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RESEARCH ARTICLE Open Access

EFFECT OF WAITING TIME BEFORE RE-VIBRATION ON FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAM

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Abstract:
The purpose of this study is to examine the impact of waiting before re-vibration. and variable time duration for vibration and re-vibration operation of structural response for flexural reinforced concrete beams and using Ordinary Portland Cement-type 1, with w/c ratio of 0.4, and a greater number of re-vibration time lag intervals ranging from half an hour to two hours to evaluate the impact of re-vibration on the mechanical properties of concrete with different time duration of vibrations ranging from 15 to 60 seconds. The experimental schedule includes a total of 28 twenty-eight rectangular reinforced concrete beams of dimension (125 mm x 250 mm) and length of 1500 mm was prepared for this work. Using the re-vibration technique in construction of structural members is expected to improve the structural properties of the beams, and cracking. The result of the waiting time before re-vibration must be investigated and time duration of vibrations on the structural response of flexural reinforced concrete beams to establish and verify the best process to apply this technique.

Keywords: *Re-Vibration; Tensile Strength; Compressive Strength; Deflection*

1. Introduction

Concrete is a constructed stone that is set in place when it is still flexible. Numerous issues can arise throughout the concrete-laying process that could compromise the hardened concrete's qualities. The goal of this study is to look at how vibration affects concrete's qualities, both in the soft and hardened states, specifically the strength. The goal of this experimental work is to investigate the influence of vibration time duration and delaying the re-vibration of concrete in order to get a better understanding of the consequences and processes at work. The impact of Kurdistan and Iraq's hot-dry environment, as well as the period of beneficial vibration, are especially targeted.

Re-vibration is the delayed vibration of previously laid and compacted concrete. It might occur while pouring consecutive layers of concrete when the higher layer of freshly-poured concrete partially set, or it could be done consciously to gain particular advantages.

Re-vibration is not detrimental and may even be advantageous, unless the concrete is exposed and under the condition that it turns plastic when vibrated. Concrete's quality can be increased by repeated vibration over a lengthy period of time (repetition of vibration begins one hour after the initial vibration), It results in full contact between the mortar and the coarse aggregate or between the steel and the mortar and provides stronger and waterproof concrete by rearranging the aggregate particles, eliminating trapped water from behind the aggregate and steel.

Plastic shrinkage fractures and other disturbances, such as void areas below the reinforcing bars and below the coarse aggregate, can therefore be closed again if the concrete softens when the vibrator head is placed. Concrete that has been re-vibrated has increased compressive and bond strengths, released water that had been trapped under horizontal reinforcing bars, and eliminated air and water pockets.

Re-vibration is most successful at the maximum duration following the original vibration if the concrete is sufficiently plastic to allow the vibrator to fall under its own weight into the concrete and briefly change it into plastic.

It has been discovered, in particular, that "re-vibration" of concrete can result in appreciable gains in strength as long as the concrete is once more returned to a pliable state. Several ideas have been proposed to explain how re-vibration increases strengths. The experimental program described in this paper, which examines how re-vibration affects the compressive and flexural strengths of concrete, is intended to aid in understanding the positive impacts that re-vibration introduces.

2. Literature Review

Auta et al [1] investigated the flexural strength of a concrete beam that had been vibrated again. The 150 x 150 x 600 mm beams were strengthened with 12 mm steel bar. After first vibration, the beams were re-vibrated for 20 seconds every 10 minutes for up to an hour. The findings demonstrated that the beam's flexural strength was improved by the re-vibration process.

Aziz et al [2] investigated the impact of re-vibration time and steel fiber content on the characteristics of concrete built using coarse aggregate formed of crushed cement-sand mortar. According to the findings, re-vibration with a volume percentage of steel fiber of about 0.5 percent occurred around an hour after the original vibration, which increased the concrete's compressive and splitting tensile strength.

Kassim [3] investigated how re-vibration affected the compressive strength of concrete cylinders made of retarded concrete. The time span ranged from two to eight hours. The findings demonstrated that the concrete had attained its highest compressive strength 2.35 hours after it was cast.

Rao & Kumar [4] studied the effects of re-vibration on the compressive strength of concrete using various water-cement ratios (0.35 to 0.7) and re-vibration times (0.5 to 4 hours). According to the findings, concrete's compressive strength rose with re-vibration time for the first 60 minutes before falling.

Tuthill & Davis [5] carried out one of the earliest investigations on the effects of re-vibration on concrete, in which both concrete and reinforcing bars were vibrated at varied intervals from zero to ten hours. According to their findings, high frequency vibration increased the strength of re-vibrated specimens over un-vibrated specimens by as much as 25%.

The researchers all agreed that re-vibration of concrete does not result in segregation and that the amount of vibration does not seem to be a problem when concrete is re-vibrated.

3. Mechanism of Re-Vibration of Concrete

The process of intentionally and systematically vibrating the placed concrete again after its consolidation is complete is known as re-vibration of concrete. Re-vibrations that are correctly carried out lead to superior concrete quality, including less surface and other voids, stronger bonding, greater impermeability, less shrinkage and creep, and fewer cracks in newly laid concrete, among other advantages. Re-vibration is often possible if the operating internal vibrator may sink into the concrete due its own weight, or whenever the external vibrator, vibrating table, or both can briefly liquefy the concrete. The stiffness limit for re-vibration is typically accepted when the penetration resistance of the standard steel needle defined in ASTM C 403 exceeds 3.5 N/mm². The concrete briefly liquefies when it is re-vibrated. The main chemical reaction that takes place in the first two hours following the placement of concrete is the creation of calcium hydroxide $Ca(OH)_2$, which normally makes up 15% to 25% of Ordinary Portland Cement concrete. Calcium silicate hydrate (C-S-H), which accounts for roughly 50% of OPC concrete and gives it hardness and durability is the other important hydration product. After the initial setting when re-vibration occurs. This causes some of the calcium hydroxide Ca(OH)2 that has already formed to break down, allowing freshly placed concrete to join with the re-vibrated concrete rather than introducing a construction joint and restoring the structure to its original state as a monolithic concrete structure.

There are many types of vibrators such as internal vibration, table vibration, surface vibration, and external vibration are the most common systems for vibrating concrete. The mechanism of vibration and the effect of the formwork on the concrete mix differ between these. (ACI 1993, ACI 1996, Bhattacharjee 2005, and CCANZ 2006).

4. Materials and Mix Proportions

Ordinary Portland cement-type I with a specific gravity of 3.15, fine aggregate (sand) with a specific gravity of 2.6, and coarse aggregate with a maximum aggregate size of (12.5) mm and a specific gravity of 2.65 were used to create the reinforced concrete beams and cylinders.

The physical and chemical characteristics of Portland cement evaluated in accordance with Iraqi Specification No.5/1984. Qualities of coarse and fine aggregate were tested in accordance with Iraqi Specification No.45/1984. The initial cement setting time was 180 minutes, and ultimate cement setting time was 245 minutes. These results were determined using Iraqi Specification No.5/1984. According to ASTM C39, at least three 150 x 300 mm concrete cylinders were utilized to assess the compressive strength of concrete at 56 days. Concrete's desired compressive strength was 35 MPa. The ASTM C496 splitting tensile strength of concrete was calculated using the average results of three 150 mm x 300 mm cylinders. Table (1) shows the mix design compositions used per cubic meter for the current experiment.

