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STUDY A NEW TECHNIQUE FOR PRODUCING VACUUM-DEWATERED CONCRETE

R.M. BHAGAT[1], U.C.CHANDEL[2], Miss P.YADAV[3]

[1]*U.G.Student, Civil Engineering Department, J.D.I.E.T Yavatmal, Maharashtra, India*, rahul7017bhagat@gmail.com

[2]*U.G.Student, Civil Engineering Department, J.D.I.E.T Yavatmal, Maharashtra, India*, umeshchandel1550@gmail.com

[3]*U.G.Student, Civil Engineering Department, J.D.I.E.T Yavatmal, Maharashtra, India*, pruthviyadav3@gmail.com

Abstract

In this work, examine a new technique for producing vacuum-dewatered concrete. Perforated PVC pipes incased in cotton cloth are used in this technique to dewater concrete from inside of concrete volume, rather than from the surface, as is the case in the conventional vacuum dewatering method. These pipes are lay in position inside concrete forms, and a vacuum pump is connected to the dewatering pipes, which is operated after casting of fresh concrete to remove the excessive water from which. Properties of vacuum dewatered concrete using the new technique are investigated by a series of tests. . The new dewatering technique is a good alternative to the conventional vacuum dewatering technique and can have a wider range of practical applications than the conventional method.Based on test results, the new technique improves concrete strength and other mechanical properties particularly at early ages.

Index Terms: Vacuum Concrete, Dewatering Process, Compressive Strength, Bleeding Water, Water/Cement Ratio.

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1. INTRODUCTION.

Vacuum concrete is concrete which includes high water content during the addition to facility the mixing process and to improve the workability to enable it to be handled, placed into complicated moulds or around extensive reinforcement. After molded, the concrete is subject to a vacuum dewatering process when water for workability no longer needed to removes the excessive quantities of water. Vacuum processed concrete which is widely used in some countries, especially for slabs and floors was first invented by Billner in the United States in 1935. In this technique a filter pad is first applied on surface of freshly cast, vibrated and leveled concrete. This filter pad used to prevent cement particles from going through it. In general, the amount of water is two to four times as much as the amount essential for hydration of the cement, it is advantageous to remove water not needed for hydration. The removal of excess water from concrete causes compaction due to mobilization of atmospheric pressure on concrete surface. Therefore, what might be termed "water of workability" is removed when no longer needed. The process is therefore reducing the final water/cement ratio of concrete before setting, which controls strength and other properties of concrete The withdrawal of water produces settlement of the concrete to the area of about 3 per cent of the depth over which the suction acts. The vacuum cannot remove water needed for hydration because the capillary diameters in the cement paste decrease as the water-cement ratio decreases. This capillary construction start at the surface and then proceeds down-ward. Wherever the water- cement ratio decreases to about 0.30, capillary diameter becomes too small to permit passage of water under the magnitude of pressure the system induces. Thus there is no risk that the water-cement ratio will fall below 0.30, which is well above the minimum of 0.20 required for hydration of cement . Permeable formwork has been used on hundreds of concrete structures around the world .

2. NEW DEWATERING TECHNIQUE

In the current method vacuum dewatering is processed from inside of the freshly placed concrete rather than the surface, through perforated PVC pipes encased to prevent the removal of cement and other fine particles with water. These pipes are embedded and fastened in place in forms via reinforcement bars or any other means, a steel bar or wire can be inserted inside the PVC pipes to give the required hardness keep alignment, make easy bending and prevent pipes from clogging due to external pressure during vacuum process. The steel bar or wire shall be of a diameter smaller than the inside diameter of the perforated pipe to allow the extracted water to flow easily inside the pipe. otherwise, a perforated pipe made of hard PVC or even metallic material can be used. The dewatering system can be multiple pipes connected directly to the vacuum pump or a net of interconnected pipes connected to the vacuum pump. The present technique allow dewatering of concrete of high thickness and of almost any pattern. The vacuum dewatering process can be initiated as soon as the concrete is cast in the forms and can be done all together with concrete vibration and finishing, which is shown to yield better dewatering and compaction process.

