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Effect of Induced Vibration on Fresh Concrete

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Abstract: Concrete is an artificial kind of stone prepared from an indefinite mixture of three basic components such as binding materials, inert materials and water. When the components are mixed together to prepare concrete, binding materials such as cement paste acts as a glue binding surrounding the inert materials during the process of hydration and curing. The freshly mixed concrete becomes hard with considerable strength following the setting procedure of cement. During the setting period, vibration may come on fresh concrete as a result of earthquake, pile driving, heavy traffic or vibratory soil compactors. The objective of this research was to perform a laboratory test to find out the effect of vibration on working strength of concrete between the initial and final setting period. On this purpose, two different sizes concrete cylinders (4”X8” and 6”X12”) were casted by mixing cement, sand, stone chips and water with two ratios (1:2:4 and 1:1.5:3). Water-cement ratio was 0.78. The initial and final setting time were recorded as 140min and 270 min respectively. The concrete cylinders were then subjected to two level of vibration for 1 min or 2 min at three different ages (2 hr, 3.5 hr and 5 hr) by the help of shaking table. The peak particle velocities were 50mm/s -100mm/s, 150mm/s and 200mm/s-300mm/s. About 96 cylinders were tested for compression and splitting tensile strength tests at 7 days and 28 days. From the test results it was found that, the compressive strength was increased up to 20% and the tensile strength was decreased up to 13% over the controlled cylinder specimen by the effect of vibration.

Keywords: *Fresh Concrete, Setting time, Vibration, Compressive Strength, Tensile Strength*

1. Introduction:

Concrete is a stone like material obtained by carefully proportioned mixture of cement, sand and gravel or other aggregate and water to harden in forms of the shape and dimensions of the desired structure (Aziz, 1995). Insufficient vibration of concrete may result defects in concrete, such as honey combing and voids. Many engineers are of the opinion that partially set concrete should not be disturbed in early days. Strong belief has been there that any disturbance to concrete, like re-vibration in the initial hardening stage makes the concrete deteriorate and loose its strength. After some year Engineers have found it necessary to disturb the hardening process.

The effect of nearby dynamite blasts, pile driving, or the simultaneous operation of machinery or vehicles on fresh or early aged concrete is often questioned. Yet there is no documented record of structural failure from these causes.

When ground shaking activities are carried out near freshly cast concrete it is necessary to control shock vibration in order to avoid damage in concrete. Most shock vibration criteria have been based on past experience and subjective judgment that they are sage limits to adopt. Although it is generally believed that the shock vibration resistance of concrete is proportional to strength of concrete it had not been tested.

2. Methodology:

The purpose of this research was to perform a laboratory test program on the effects of induced vibrations on concrete: before, during or after the setting period. For this purpose, a laboratory program was performed. The laboratory program was for casting (4”X8”) concrete cylinders about 96 Nos.

At first, the laboratory tests on the course aggregate and fine aggregates such as unit weight, specific gravity, sieve analysis, moisture content of coarse and setting time and consistency of cement has been performed to prepare concrete. For compression and splitting tensile test (4”X8”) concrete cylinders of mix proportion 1:2:4 and 1:1.5:3 were casted.

After casting the specimen, the vibration was applied on the fresh concrete between initial and final setting time. There were 3 variables considered in case of vibrating the concrete:

- Age when vibrated
- Peak particle velocity
- And duration of vibration.

The observed initial and final set times were 140 min and 270 min, respectively. The ages at which groups of cylinders were vibrated were 2 h, 3.5 h and 5 h after water–cement contact. Two levels of vibration were conducted for the test: the lower level (L) with particle velocities of approximately 50–100 mm/ s (2–4 in/s) and the higher level (H) with particle velocities of approximately 200–300 mm/ s (8–12 in/s). Durations of 1 and 2 min were used to represent a range of possible times for vibration. Vibration was conducted by using shaking table.

