor was calculated as ratio (W_1/W_2) according to BS 1881: Part 103 (1993).

2.13. Vebe test

This test is suitable for a whole wide range of mixes and it is sensitive to variations in workability of very dry mixes and precast concrete mixes. The test measures the time taken to transform or remold a standard frustum of concrete by vibration to a compacted mass. Thus the time required to perform this action is the *vebe time* in seconds. The apparatus consists of a slump frustum placed at the center of a metal cylindrical container mounted on a vibrating table whose vibration is sinusoidal. A slump test as described above was conducted first, and then a clear plastic disc was placed on top of the fresh concrete. Then the vebe table is vibrated and the time taken for the remolding of the slump frustum shape to the shape of the metal cylindrical container was recorded as a measure of the consistency. The test is according to BS 1881-104, EN 12350-3 (2000).

3.0 RESULT AND DISCUSSIONS

3.1 Slump Test Result

The result of the slump test in table 4 shows that each concrete mixture whether disturbed or undisturbed after ¼hr had similar slump since the consistency of the mix at that time is still very plastic.

Fig 1: Workability Loss (MX) with time by slump

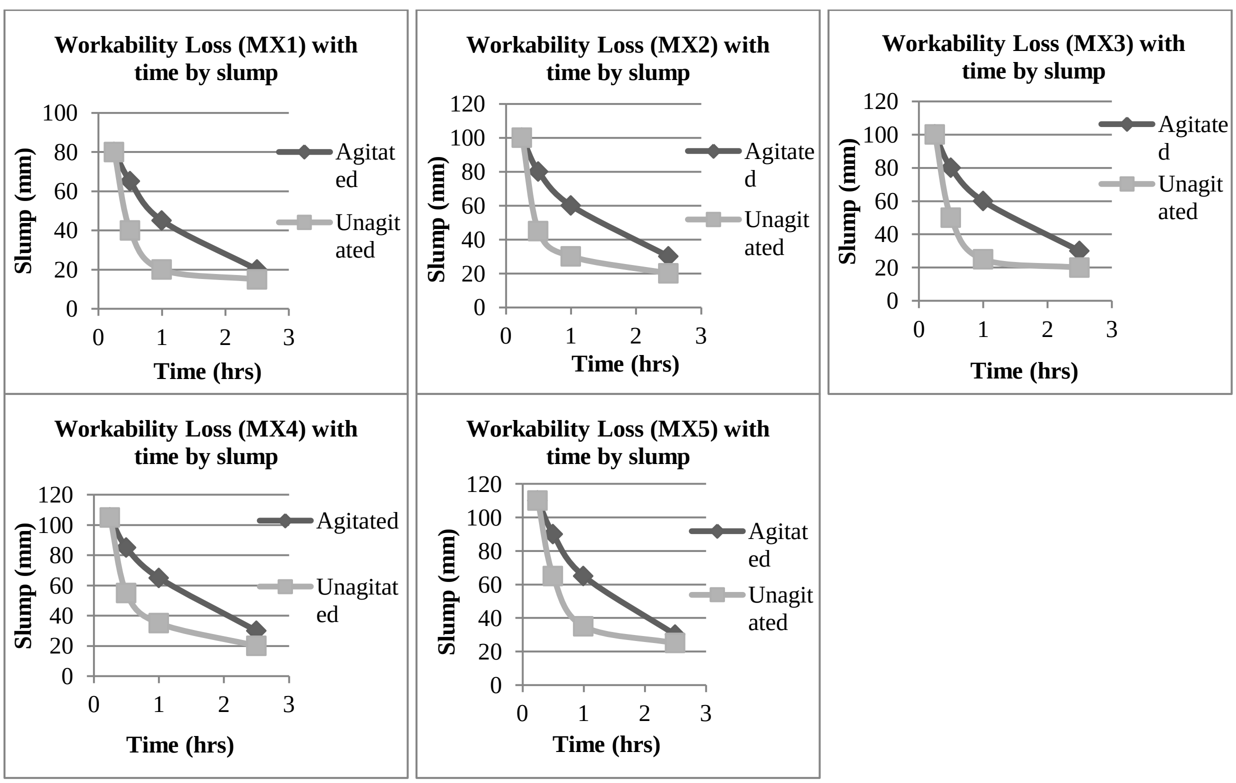

Table 4: Result of the experimental investigations

S/No	Mix Ratio	Delayed Time (hrs)	Slump (mm)		Compacting factor		Vebe degree (sec)	
			Agitated	Unagitated	Agitated	Unagitated	Agitated	Unagitated
1	MX1 1:3:6	¼	80	80	0.86	0.86	6.0	6.5
		½	65	40	0.83	0.76	6.8	8.5
		1	50	20	0.80	0.73	8.0	12.2
		2½	20	15	0.75	0.70	9.5	14.1
2	MX2 1:2:4	¼	100	100	0.90	0.89	5.5	5.8
		½	80	45	0.88	0.8	6.0	7
		1	60	30	0.84	0.77	7.4	10.5
		2½	30	20	0.77	0.74	10.1	13.2
3	MX3 1:1½:3	¼	100	100	0.91	0.90	5.5	5.5
		½	80	50	0.88	0.82	6	7.2
		1	60	25	0.84	0.79	7.4	10.5
		2½	30	20	0.78	0.75	10.1	13
4	MX4 1:1:2	¼	105	105	0.92	0.91	4.0	4.0
		½	85	55	0.90	0.85	5.2	7
		1	65	35	0.87	0.81	6.8	9.5
		2½	30	20	0.80	0.75	10.0	12.8
5	MX5 -	¼	110	110	0.93	0.93	4.0	4.1
		½	90	65	0.92	0.86	5.0	7.2
		1	65	35	0.87	0.81	6.8	9.8
		2½	30	25	0.81	0.78	10.5	12.5