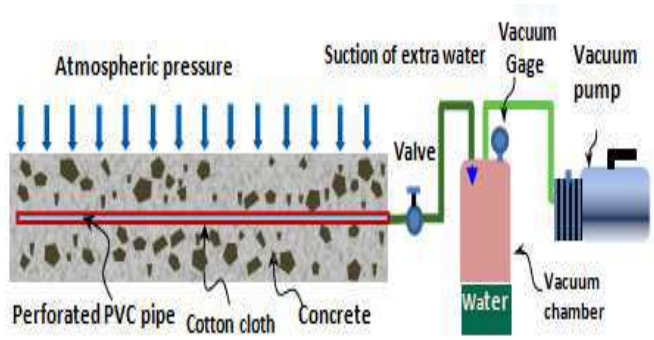

Fig (1) diagrammatic representation for new vacuum dewatering technique.

As a result, in the new technique, most of the work is done during training for casting and minimum time is extreme during vacuum dewatering. The dewatering pipes are to be left in place in concrete, since they cannot be removed from rapidly stiffened concrete by vacuum process. However, these pipes are not valuable, and the effect of dewatering pipes on the compressive strength is found to be small as the area of such pipes is small compared to the total area. In addition, the dewatering pipes can be grouted subsequently, if wanted, for very sensitive situations, i.e. water retaining structures. In laboratory, new vacuum dewatering technique applied by plywood molds

Fig (2) new vacuum dewatering technique

3. MATERIALS AND METHODS

The materials used in this study were ordinary Portland cement (OPC) type 1, river sand of degree accourding to BS EN 882 and fineness modulus of 2.18, and river coarse aggregate of 20mm maximum size. Specific gravity of fine and coarse aggregates were 2.63 and 2.65 respectively. Clean tap water was used in all mixes. Electrical vacuum pump of 1.5 kW power produce vacuum pressure of 60mm of mercury was used in all tests. Concrete was cast in moulds of various dimensions (150 x 150 x 750 mm, 200 x 200 x 750 mm and 250 x250 x 750 mm) using single dewatering pipes (see Fig. 1) laid along center of mold section. The molds were conserved at corners with silicon seal to simulate the form of a continuous concrete volume around multiple dewatering pipes. Thus the cross sectional dimensions of molds represent horizontal and vertical spacing of dewatering pipes. Vacuum dewatering was started after casting the concrete. Concrete vibration was done all together with vacuum dewatering process. Table vibrator was used for small (150x150x750 mm) molds and an internal vibrator (vibrating bar) was used for larger molds (200x200x750 mm and 250x250x750 mm). The volume of extract water from fresh concrete was monitored and recorded normally by put the vacuum chamber on a digital weighing apparatus. Records were taken at small time intervals at the beginning of vacuum process and the time interval was increased later with a decrease in dewatering rate. For evaluation purposes, reference specimens were also cast and vibrated in a similar method but without vacuum dewatering. The formwork for beams was uncovered off after 24 hours and specimens were moist cure at room temperature. To calculate compressive strength of concrete, core samples with 100 mm diameter and of a height / diameter ratio of 1.5 were taken and tested at different ages. The measures and testing procedures to determine the compressive strength of the samples was in agreement with BS EN 12504-1:2000.