The American Concrete Institute Method ACI 211.1-9114.5 was followed for making and curing concrete test specimens in the laboratory and all specimens were placed in a lime water bath after 24 h and maintained in the bath until testing. The ratios of concrete mixes were 1:2:4 and 1:1.5:3.

All of the specimens with a particular combination of vibration duration and intensity were vibrated simultaneously on a shaking Table. After conducting vibration, each cylinder was given a serial number. Finally, ASTM C39 and IS 1516:1999 were followed to perform 7- and 28-day compression strength and splitting tensile strength tests, respectively.

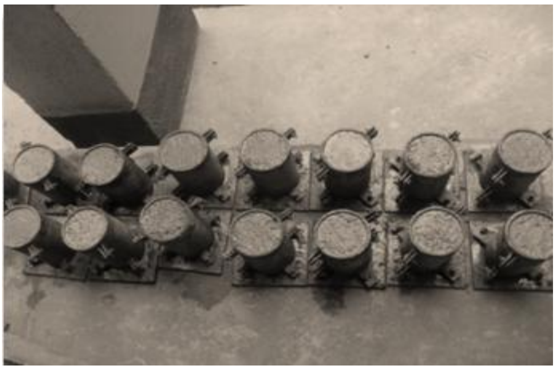

***Figure 1**: Concrete in molds*

***Figure 2**: Cylinders in shaking table*

3. Illustrations:

Compressive strength (7days)

Peak particle velocity :H=200 mm/s~300 mm/s
L=50 mm/s~100 mm/s

***Table 1**: Results of compression test at 7 days*

Concrete ratio	Age when vibrated	Peak particle velocity	Duration of time	Age when tested	Compressive force	compressive strength	Change over control average
1:2:4	(hour)	(mm/s)	(min)	(days)	(Ib)	(psi)	%
1:2:4	Control	-	-	7	24000	1910	-
1:2:4	2	H	1	7	25000	1988	4
1:2:4	2	H	2	7	29000	2307	20
1:2:4	2	L	1	7	26000	2068	8
1:2:4	2	L	2	7	27000	2148	12
1:2:4	3.5	H	1	7	31000	2466	29
1:2:4	3.5	H	2	7	29000	2307	20
1:2:4	3.5	L	1	7	30000	2386	24
1:2:4	3.5	L	2	7	31000	2466	29
1:2:4	5	H	1	7	23000	1828	-4
1:2:4	5	H	2	7	24000	1910	-
1:2:4	5	L	1	7	30000	2387	24
1:2:4	5	L	2	7	25000	1989	*4*
1:1.5:3	Control	-	-	7	36000	2864	-
1:1.5:3	2	H	1	7	37000	2943	*3*
1:1.5:3	2	H	2	7	39000	3103	*8*
1:1.5:3	2	L	1	7	33000	2625	*-8*
1:1.5:3	2	L	2	7	36000	2864	-
1:1.5:3	3.5	H	1	7	40000	3182	*11*
1:1.5:3	3.5	H	2	7	35000	2785	*-3*
1:1.5:3	3.5	L	1	7	41000	3262	*14*
1:1.5:3	3.5	L	2	7	37000	2943	*3*
1:1.5:3	5	H	1	7	36000	2864	-
1:1.5:3	5	H	2	7	37000	2943	*3*
1:1.5:3	5	L	1	7	39000	3103	*8*
1:1.5:3	5	L	2	7	40000	3182	*11*

Graphical representation:

Vibration strengthens the concrete in compression, increasing the compressive strength by as much as 15% over the control cylinders. In figure, the changes in compressive strength compared to controlled cylinder have shown. Results were measured with respect to three variables. In Figure 1 the marked line indicates the control cylinder compressive strength, which was not vibrated.