Table 1: The ingredients of the concrete mix design per cubic meter

Max. agg. Size D max (mm)	Water (kg/m3)	Cement (kg/m3)	Sand (kg)	Course agg. (kg)	W/C ratio	Mix design ratio	Average compressive strength (MPa)
12.5	220	545	681	954	0.4	1: 1.25: 1.75	35

Table 2: Physical properties of the cement

Physical Tests	Results	ASTM C150-10
Initial setting time	180 min.	At least to be 45min.
Final setting time	245 min.	Not more than 600min.
Compressive strength 3 days age	22.68	14.7 MPa, a lower limit
Compressive strength 28 days age	32.25	22.5 MPa, a lower limit
Specific gravity	3.15	
Density	1400 kg/m^3	

Table 3: Grading of the Fine Aggregates (sand)

Sieve size (mm)	Passing %	ASTM Limits	
		Lower	Upper
9.5	100	100	100
4.75	95.77	95	100
2.36	86.59	80	100
1.18	71.44	50	85
0.6	48.1	25	60
0.3	20.32	5	30
0.15	7.17	0	10

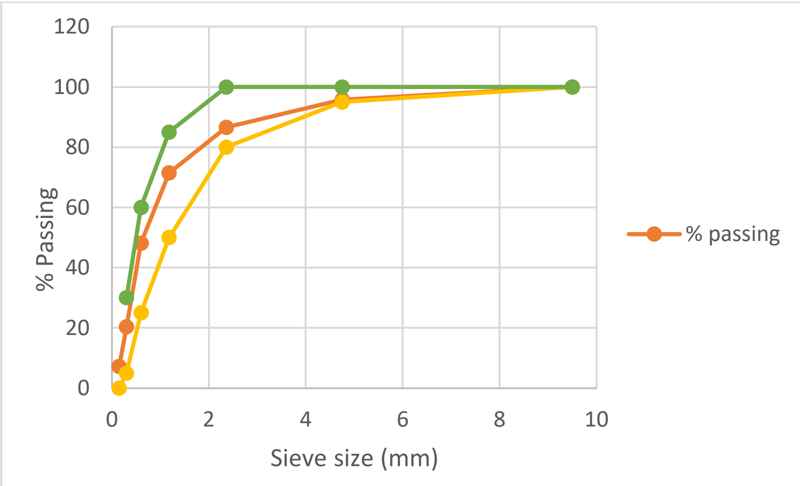


Figure 1: Grading curve for the fine aggregate with ASTM limits

Table 4: Grading of the Course Aggregates maximum size (D max = 12.5 mm)

Sieve size (mm)	Passing %	ASTM Limits	
		Lower	Upper
12.5	100	100	100
9.5	87.48	85	100
4.75	22.3	10	30
2.36	6.8	0	10
1.18	3.34	0	5

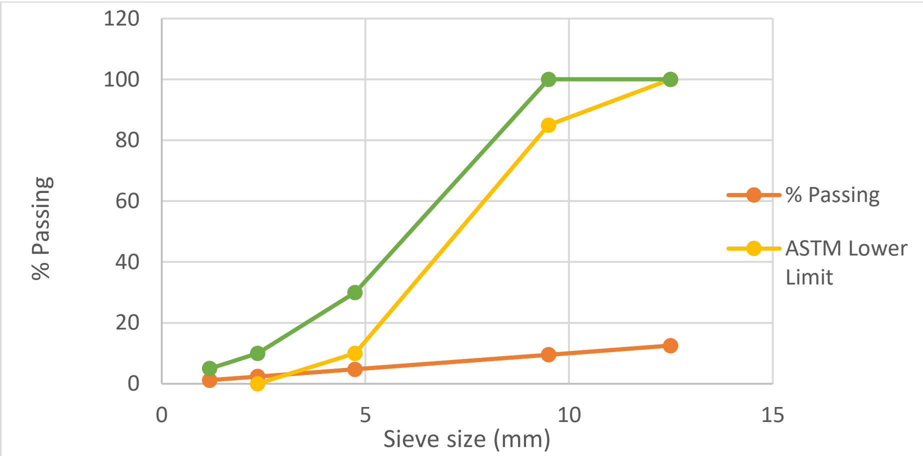


Figure 2: Grading curve for the course aggregate with ASTM limits

Table 5: Properties of reinforcing steel for the experiment

No.	Diameter	L1(mm)	fy (yield) (MPa)	Average (fy) (MPa)	Fu (Ultimate) (MPa)	Average (Fu) (MPa)	Elongation (%)
1	10	226	630.6	648.8	733.76	752.04	24
2	10	231	666.2		775.8		29
3	10	230	649.6		746.56		28
4	12	234	636.1	661.43	756.37	783.39	32
5	12	233	644.9		767.87		31
6	12	231	703.3		825.94		29

5. Experimental Program

For this project, a total of 28 twenty-eight rectangular reinforced concrete beams with dimensions (125 mm x 250 mm) and lengths of 1500 mm were manufactured. Which were divided into seven groups each group consists of four samples. The beams for group (A, B, C, D, E and F) reinforced with longitudinal top reinforcement of (2ø10mm) and bottom reinforcement of (2ø12mm) with transvers reinforcement (Stirrups) ø12mm all over the beams except group F which are without transverse reinforcement and group G is without longitudinal and transverse reinforcement. And 144 cylinders (300 mm height and 150 mm diameter) were used for testing the compressive and tensile strength of concrete. According to the ASTM C617 cylinder, capping was required to give a smooth and level surface for applying a compressive load to concrete cylinders. The stone powder method was used for cylinder capping, as shown in figure (6). These samples were examined after 56 days to explore the consequences of vibration, re-vibration delay, and vibration time length on the development of concrete strength.

The specimens in this investigation were vibrated for intervals of 15, 30, 45, and 60 seconds, and the waiting periods between the casting of the specimen and the first vibration (the re-vibration time lag) were chosen to be 30, 60, 90, and 120 minutes. Four re-vibration periods of 15, 30, 45, and 60 seconds each were chosen in order to evaluate the impact of the second vibration's length. The homogeneity of the mixture and the outward indication of good compaction are proof that these re-vibration time durations provided good vibration of the mixes.