4. EXPERIMENTAL WORK

To access the probable method and its validity and applicability, a series of experiments have been conducted. These experiments focused on the parameters affecting practical consideration and properties of concrete produced by the proposed method. The parameters studied were: Diameter of dewatering pipe and size and number of perforation per unit length of the pipe, water-cement ratio, specimen size and duration of vacuum process. while other parameters such as vacuum pressure level, cement/aggregate ratio, grading of aggregates, finesse of cement, etc. control properties of vacuum processed concrete, these parameters are considered of secondary importance and not studied here. Mix proportions of all mixes was (1 cement: 2.5 sand: 3.5 coarse aggregate) by weight. To study the effect of dewatering pipe character, Pipes with three different outside diameters (6, 10 and 14 mm) and of 1.5 mm wall thickness were used. The number of perforation was 12, 16 and 20 holes per 100 mm of dewatering pipe in all pipe sizes. The holes were 2mm diameter and equally circulated on the pipe surfaces. The size of test specimens was 150x150 in cross section and 750 mm long. No appreciable difference in volume of extracted water was noted using three pipe sizes. Also, no further increase in range of extracted water was recorded by increasing number of perforations by more than 12 holes per 100 mm of dewatering pipe length. Thus, for the pipe sizes used, the surface area of dewatering pipe has little effect on the volume of extracted water. However, pipes with inside diameter of 7mm and outside diameter of 10 mm and with 12 holes per 100 mm of pipe length were measured as practical, and used in all subsequent tests. unimportant amount of cement and fine particles were extracted with water. Wet sieving of vacuum treated fresh concrete samples taken from upper, middle and bottom regions of remoulded concrete showed that no replacement of cement, fine aggregate and coarse aggregate was taken place due to vacuum process. This is in agreement with the conventional method of vacuum dewatering. To study the result of spacing of dewatering pipes and water/cement ratio on efficiency of the process and properties of concrete produced, molds of different sizes were used. Molds were of

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dimensions: 150 x 150 mm, 200 x 200mm and 250 x250 mm in section and 750mm long. Concrete with same mix extent and water/cement ratio of 0.55 were cast in each mold size. Fig. 4 shows typical curves for rate of withdrawal of water with time for dissimilar mold sizes.

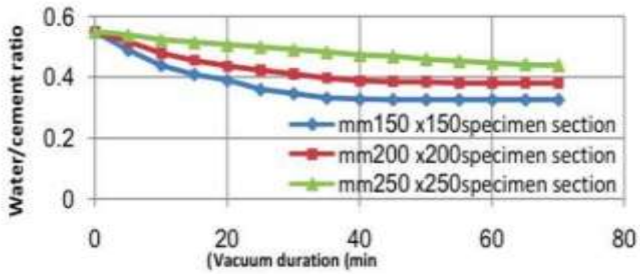

Figure (3) Relation between water/cement ratio and vacuum duration

The reduce in water content achieved by the new technique was up to 20 per cent in specimens of dimensions 250x250x750 mm. The reduction was increased to 41 per cent for 150x150x750 mm specimens. Whereas the usual method reduces water content up to 20 per cent only, and it is usual to assume the suction in the conventional method to be fully effective over a depth of 100 to 150 mm only Therefore, the present technique gives solutions for the problem of vacuum dewatering of concrete of large dimensions. Figure 4 shows that the rate of remove of water falls off with time in a way similar to that of the conventional method. Little reduction in water content occurs after 40 minutes of dewatering and there is a limit for final water/cement ratio for each specimen size. The decrease in rate of water extraction is due to two reasons. Firstly, the capillary diameters in the cement paste decrease as the water-cement ratio decreases in fresh concrete near dewatering pipes. Secondly, hydration and location of cement paste at later times reduces capillary diameters as well. Thus, it is considered that vacuum processing during 40 minutes is practical and economical and is used in all subsequent tests.