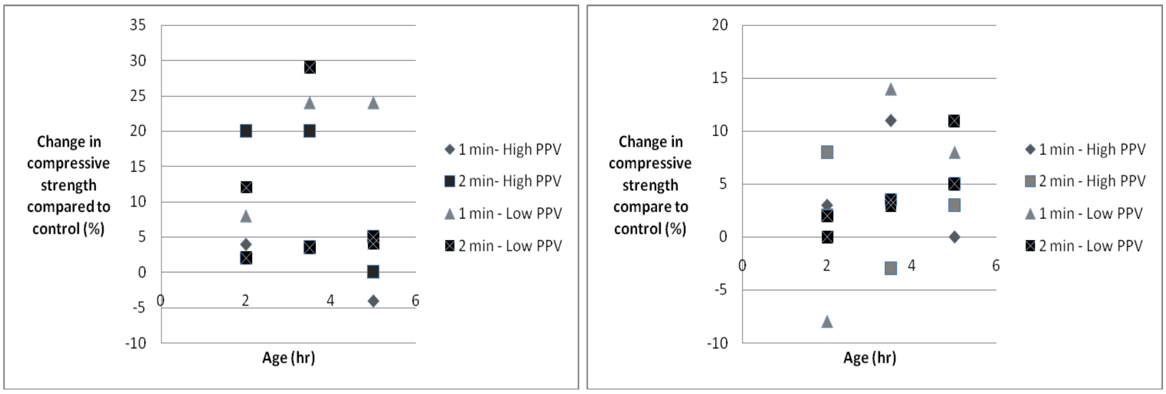

Figure 3*: Impact on compressive strength at 7 days for four combination of PPV and duration of induced vibration. Percentages based on average control cylinders, which were not vibrated. (ratio 1:2:4 left; ratio 1:1.5:3 right)*

Compressive strength (28 days):

Table 2*: Results of compression test at 28 days*

Concrete ratio	Age when vibrated (hr)	Duration of vibration (min)	Peak particle velocity (mm/s)	Age when tested (days)	Compressive force (Ib)	Compressive strength (psi)	Change over control average(%)
1:2:4	Control	-	-	28	68000	2405	-
1:2:4	2	1	150	28	70000	2476	3
1:2:4	3.5	1	150	28	67000	2370	-2
1:2:4	5	1	150	28	72000	2547	6
1:1.5:3	Control	-	-	28	105000	3714	-
1:1.5:3	2	1	150	28	107000	3785	2
1:1.5:3	3.5	1	150	28	109000	3856	4
1:1.5:3	5	1	150	28	110000	3891	5

Graphical representation:

The same trend can be seen much more dramatically in the 28-day compression test results, where all of the groups of cylinders that were vibrated had stronger average strengths than the control group as seen in Figure 4. In fact only 1 of the cylinders had a weaker compressive strength than the control average. It is clear that, the compressive strength was increased in average because of induced vibration

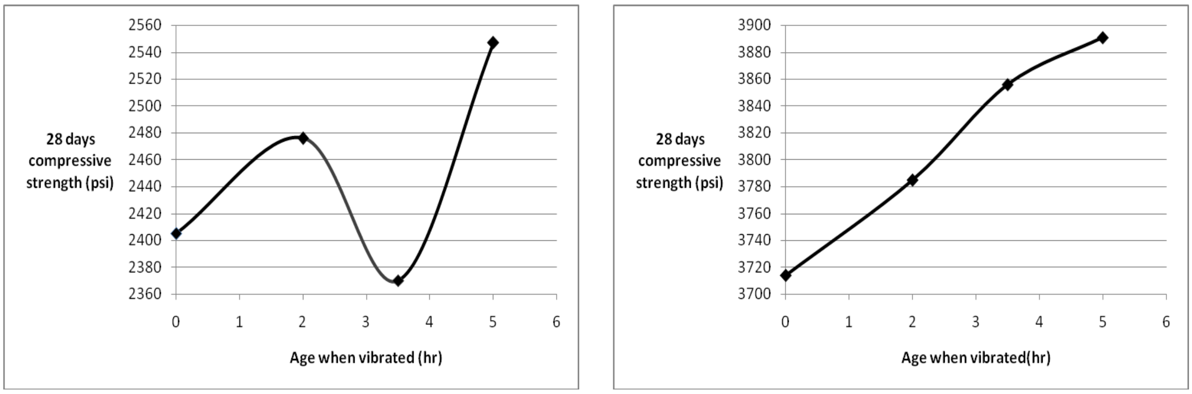

Figure 4*: 28 days compressive strength with time comparison (ratio 1:2:4 left and ratio 1:1.5:3 right)*