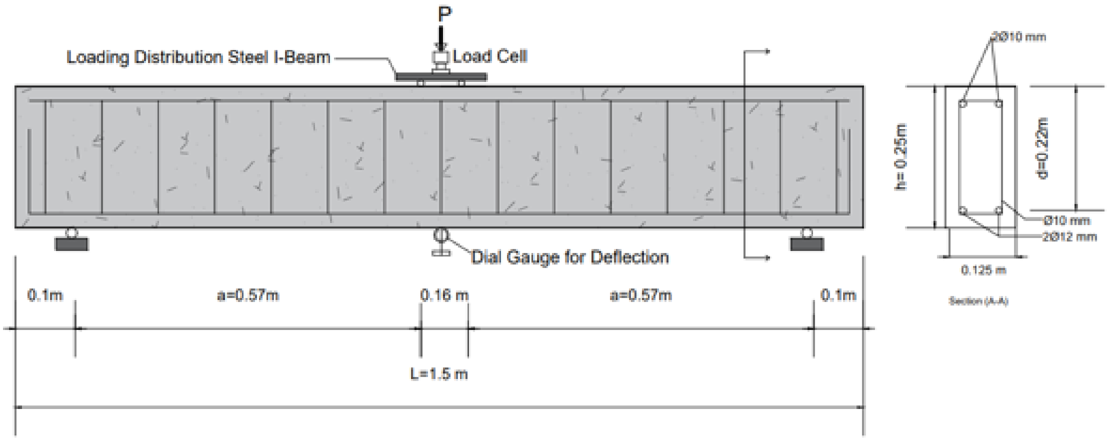


Figure 3: Longitudinal and transverse cross section view

Table 6: Experimental program of beam specimens

No.	Group	Specimen	Initial Vibration (sec)	Waiting time after initial vibration (min)	Re-vibration (sec)
1	With Stirrups	A1	15	0	0
2		A2	30	0	0
3		A3	45	0	0
4		A4	60	0	0
5	With Stirrups	B1	15	30	15
6		B2	15	30	30
7		B3	15	30	45
8		B4	15	30	60
9	With Stirrups	C1	15	60	15
10		C2	15	60	30

11		C3	15	60	45
12		C4	15	60	60
13	With Stirrups	D1	15	90	15
14		D2	15	90	30
15		D3	15	90	45
16		D4	15	90	60
17	With Stirrups	E1	15	120	15
18		E2	15	120	30
19		E3	15	120	45
20		E4	15	120	60
21	without Stirrups	F1	15	60	15
22		F2	15	60	30
23		F3	15	60	45
24		F4	15	60	60
25	without reinforcement	GI	15	60	15
26		G2	15	60	30
27		G3	15	60	45
28		G4	15	60	60

6. Loading Setup

The beams were tested in the College of Engineering at Tishk International University in (Civil Engineering Laboratory). At the age of 56 days all the beams were tested. When the curing was completed, the specimens were placed at the laboratory temperature and were painted with white color and drawing the gridlines over the beam, so the cracks could be seen quickly and clearly and the crack pattern could be marked, as shown in figure (4). For installing the strain gauge over the beam first able the beams surface was polished by using diamond angle grinder disc to obtain smooth surface, then the strain gauge was placed over a clean glass surface and covered the strain gauge with an adhesive tape, the strain gauge and the surface are now ready for the bonding process. For this process super glue loctite bonding materials was used that was set few seconds after application. After that a metal load was placed over the stain gauge for 24 hours till it completely hardened. The load was applied over the beam on the two-point line load with a distance of 16 cm. The applied load was calculated with digital readout as shown in the figure (5), and the stain gauge was connected to data logger for reading the maximum strain. And a dial gauge used that had the smallest count of 0.01mm for measuring the displacements that was placed at the center of the beam to determine the center displacement, as illustrated in figure (5). The loading process for all the beams were videoed for the purpose recording crack behavior of the beams.

Figure 4: Beam Specimens painted with a white color and smoothed the strain gauge area

Figure 5: Test setup with the loading frame

7. Experimental Results

The experimental results of twenty-eight beams were presented through this paper in many figures and tables to explore and show the effect of re-vibration of beams on the mechanical properties of concrete, behavior of reinforced concrete beam, modes of failure load, strain and maximum deflection of the beams, behavior of each beam are described in this paper.

8. Concrete Compressive Strength

According to ASTM C39, three cylinders (150x300) were tested for each beam. After testing and according to the ASTM C617 cylinder shown in figure (6) capping was required to give a smooth and level surface for applying a compressive load to concrete cylinders. Table (7) and figure (7) shows the results of concrete compressive strength of all beams.

Figure 6: Cylinder capping concrete and compressive testing equipment

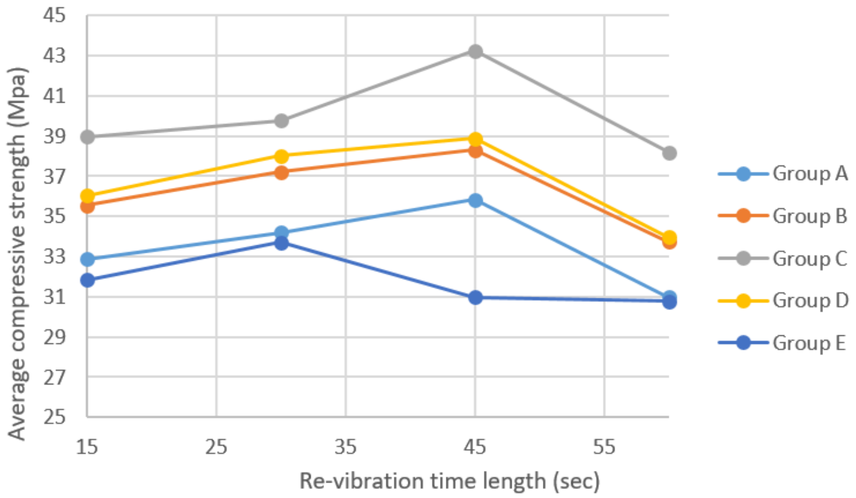


Figure 7: Average compressive strengths of concrete for initial vibration and re-vibrated concrete specimens with time length

The concrete mixtures made with the different re-vibration time lags showed that the maximum compressive strengths of concrete obtained in group A were they vibrated for one time and for 45 seconds without re-vibration was (35.83 MPA), were increased up to 6.92 % and 20.7% when the application of a second vibration was applied after 0.5 and 1 hours then decreased.

9. Splitting Tensile Strength

According to ASTM (ASTM-C469), For each beam, three (150 x 300) mm cylinders were tested to find out the splitting tensile strength of concrete, the test machine shown in figures (8,9) and table (7) shows the results of splitting tensile strength of concrete.

(1) $$f_{sp} = \frac{2P}{\pi L d}$$

Where:

fsp = splitting tensile strength (MPa)

P = maximum applied load (KN)

L = length (mm)

d = depth (mm)

Figure 8: ALFA testing equipment for tensile strength

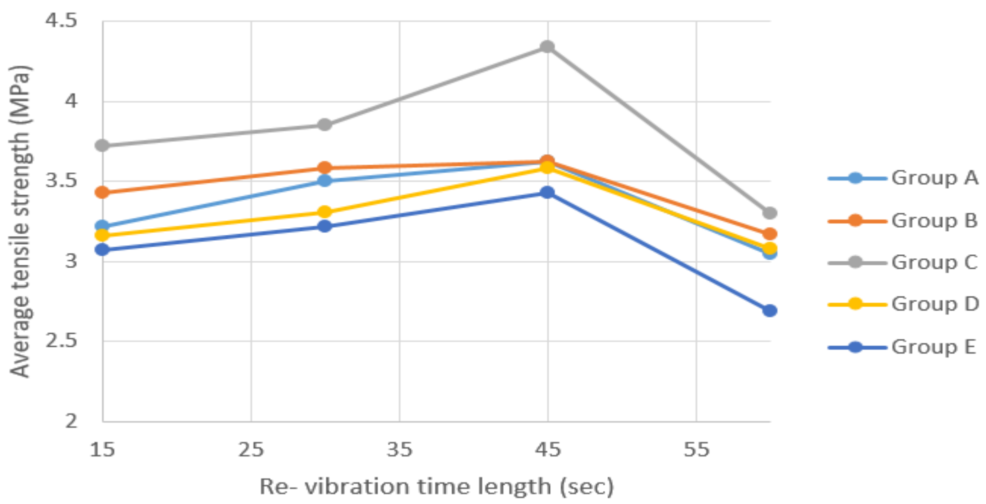


Figure 9: Average tensile strengths of concrete for initial vibration and re-vibrated concrete specimens with time length