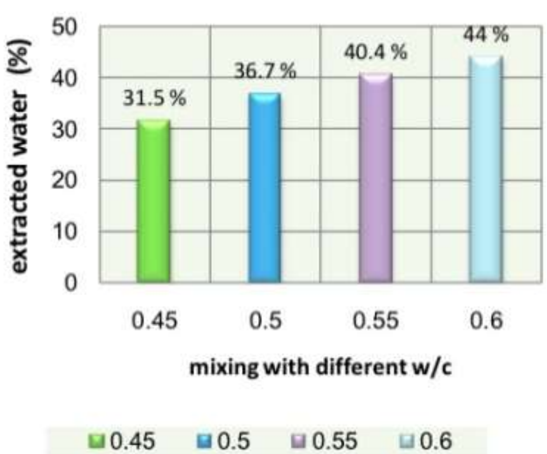

Figure (4): relation between water/cement ratio and extracted water

The amount of the extracted water directly proportional to the water/cement ratio for the same size of the specimens. Fig. 4 shows the percentage of extracted water from the total amount of mixing water through the vacuum processing which was continued for 40 minutes. Four mixes of the same cement/aggregate ratio but with dissimilar water/cement ratios were cast in 150x150x750mm molds. Table 1 shows the effect of initial water/cement ratio on strength of vacuum processed concrete at different ages. Four mixes of same cement/aggregate ratio but with different water/cement ratios were cast in 150x150x750mm molds. Core samples of 100mm diameter and 150mm height were taken from 150x150x750mm specimens. The specimens were vacuum processed for 40 minutes, and unprocessed specimens were also cast for comparison as control. To eliminate the need for capping, cores were drilled horizontally using the following expression: Estimated in-situ cube strength =D/ (1.5+1/λ) x measured compressive strength of core. Where D is 2.5 for cores drilled horizontally (perpendicular to height when cast); or 2.3 for cores drilled vertically (parallel to height when cast); λ= length/diameter of core.

Table (1): Water/Cement ratio and of strength of vacuum processed concrete at different ages

W/C Ratio	Compressive strength (MPa) at age of							
	3 days		7 days		14 days		28 days	
	Control	Vacuum Processed	Control	Vacuum Processed	Control	Vacuum Processed	Control	Vacuum Processed
0.45	8.5	25.7	17.8	29.2	21.8	39.9	25.7	43.2
0.5	8.1	21.5	14.5	24.6	18.5	32.8	21.5	37.6
0.55	7.7	13.9	12.7	21.3	14.4	32.0	18.4	37.3
0.6	7.2	16.1	9.9	16.5	12.6	33.9	16.3	35.3

The new dewatering technique increased strength by up to about 3 folds at early ages. The gain in strength is much higher than that obtained by the conventional method in which, the strength increase achieved in practical work was 25to 40 percent. The increase in strength at early ages is of considerable importance especially in precast concrete factories, where removal and reuse of formworks at frequent intervals is essential. To investigate the early strength more thoroughly, and since core samples may be impaired by coring process at subchages, concrete specimens of dimensions 150x150x750 mm where cast with and without void dewatering and tested for flexure and compression at ages of one and three days. Two points loading was used to determine modulus of rupture of specimens according to BS 1881: part 118:1993 specifications. The compressive strength of the same concrete for both void processed and control specimens was determined using intact parts of beams tested in flexure. Because the beams are of square cross-section, an ‘equivalent’ or ‘modified’ cube is obtained by applying the load through square steel plates of the same size as the cross-section of the beam (150x150mm). The specimen is located so that the as-cast top surface of the beam is not in contact with either plate. The test is prescribed by BS 1881- 119: 1983. Table 2 shows flexural and compressive strength of vacuum processed and control specimens at early ages. Average values of comparable cube strength for the two parts of each beam are shown in the table. It can be shown that the strength obtained by core samples (table 1) and equivalent cubes (table 2) at age of 3 days are consistent.

Table (2): Flexural and compressive strength of vacuum processed concrete at early on ages

W/C Ratio	1 day				3 days			
	Flexural strength MPa		Compressive strength (equivalent cube) MPa		Flexural strength MPa		Compressive strength (equivalent cube) MPa	
	Control	Vacuum processed	Control	Vacuum processed	Control	Vacuum processed	Control	Vacuum processed
0.45	2.12	3.56	9.0	18.1	2.98	3.77	12.7	21.3
0.5	1.63	3.40	7.5	14.4	2.15	3.82	9.0	16.2
0.55	1.41	3.09	5.8	12.8	1.82	3.41	7.5	14.2
0.6	1.13	2.87	4.2	10.7	1.63	3.14	6.0	11.7