However as the time increases there were a reduction in the workability of the concrete in both cases. Interestingly, fig. 1 showed a sharp fall in the workability of the un-agitated concrete for all the mixes against a gradual fall in the workability of the agitated concrete in 0-1hr time. To buttress this also, table 5 clearly showed a workability loss of 75% in 0-1hr time for the undisturbed mix (MX1) which is far less than the 43.8% for agitated mix. Table 5 showed that there is increase in workability as the mix ratio decreases. Also, comparing column 4 and 7 of table 5, the %loss of workability is higher for the un-agitated mixes in 0-1hr time than the 1-2½hrs interval. Therefore, it can be said that much of the loss of workability takes place in the first 1hr time for un-agitated concrete. The flat zone of fig 1 explains this.

Table 5: % loss of workability (slump)

S/No	Mix	% loss of workability in agitated condition in 1hr	% loss of workability in un-agitated condition in 1hr	% loss of workability in agitated condition in 1-2½hrs	% loss of workability in un-agitated condition in 1-2½hrs
1	MX 1	43.8	75	55.6	25
2	MX 2	40	70	50	33.3
3	MX 3	40	75	50	20
4	MX 4	38	66.7	53.8	42.9
5	MX 5	40.9	68.2	53.9	28.6

Too much hydration of the un-agitated concrete which had already taken place after 1hr time accounts for the low % loss of workability of un-agitated concrete in 1-2½hrs time. There was also a large % reduction of the workability of agitated concrete in 1-2½hrs which is observed in the gradual fall of the agitated curve in fig 1. This indicates that an agitated concrete is still workable between 1-2½hrs after mixing.

3.2 Compacting factor Result

The similar compacting factor recorded in table 4 after ¼hr indicates that the concretes are still plastic. However, as the time increased, workability of all the mixes reduced. Interestingly, fig 2 clearly showed a sharp decline in the workability of the undisturbed concrete contrary to the gradual decline for that of the agitated mixes in 1hr time. This is supported by table 6, with a similar trend. Comparing table 6, column 3 & 4 for example, there is 15.1% loss of workability of un-agitated MX1 as against 3.5% loss for the agitated MX1 in the 0-1hr. The almost horizontal part of fig 2 indicates a very small decrease in the already lost workability of the un-agitated concrete. This can be attributed to the fact that the concrete has undergone a lot of hydration in 1-2½hrs and hence unworkable after 1hr time. Contrarily, the curves (same trend in table 6, column 6) showed a gradual fall indicating the agitated mix still has appreciable workability in 1-2½hrs time.

