The Effect of Vibration Energy Changes on Compressive Strength of Concrete Paving Block (CPB) in Concreting Process with Vibropressing System

Erno Widayanto¹,²,a, Agoes Soehardjono²,b, Wisnumurti²,c, Achfas Zacoeb²,d

¹Department of Civil Engineering, Engineering Faculty, University of Jember, Jember 68121, Indonesia
²Department of Civil Engineering, Engineering Faculty, Universitas Brawijaya, Malang 68121, Indonesia

a widayantoerno@gmail.com; b agoessmdi @ub.ac.id; c wisnumurti@ub.ac.id; d zacoebc93i@ub.ac.id

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Abstract. The Concrete which has low w/c, or Concrete Paving Block (CPB) requires technology in the compaction process. Compaction with vibropressing technology is a compaction technology that combines vibrations and presses that carried out simultaneously. The objection of the research is finding the effect of vibration energy changes on CPB compressive strength characteristics. The research method accordance with the ACI method used the volume proportioning of the mixture are 1 cement: 4 fine aggregate: 4 coarse aggregate with w/c ratio 0.6 and the target compressive strength of the average CPB 18.3 N / mm². Coarse aggregates take from processing rock breakers with a grain size of 0-5 mm. The samples were tested using a treatment method using a regulator with parameters as a measure to observe the CPB compressive strength characteristics. The settings in question are frequency, vibration time, and pressure during production. This study was conducted repeatedly using a 4 HP electric motor for the first and using a 7HP electric motor. The results showed differences that occurred, starting from recording data on vibration acceleration fluctuations when installing 4HP and 7HP. The higher the vibration energy, the higher the number of vibrations, and the higher the compressive strength produced.

1. Introduction

Concrete which has a low w/c, or what is known as Concrete Paving Block (CPB) is in desperate need of exclusive technology in the compaction process. The technology meant a mixing (mixing), handling (handling), placement (placing), and compacting (compacting) [1]. For CPB, the technology commonly used with the vibropressing method. Compaction with vibropressing technology is a technology that combines vibration and pressing which done simultaneously.

This study aims to determine the character of CPB compressive strength if there is a change in the use of a vibrator electric motor from 4 HP to 7 HP by making samples using a mixture composition, high vibration, significant pressing, and frequency are at the same. Then, it assembled to become a machine CPB engine unit. Among the constituent elements are divided into the body frame engine, hydraulic, electric motor, electrical panel box, mold mat, hydraulic engine handle, oil tank, oil hose for hydraulic drive, dial gage pressing gauge, vibrating old-timer and android application to record vibration acceleration. All of the above tools assembled in such a way that the machine can operate for CPB concreting with one mold producing 8 pcs to 12 pcs.

Especially for the mechanism of CPB production, in the vibropressing method, several parameters determine the quality of CPB which is a high pressure [2]. Sulistyana (2014) made specimens with a mixture of sand, cement, sand and stone ash 0 - 5 mm = 1; 1.6; 1.6; 4 with w / c = 0.6. The mixed sample put on a steel cylinder ring with a diameter of 96 mm and a height of 200 mm, then pressed up to 80 MPa. The maximum compressive strength test results are around 70 Mpa or two times greater than the pressure without vibration when making test specimens. The following is a reverse study conducted by Arslan, ME (2011) with a mixture of high-quality concrete designs, using several types of b / c ratios between 0.3 to 0.6 and a time vibrating of 0 to 240 seconds.
without pressing, it found that compressive strength the maximum occurs between 65 seconds with an \(aw/c\) ratio of 0.3 [3]. The two studies above cannot be applied to the CPB manufacturing process except for low w/c, because the CPB manufacturing process demanded with fast processing and high compressive strength.

Research on compaction of vibropressing is also carried out by Auzins, J. (2009), according to him the application of the vibropressing method is very important involving the factors that form characterize the properties and methods of raw concrete treatment such as granulometric parameters, water-cement ratio and others, and calculate strength the actual block of mold used as a CPB printing device [5]. Similar research was also conducted by Giantautas (2014), which examined the characteristics of compressive strength and tensile strength of CPB on one pallet. The highest tensile strength obtained on the pallet reached 15.6%. The variety of density, freeze-thaw resistance, when using salt on one side, and abrasion resistance are ranging from 0.5% to 2.7%. The less mixture or tip of the moldless filled with the concrete mix; it results in lower product density and strength [6].