The maximum tensile strengths of concrete obtained in group A were they vibrated for one time and for 45 seconds without re-vibration was (3.62 MPA), were increased up to 19.88% when the application of a second vibration was applied after 1 hour then decreased

10. Results and Behavior of Tested Beams

A summary of compressive strength, splitting tensile strength, first crack and maximum applied load of the concrete beams shows in table (7) and figure (10). Strain results and Deflection of the beams with re-vibration shows in table (8) and figures (11,12). The relation of apply load on deflection and strain shows in figures (13,14).

Table 7: Results and behavior of tested beams

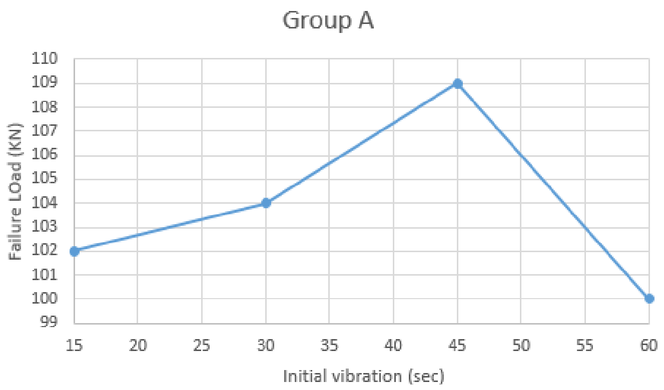
No.	Specimen	Initial Vibration (sec.)	Waiting time after initial vibration (min.)	Re-vibration (sec.)	Compressive strength f'_c (MPa)	Tensile strength f_{sp} (MPa)	Diagonal shear load kN	Failure load kN
1	A1	15	0	0	32.87	3.22	42	102
2	A2	30	0	0	34.20	3.5	44	104
3	A3	45	0	0	35.83	3.62	45	109
4	A4	60	0	0	30.95	3.05	47	100
5	B1	15	30	15	35.55	3.43	45	104
6	B2	15	30	30	37.21	3.58	47	113
7	B3	15	30	45	38.31	3.62	49	116
8	B4	15	30	60	33.75	3.17	46	107

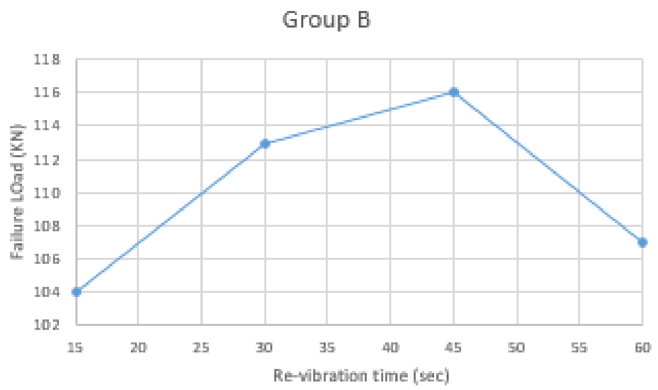
9	C1	15	60	15	38.98	3.72	49	107
10	C2	15	60	30	39.76	3.85	51	114
11	C3	15	60	45	43.256	4.34	55	119
12	C4	15	60	60	38.20	3.3	53	111
13	D1	15	90	15	36.03	3.16	46	102
14	D2	15	90	30	38.01	3.31	48	109
15	D3	15	90	45	38.88	3.58	50	112
16	D4	15	90	60	33.93	3.08	47	107
17	E1	15	120	15	31.83	3.07	46	102
18	E2	15	120	30	33.70	3.22	48	107
19	E3	15	120	45	30.98	3.43	49	109
20	E4	15	120	60	30.79	2.69	43	105
21	F1	15	60	15	38.98	3.72	41	73.8
22	F2	15	60	30	39.76	3.85	43	78
23	F3	15	60	45	43.25	4.34	47	80
24	F4	15	60	60	38.20	3.3	42	70
25	GI	15	60	15	38.98	3.72		11.9
26	G2	15	60	30	39.76	3.85		14.5
27	G3	15	60	45	43.25	4.34		18.7
28	G4	15	60	60	38.2	3.3		9.5

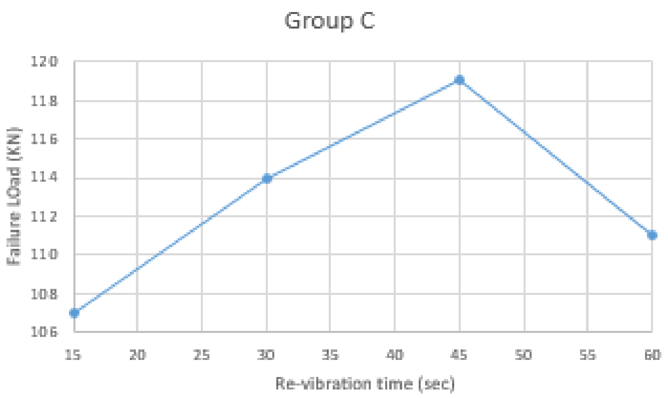
Table 8: Strain and Deflection results of the beams

No.	Specimen	Initial Vibration (sec.)	Waiting time after initial vibration (min.)	Re-vibration (sec.)	Deflection (mm)	Strain mm/mm
1	A1	15	0	0	5.5	0.001726
2	A2	30	0	0	7.8	0.002075
3	A3	45	0	0	9	0.002188
4	A4	60	0	0	6.9	0
5	B1	15	30	15	8.1	0
6	B2	15	30	30	8.5	0.001751
7	B3	15	30	45	10.2	0.002085
8	B4	15	30	60	7.78	0.0014152
9	C1	15	60	15	9.1	0.001978
10	C2	15	60	30	10.2	0.002182
11	C3	15	60	45	13.35	0.002987
12	C4	15	60	60	8.5	0.001752
13	D1	15	90	15	8	0.001518
14	D2	15	90	30	9.5	0.001602
15	D3	15	90	45	10.2	0.001704
16	D4	15	90	60	7.8	0
17	E1	15	120	15	7.3	0.001681
18	E2	15	120	30	8.1	0.001819
19	E3	15	120	45	8.5	0.002073
20	E4	15	120	60	6.9	0
21	F1	15	60	15	4	0.0007095
22	F2	15	60	30	4.2	0.0009322
23	F3	15	60	45	5.1	0.001102
24	F4	15	60	60	3.55	0.0006885