Fig 2: Workability Loss (MX) with time by compacting factor

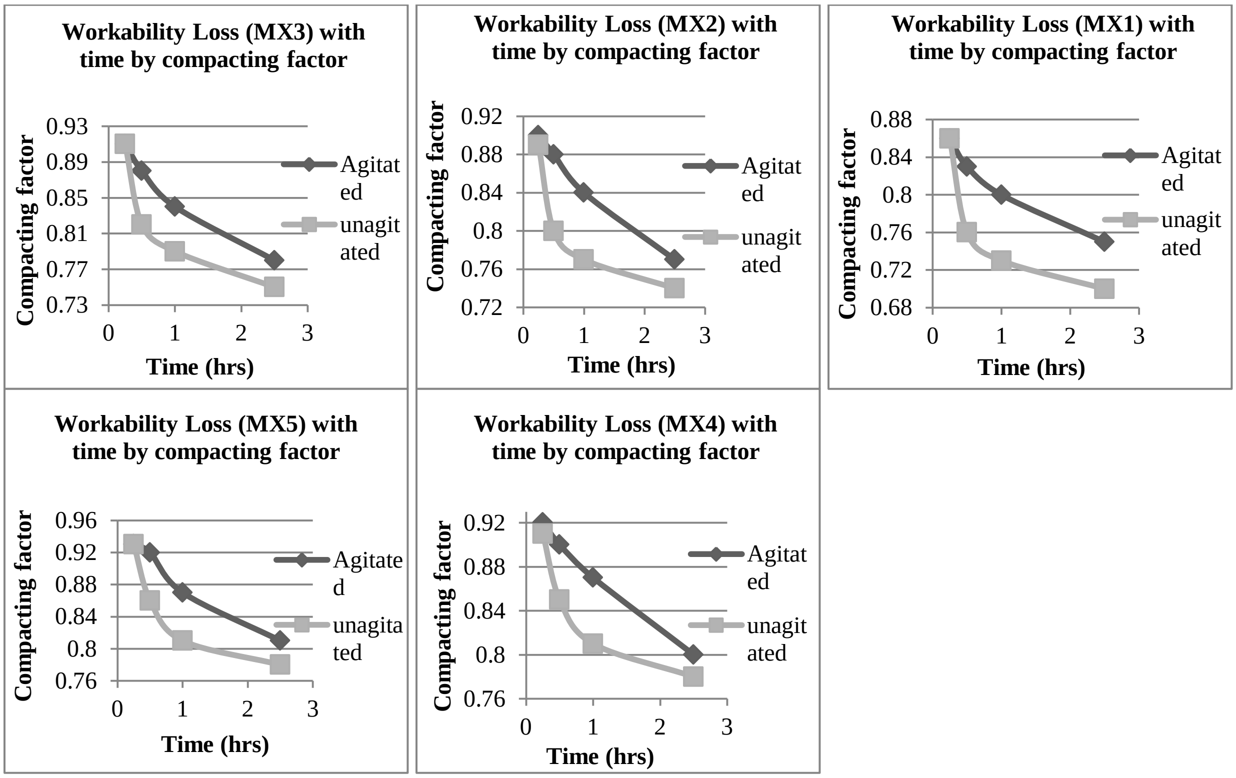

Table 6: % Loss of workability by Compacting factor

S/No	Mix	% loss of workability in agitated condition in 1hr	% loss of workability in un-agitated condition in 1hr	% loss of workability in agitated condition in 1-2½hrs	% loss of workability in un-agitated condition in 1-2½hrs
1	MX 1	3.5	15.1	6.3	4.1
2	MX 2	6.7	13.5	8.3	3.9
3	MX 3	7.7	13.2	7.1	5.1
4	MX 4	5.4	11.0	8.1	3.7

5	MX 5	6.5	12	6.9	3.7

3.3 Vebe test result

The vebe time recorded in table 4 shows that as the vebe time increases, the concrete loses its workability. Thus the curve in fig 3 has a proportional shape. It can be observed that there is a sharp reduction of the workability of the un-agitated mixes.