The effect of the process on compressive strength at early ages obtained by the new technique is consistent with those obtained by the conventional technique [8]. However, the increase in force using the new technique is substantial and more pronounced. Table 3 shows the effect of spacing of dewatering pipes on compressive strength of core samples taken from vacuum processed and unprocessed (control) concretes at 28 days of age. Four mix of same cement/aggregate ratio but with different water/cement ratios were cast in molds of 150x150mm, 200 x 200mm and 250 x250 mm in cross section and 750mm long, using single dewatering pipe laid along center of each mold section. Specimen sectional size, as discussed earlier, represent spacing of dewatering pipes in larger concrete sections to be used in practice. Since the vacuum pressure is constant along horizontal dewatering pipes, the length of specimens does not have an effect on processed concrete properties. However, for very lengthy and small size pipes, friction losses of extracted water may have small effect on dewatering rate along pipes at initial stages. At subsequent stages, where the dewatering rate is reduced, it is expected that the final water/cement ratio will not differ a lot along dewatering pipes. For vertical pipes, where the external pressure is increased with depth of fresh concrete, it is expected that water/cement ratio after dewatering will be lower at lower concrete sections and higher at upper concrete sections due to variation in pressure and bleeding of concrete.

Table (3): Water/cement ratio and strength of vacuum processed concrete for different specimen cross sections.

Before processing		After processing					
W/C ratio	specimen size 150x150x750mm	specimen size 150x150x750mm		specimen size 200x200x750mm		specimen size 250x250x750mm	
	Compressive strength MPa	W/C ratio	Compressive strength MPa	W/C ratio	Compressive strength MPa	W/C ratio	Compressive strength MPa
0.45	25.7	0.308	43.3	0.373	42.4	0.386	34.0
0.5	21.5	0.316	37.7	0.389	34.1	0.432	30.5
0.55	18.4	0.328	37.3	0.389	33.5	0.476	32.1
0.6	16.3	0.337	35.3	0.456	27.1	0.464	25.7

Although the water/ cement ratio is reduced amazingly in all tests, the relation between strength of vacuum processed concrete and water/cement ratio was however not consistent. The strength of vacuum processed concrete almost follows the usual dependence of the final water/cement ratio. The withdrawal of water produced settlement of the concrete to about 3.5 per cent of the depth of concrete for specimens of 250 mm high, and about 4 percent for specimens of 150 mm high. In the conventional method, the ratio of settlement is about 3 per cent of the depth over which the suction acts. In fact, the increase in power on vacuum treatment is proportional to the amount of water removed up to a critical value beyond which there is no significant increase, so that prolonged vacuum treatment is not useful. In the conventional method, the critical value depends on the thickness of concrete and on the mix proportions. Where as in the present technique, the critical value depends on spacing of dewatering pipes, and also on mix proportions. However, prolonged vacuum accelerates concrete setting and can be useful in precast concrete plants and other situation were rapid setting is beneficial.

5. Conclusions

In this study a new void dewatering technique is used to extract excess water from inside of concrete volume rather than the surface. Based on tests conducted to study the parameters affecting practical considerations and properties of concrete produced by the proposed method, the following conclusions were made: The new technique is a good alternative to the conventional vacuum dewatering technique, and is suitable and more convenient for concrete of high thickness and large dimensions. Perforated PVC pipes of 10mm outside diameter enclosed in cotton cloth can be used as practical artificial drains to consolidate concrete and improve concrete properties by vacuum process. The most proper and practical spacing of dewatering pipes for concrete of large dimensions is 200-250 mm. Vacuum duration depends on spacing of dewatering pipes and cement/aggregate ratio, for spacing of 200- 250mm, vacuum processing during 40 minutes is convenient. The new dewatering system increases preliminary work before concrete casting, but save work and time during concrete casting in comparison with the conventional method.

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