25	GI	15	60	15	0	0
26	G2	15	60	30	0	0
27	G3	15	60	45	0	0
28	G4	15	60	60	0	0.0000729







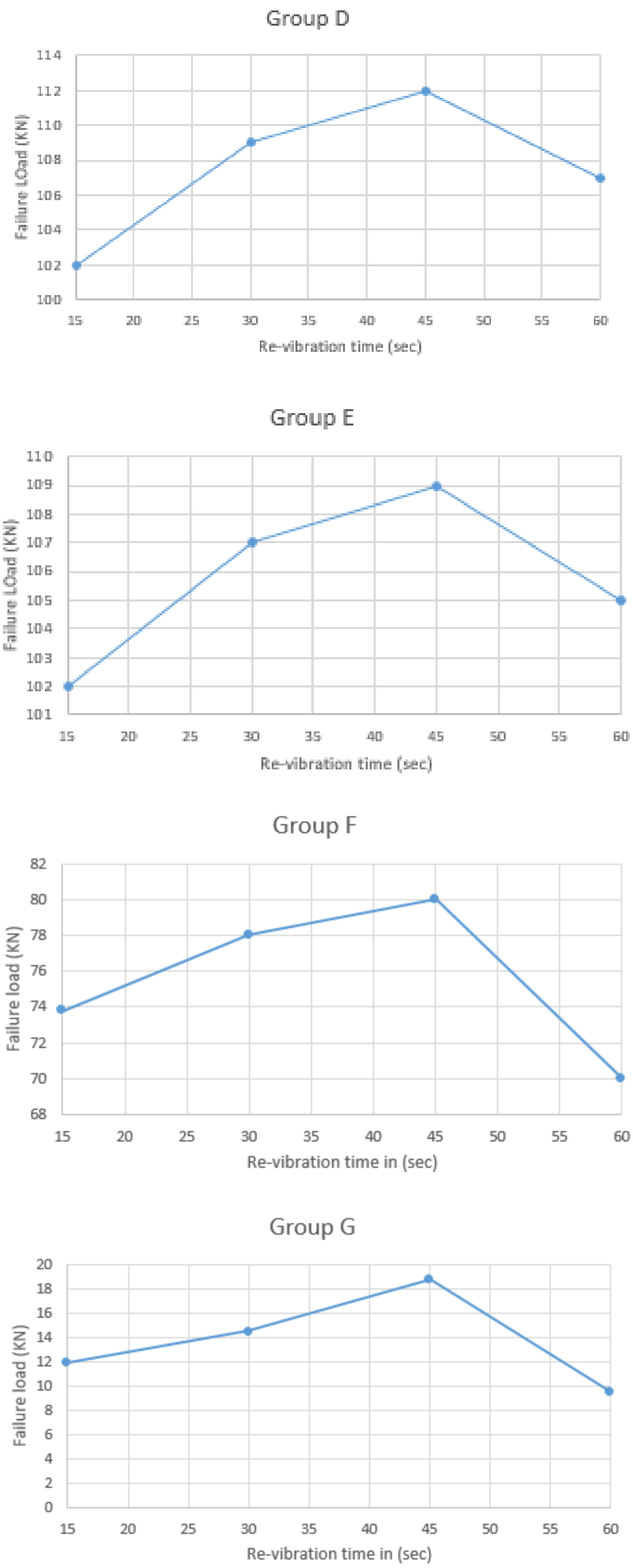
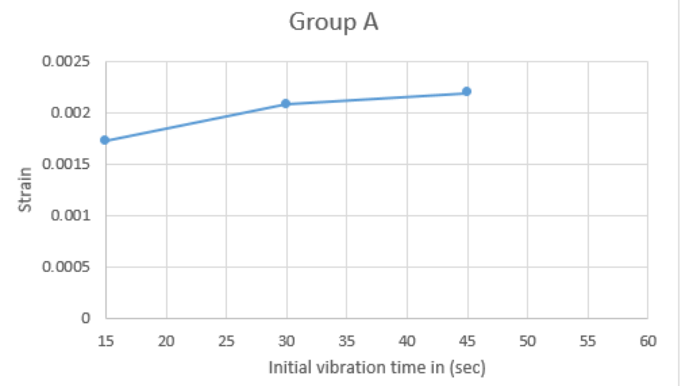
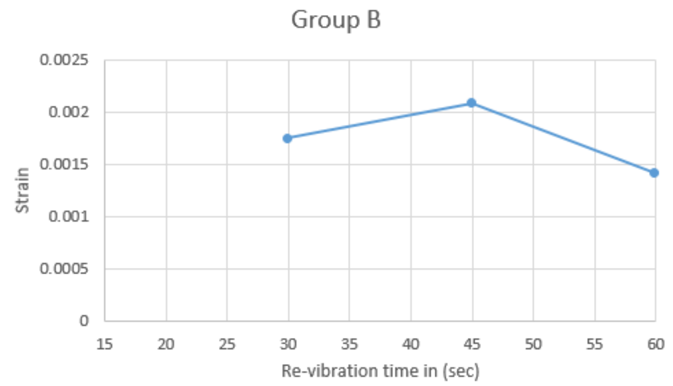
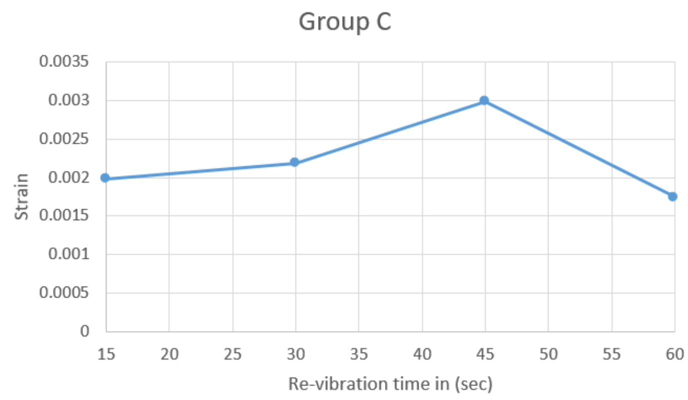


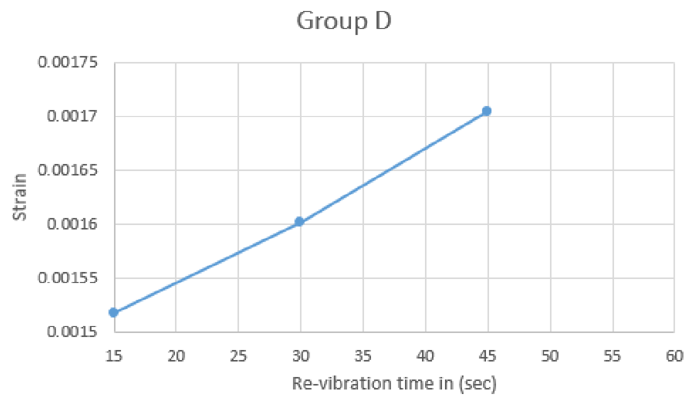
Figure 10: Failure load of the beams and Re-vibration time in (sec)