Fig 3: Workability Loss (MX) with time by Vebe time

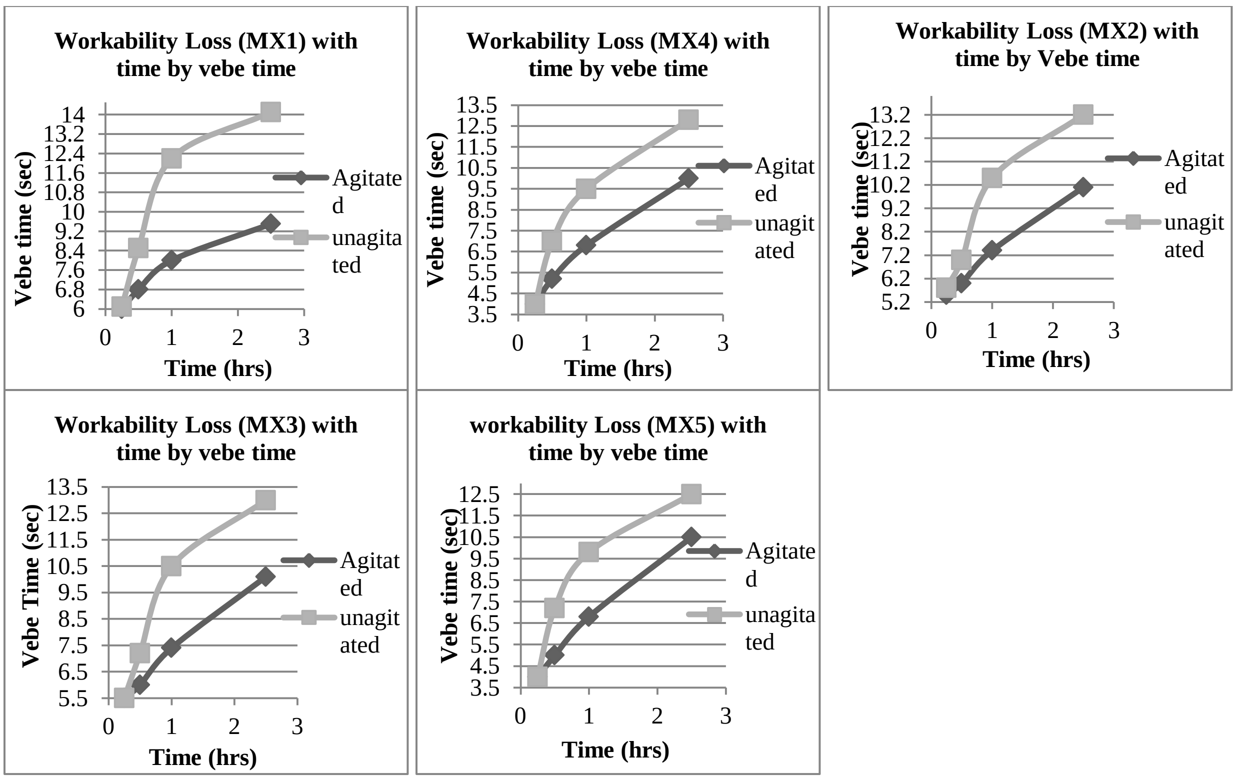

Table 7.0**:** % loss of workability (vebe time)

S/No	Mix	% loss of workability in agitated condition in 1hr	% loss of workability in un-agitated condition in 1hr	% loss of workability in agitated condition in 1-2½hrs	% loss of workability in un-agitated condition in 1-2½hrs
1	MX 1	25.0	50	15.8	13.5
2	MX 2	25.7	44.8	31.7	20.5

3	MX 3	25.7	47.6	31.7	20.5
4	MX 4	41.2	61.1	32	25.8
5	MX 5	41.2	59.2	35.2	21.6

.