Tensile strength (7days):

Peak particle velocity :H=200 mm/s~300 mm/s, L=50 mm/s~100 mm/s

Table 3: *Results of tensile strength in 7 days*

Concrete ratio	Age when vibrate	Peak particle velocity	Duration of vibration	Age when tested	Force	Tensile strength	Change over control average
1:2:4	(Hour)	(mm/s)	(min)	(days)	(Ib)	(psi)	%
1:2:4	Control	-	-	7	11333	225	-
1:2:4	2	H	1	7	10500	209	-7
1:2:4	2	H	2	7	11000	219	-3
1:2:4	2	L	1	7	11500	229	2
1:2:4	2	L	2	7	12000	239	6
1:2:4	3.5	H	1	7	13000	259	13
1:2:4	3.5	H	2	7	10500	209	-7
1:2:4	3.5	L	1	7	11000	219	-3
1:2:4	3.5	L	2	7	10000	199	-11
1:2:4	5	H	1	7	11000	219	-3
1:2:4	5	H	2	7	10500	209	-7
1:2:4	5	L	1	7	10000	199	-11
1:2:4	5	L	2	7	11000	219	-3
1:1.5:3	Control	-	-	7	17000	338	-
1:1.5:3	2	H	1	7	16500	328	-3
1:1.5:3	2	H	2	7	16000	318	-6
1:1.5:3	2	L	1	7	17500	348	3
1:1.5:3	2	L	2	7	16000	318	-6
1:1.5:3	3.5	H	1	7	15500	309	-8
1:1.5:3	3.5	H	2	7	15000	299	-11
1:1.5:3	3.5	L	1	7	16000	318	-6
1:1.5:3	3.5	L	2	7	15000	299	-11
1:1.5:3	5	H	1	7	18000	358	6
1:1.5:3	5	H	2	7	17000	338	-
1:1.5:3	5	L	1	7	16500	328	-3
1:1.5:3	5	L	2	7	17500	348	3

Graphical representation:

In figure 5, it has shown that vibration weakens the concrete tensile strength by up to 13%. The marked line indicates the control cylinder tensile strength, which was not vibrated. So, the tensile strength decreases in average with vibration.