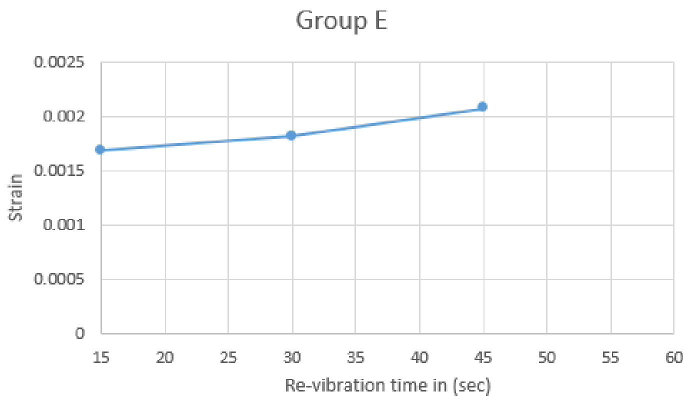
Failure load of beams obtained in group A were they vibrated for one time and for 45 seconds without re-vibration was (109 KN), were increased up to 3.66 % and 12.84% when the application of a second vibration was applied after 0.5 and 1 hours then decreased


Group A
0.0025
0.002
0.0015
0.001
0.0005
0
Strain
15 20 25 30 35 40 45 50 55 60
Initial vibration time in (sec)


Group B
0.0025
0.002
0.0015
0.001
0.0005
0
Strain
15 20 25 30 35 40 45 50 55 60
Re-vibration time in (sec)


Group C
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Strain
15 20 25 30 35 40 45 50 55 60
Re-vibration time in (sec)


Group D
0.00175
0.0017
0.00165
0.0016
0.00155
0.0015
Strain
15 20 25 30 35 40 45 50 55 60
Re-vibration time in (sec)



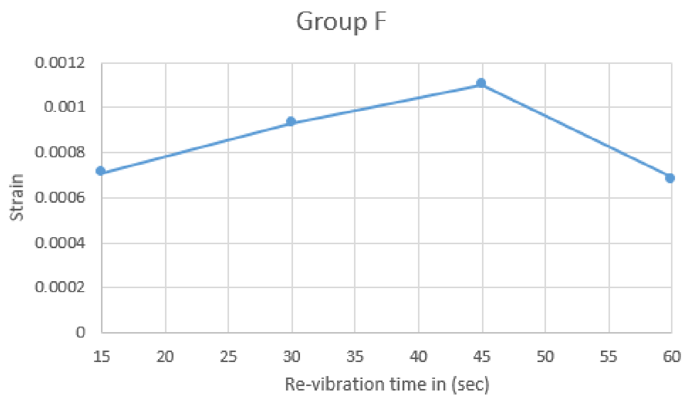
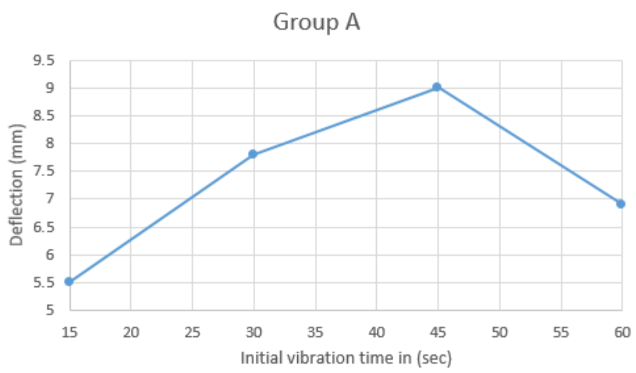
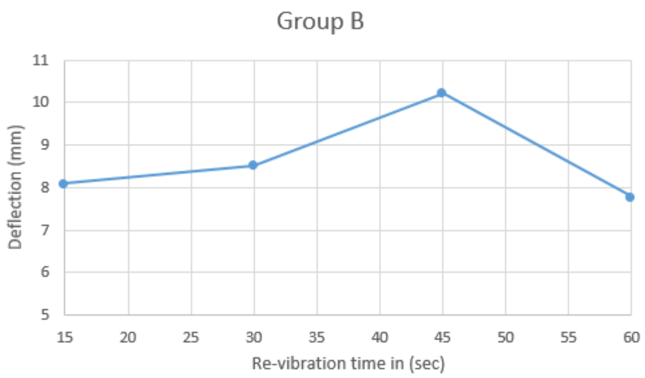


Figure 11: Strain of the beams and Re-vibration time in (sec)

The study found that the strain was also increased with the re-vibration process up to 36.51% when the waiting time for the re-vibration was 1 hour and re-vibrated for 45 seconds then decreased