This is represented by the steep sloped area. For example, the workability of un-agitated MX1 concrete reduced from 6.1-12.2 sec representing 50% (table 7) loss in workability in 0-1hr while the same agitated concrete lost workability from 6.0-8.0sec representing only 25% loss in workability in same time interval. From fig 3 and table 4, the mix ratio is decreasing with increasing workability. Interestingly, fig 3 also showed a gentle rising part in 1hr time, showing that the un-agitated mix had lost a considerable workability. Table 7 quantitatively gave the % loss of workability as 13.5% for MX1 in 1-2½hrs. This implies that, the un-agitated concrete is no longer workable after 1hr unlike the 15.8% and 30.7% (MX1 and MX2) loss of workability of agitated MX1 and MX2 respectively showing that after 1hr the agitated concrete still has appreciable workability. This further showed that agitated mix can still be workable in 2½hrs time after mixing provided it can be agitated optimally before placement and compaction. From the result, a similar explanation followed the slump and compacting factor even if there is no relationship between them for different concretes.

4.0 CONCLUSIONS

From the results obtained and presented in this paper, the following conclusions were made:

- Workability tend to decrease with increasing time wastage before placement and compaction
- The higher the cement-aggregate ratio, the better the workability. This is as a result of more available paste to facilitate better workability
- The loss of workability of the concretes was remarkable or sharp for the un-agitated concrete than the agitated mix in 1hr time. Implying that un-agitated concrete loses its workability faster under 1hr time hence concretes should be placed and compacted within a minimum of 1hr after mixing unless optimally agitated before placement and this should be done in 2½hrs.
- From the slump, compacting factor and vebe test results, the workability of the un-agitated and agitated mixes tend to have the same workability in 15mins time ostensibly because water is still very much available for hydration of cement compounds for bonding.
- From the slump test, the workability of un-agitated concrete drops by 75%, 70%, 75%, 66.7% and 68.2% for MX1, MX2, MX3, MX4, and MX5 respectively in the first 1hr
- The agitated concretes tend to retain appreciable workability beyond 1hr due to the disturbance and this is gradually lost in 1-2½hrs time.

- Therefore, agitating the already mixed concrete before compaction is very vital in keeping the workability of the concrete intact and hence provides an avenue for proper bonding.

References

Abdullah, A .A. (2001). The effect of Environmental conditions on the properties of Fresh and Hardened Concrete. Cement and Concrete composites, 23 (4), 353-361.

ACI Committee 238. (2008). Report on Measurements of workability and Rheology of fresh Concrete. American Concrete Institute, 238.1R-08.

BS 882: (1992). Specification for aggregates from natural sources for concrete. British Standard Institute.

BS 1881-102: (1993). Method for determination of Slump. British Standard Institute.

BS 1881-103: (1993). Method for determination of Compacting factor. British Standard Institute.

BS EN 12350-2 (2000). Testing Fresh concrete: Slump test. British Standard Institution.

BS EN 12350-3 (2000). Testing Fresh concrete: VeBe test. British Standard Institution.

BS 4550: (1978). Methods of testing cement. British Standard Institution.

Donzar, H., Cabrera, O., & Irassar, E.F. (2002). High-strength concrete with different fine aggregate. Cement and Concrete Research. 32 (11), 1755-1761.

Duggal, S. K. (2012). Building Materials. New Age int'l (P). (4th ed.), New Delhi.

Kaplan, M.F. (2015, May 25). The effects of the properties of coarse aggregates on the workability of concrete. Magazine of Concrete Research. 10 (29), 63-74.

Pereira, P., Evangelist, L., & De Britto, J. (2012). The effect super plasticizers on the mechanical performance of concrete made with fine recycled concrete aggregates. Cement and Concrete composites. 34 (9), 1044-1052.