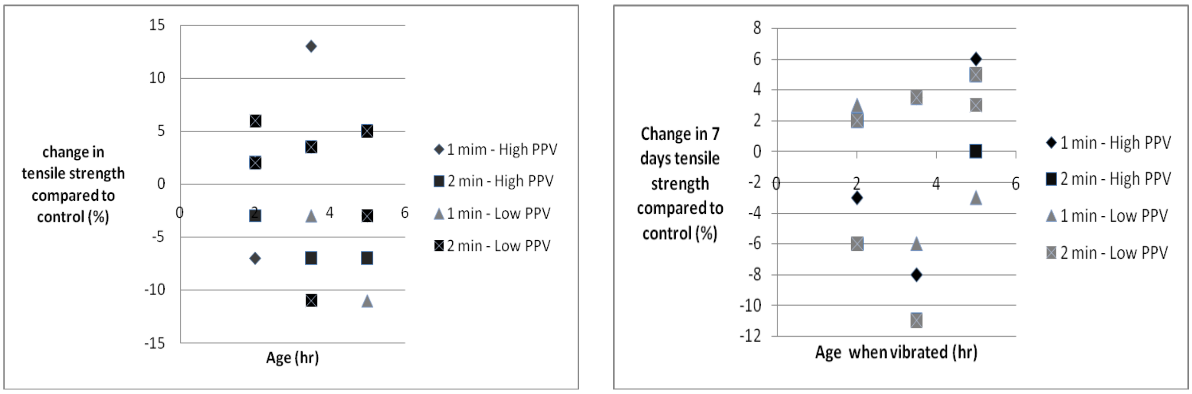

Figure 5 *: Impact on tensile strength at 7 days for four combination of PPV and duration of induced vibration. Percentages based on average control cylinders, which were not vibrated (ratio 1:2:4 left and ratio 1:1.5:3 right)*

Tensile strength at 28 days:

Table 4.6 : *Results of tensile strength tests at 28 days*

Proportion	Age when vibrated (hr)	Duration of vibration (min)	Peak particle velocity (mm/s)	Age when tested (days)	Tensile force (Ib)	Tensile strength (psi)	Change over control average(%)
1:2:4	Control	-	-	28	37000	327	-
1:2:4	2	1	150	28	34000	300	-8
1:2:4	3.5	1	150	28	32000	283	-13
1:2:4	5	1	150	28	35000	309	-6
1:1.5:3	Control	-	-	28	51000	451	-
1:1.5:3	2	1	150	28	52000	460	2
1:1.5:3	3.5	1	150	28	48000	427	-6
1:1.5:3	5	1	150	28	47000	416	-8

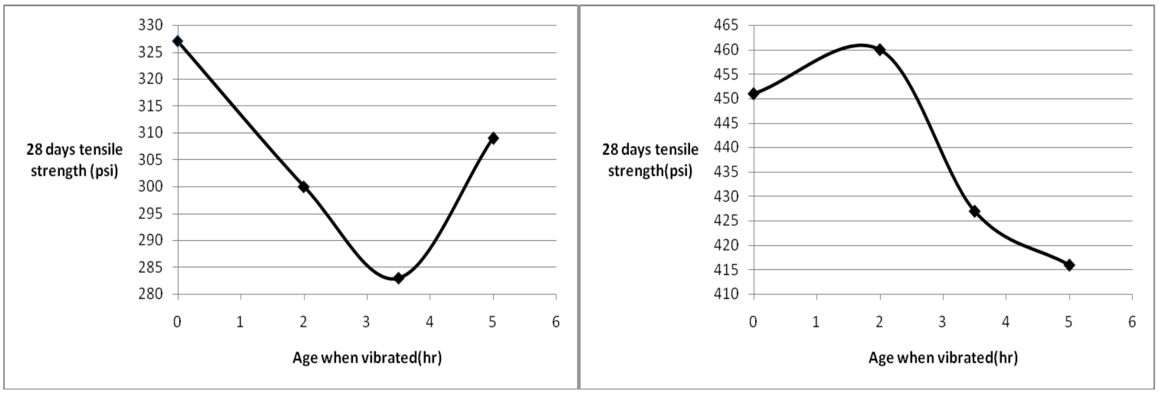

Figure 6 *: 28 days time comparison (ratio 1:2:4 left and ratio 1:1.5:3 right)*

Graphical representation:
The same trend can be seen much more dramatically in the 28-day temsile test results, where all of the groups of cylinders that were vibrated had weaker average strengths than the control group as seen in Figure 6.

4. Conclusions:
The compressive strength of the cylinders has increased, but tensile strength has decreased. The vibrations could reduce the water content of the concrete. The final setting period was 4.5 hour. Therefore any cylinders that were vibrated before 4.5 hours could have experienced the effect of lower water content. The vibrations could have strengthened the concrete is if the vibrations closed some of the air voids in the concrete. It has been suggested (Buenfeld 1999) that reduction of air voids in concrete increases the compressive strength. This effect may also explain some of the strength loss in tension strength. The results of this study have shown that vibration under a limit has a positive impact on the ultimate compressive strength of concrete. But it has a slight negative effect on the tensile capacity.

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