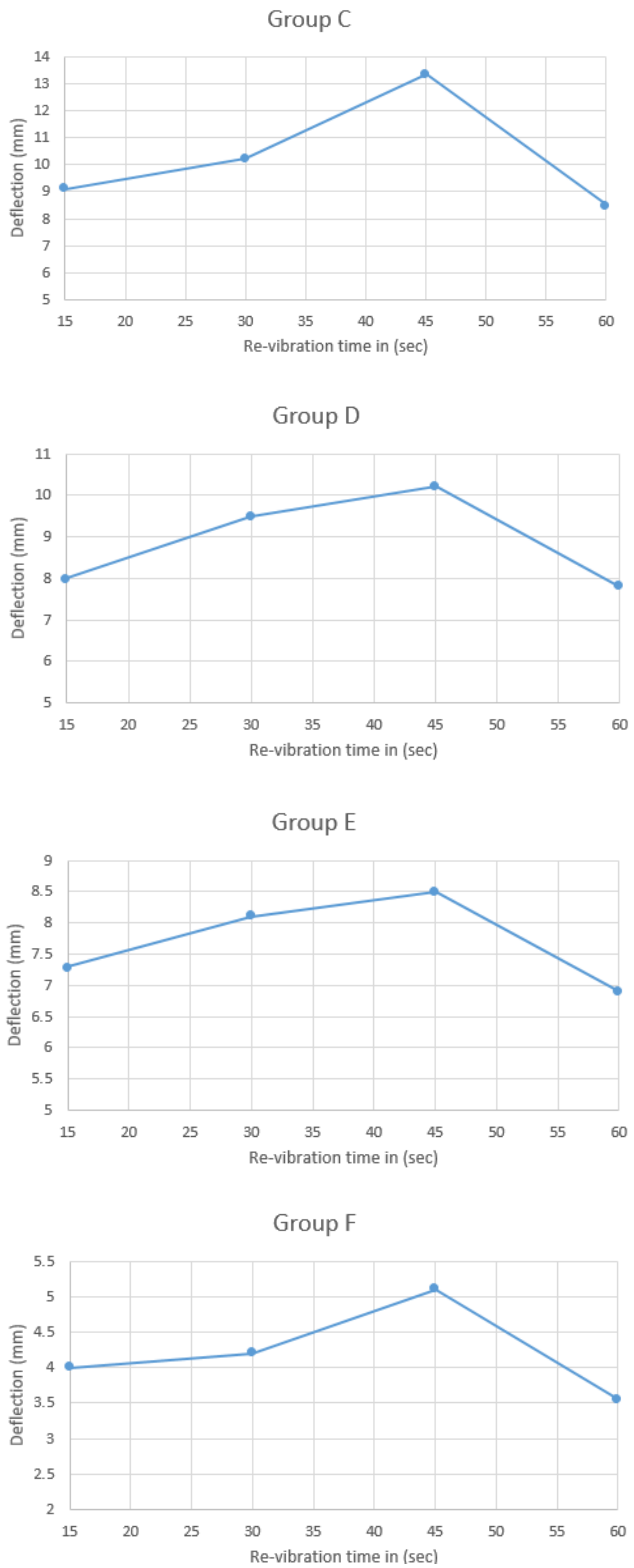
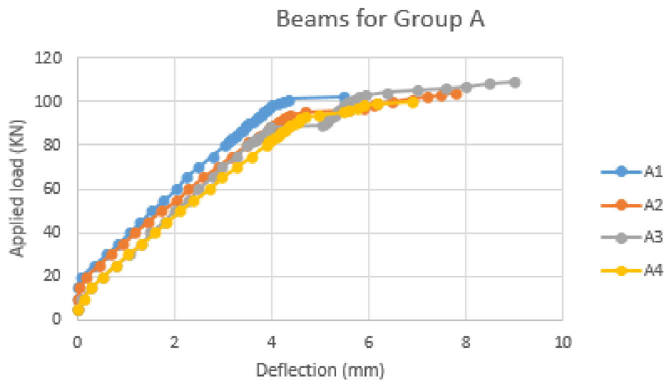
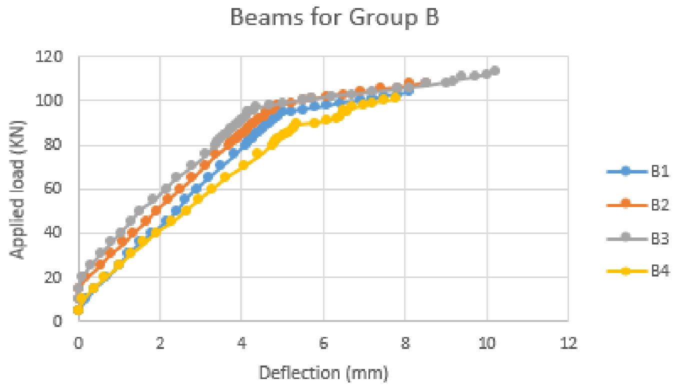
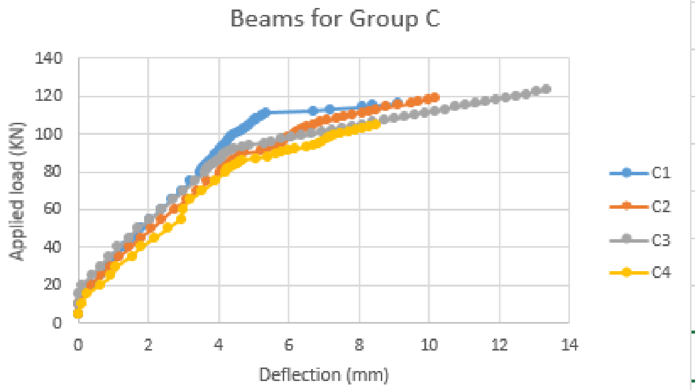


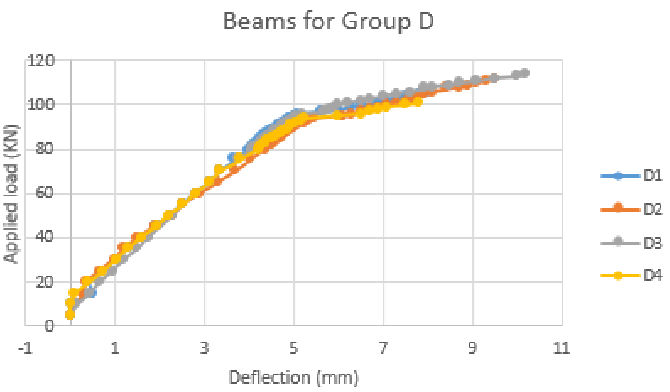
Figure 12: Deflection of the beams and Re-vibration time in (sec)

The experimental results show that the maximum deflection of the beam was obtained in groups C which was (13.35 mm) were the waiting time for the re-vibration was 1 hour and re-vibrated for 45 seconds.


Beams for Group A
Applied load (KN)
Deflection (mm)
A1
A2
A3
A4


Beams for Group B
Applied load (KN)
Deflection (mm)
B1
B2
B3
B4


Beams for Group C
Applied load (KN)
Deflection (mm)
C1
C2
C3
C4


Beams for Group D
Applied load (KN)
Deflection (mm)
D1
D2
D3
D4

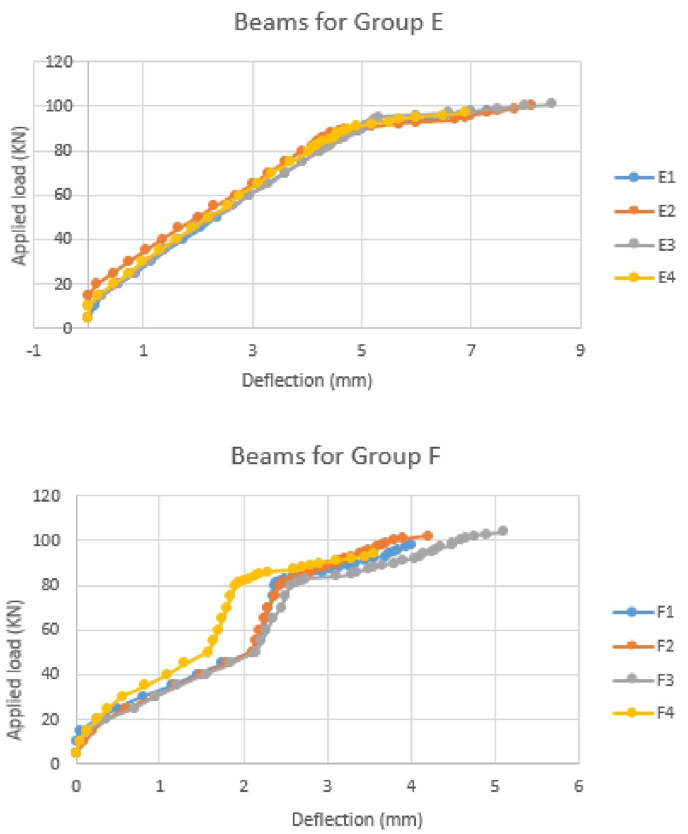
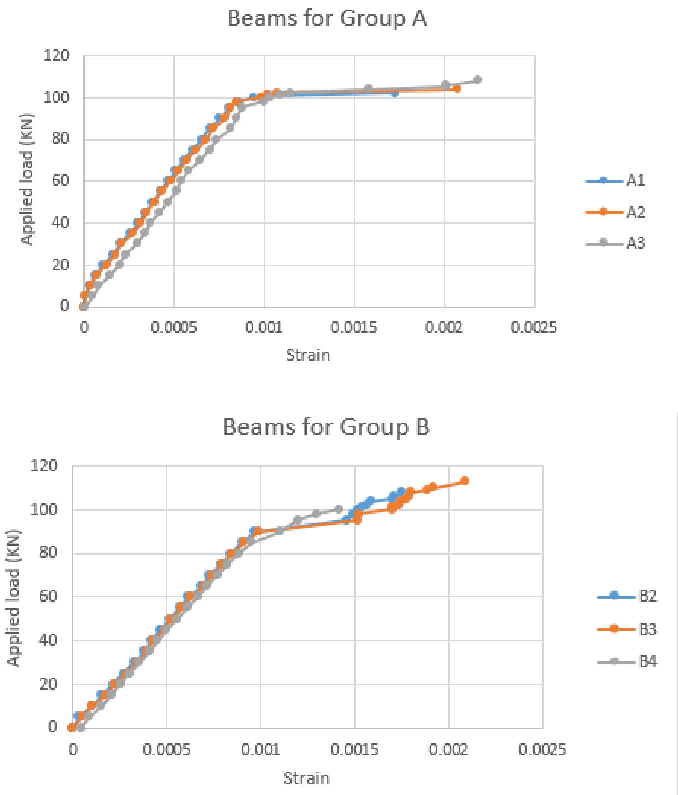


Figure 13: Applied load and Deflection curve of the Groups



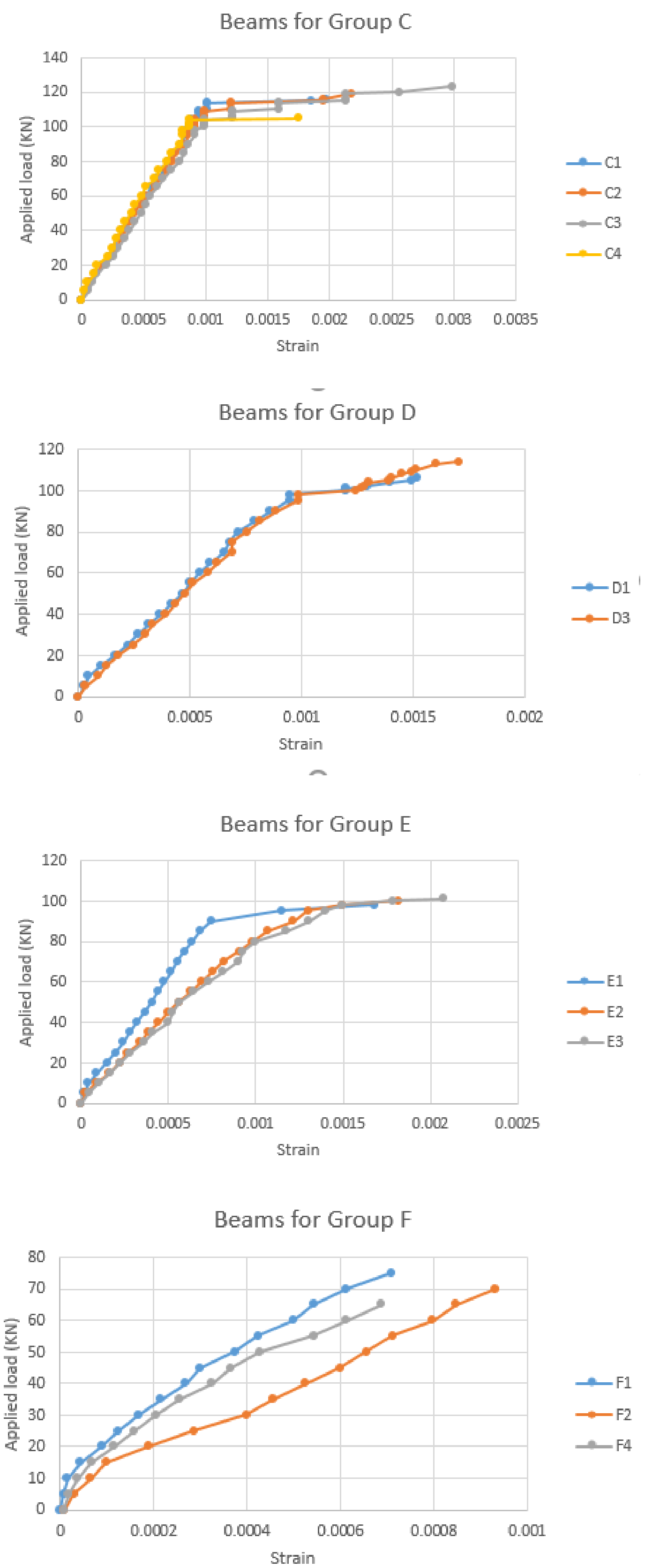


Figure 14: Applied load and Strain curve of the Groups

The results have shown that the beams with the same compressive strength and the maximum size of aggregate (12.5) the mechanical properties of concrete (compressive strength, tensile strength, flexural strength, and modulus of elasticity), strain, and deflection of concrete with various time duration and re-vibration techniques was increased for the 1st one hour and re-vibrated for 45 seconds time duration. After that for waiting time 1.5 and 2 hours before re-vibration and re-vibrated for 60 seconds was decreased.

11. Conclusion

In the article, several fracture patterns and failure mechanisms were found. The failure modes of the reinforced concrete beams under variant re-vibration time legs and waiting time of the vibration of beams. The beams were separated into seven groups; each group has four samples. Beams for group (A, B, C, D, E and F) were reinforced beams, and group F which are without transverse reinforcement and group G is without longitudinal and transverse reinforcement.

In group (A, B, C, D, E and F) were the beams subjected to applied load during the tests, initial cracks were appeared hairline cracks and distributed spirally across the section along with an amount of small inclined cracks. The first crack appears at the center of the beams. These cracks were seen on both sides of the beams. The initial fracture in group F, beam specimens (F1, F2, F3, and F4) occurred towards the ends of the lever arm on both sides of the specimens, and it was found that the cracks formed a (45o) angle with the sides of the beams. Beam specimens (G1, G2, G3, and G4) in group G had sudden failures after the initial crack emerged.

This experiment was carried out to test the key theories concerning the role of vibration and re-vibration with different time intervals and waiting time on the reinforced and non-reinforced concrete beams.

References

[1] Auta SM, Uthman A, Sadiku S, Tsado TY, Shiwua JA. Flexural strength of reinforced revibrated concrete beam with sawdust ash as a partial replacement for cement. Flexural strength of reinforced revibrated concrete beam with sawdust ash as a partial replacement for cement [Internet]. 2016.Available from: http://repository.futminna.edu.ng:8080/jspui/handle/123456789/8242

[2] Aziz DOQ, Yousif AR, Hassan P. EFFECT OF RE-VIBRATION TIME AND STEEL FIBER CONTENT ON THE PROPERTIES OF CRUSHED CEMENT-SAND MORTAR CONCRETE. 2005. https://www.iasj.net/iasj/download/6269ff1dfc5892a3

[3] Kassim MM. Effects of revibration on early age retarded concrete. High-Performance Structures and Materials, VI. 2012 Jun 19; 124: 85-93. https://doi.org/10.2495/HPSM120081

[4] Rao MVK, Kumar PR. EFFECT OF RE-VIBRATION ON COMPRESSIVE STRENGTH OF CONCRETE. https://doi.org/10.1088/1757-899X/271/1/012057

[5] Tuthill LH, Davis harmer E. Overvibration and Revibration of Concrete. J Proc. 1938 Sep 1; 35(9): 41–8. https://doi.org/10.14359/8477