One component of vibropressing that is very dominant is the amount of vibration frequency in the process of making CPB. According to Agrita K (2011), computational analysis shows that the rate, pressing, and amplitude of vibration in the compaction process greatly influence the compressive strength of concrete. Even the frequency has an effect of 42% of the three parameters on the compressive strength of concrete [7]. In perlite Yanjun X (2015) manufacturing test, the difference in vibration dynamo power will significantly affect the time required for compaction. Increased frequency, product density increases, and the time for compaction will decrease. When the frequency set to 20 Hz or 25 Hz, the time to jump back is relatively longer. When the rate is 35 Hz, the time to jump back is too short of having a good effect [8].

2. Technology Vibropressing machine
2.1 CPB Machine Tool
The next picture sketch of a CPB machine with a vibropressing combination system or known as a combination of vibration and pressure in the production process. This CPB engine is driven by two electric motors, one for 3 HP for the other medium hydraulic needs of 4 HP or 7 HP for vibration. It is assembling a machine for production. In more detail can be seen in Figure 1 below:

![Fig. 1 CPB paving machine for vibropressing](image)

In this research, paving with the same mixture was carried out, but the specimen was vibrated using different vibratory dynamo power. In treatment one, it echoed with a dynamo that has a power of 4 HP while the other is used vibrating dynamo with a power of 7 HP. They are the measurement of pressing, frequency, and vibration time treated equally. This research was conducted to minimize the energy of vibropressing with optimum quality.
2.2 CPB Concreting Technology with Vibropressing

The steps in the CPB production process are as follows:

1. The method of making paving starts by mixing cement + aggregate into a mixer bath.
2. After the cement evenly distributed on the aggregate, then put water into the mixer to continue mixing.
3. The next step is put to the mixture into the vibropressing mold on the CPB machine to try with various treatments. And measure them for researching.
4. Placing the specimen in a shaded place and keeping the humidity up to the age of 28 days.
5. Stage 4 carried out until it reaches sufficient volume and depends on the strength of the operational funds.
6. Shipment according to the buyer's order.

In detail, the steps contained in the following scheme:

![Diagram of CPB concreting process](image)

**Fig. 2 The process of making paving**

2.3 Regulator of vibropressing machines

To optimum quality, every energy load in the CPB concreting process with the vibropressing method must always carefully measured. The tools included are:

1. The timer is a device installed with a panel that functions to regulate the motor dynamo connection with electricity for a particular duration.
2. The pressure regulator is measuring the magnitude of pressing energy the CPB machine. It is essential because to know the capacity of the mattress when experiencing pressing.
3. Inventer, this tool is used to adjust the number of dynamo rotation vibrations in each minute, the amount of rotation per minute is set ranging from 30 rpm to 60 rpm.
4. Android accelerometer application, this tool is used to record the vibration acceleration due to the regulation of the number of dynamo rotations used to vibrate the mattress table.
3. Characteristics of Sample Materials, Mix Designs and Treatment of Test Objects

3.1 Material characteristics

Material testing is used to limit the widening of research problems by examining the character of the materials used as research. Several samples are tested for their properties before the mixture carried out, namely cement, sand, stone ash produced by stone crushers. In SNI 03-0691-1996 regarding concrete bricks (Paving Block) there are no special requirements regarding the material for CPB materials but only describes the reference, classification, quality requirements, sampling methods, test methods and requirements for passing the test. So it was concluded that the material criteria for CPB were identical to standard concrete. This SNI regulation only describes the character of production, while the characteristics of the material not explicitly discussed. More fully, the results of the sand material test explained in the following table:

| No | Type of testing                | Sand properties | Stone ash properties |
|----|--------------------------------|-----------------|---------------------|
| 1  | Volume weight (g/cm³)          | 0.00111         | 0.00164             |
| 2  | Specific gravity (gr/cm³)      | 2.471           | 2.167               |
| 3  | Large water absorption (%)     | 6.839           | 1.522               |
| 4  | clay content(%)                | 2.52            | 9.610               |
| 5  | Moisture content(%)            | 8.885           | 1.299               |
Table 2 Sand sieve analysis

| number | mm  | gram | %   | retained | pass  |
|--------|-----|------|-----|----------|-------|
| 4      | 4.76| 11.5 | 1.15| 1.15     | 98.85 |
| 8      | 2.38| 24.3 | 2.43| 3.58     | 96.42 |
| 16     | 1.19| 89.7 | 8.97| 12.55    | 87.45 |
| 30     | 0.59| 306.3| 30.63| 43.18   | 56.82 |
| 50     | 0.30| 361.5| 36.15| 79.33   | 20.67 |
| 100    | 0.15| 170.9| 17.09| 96.42   | 3.58  |
| Pan    | 0.00| 35.8 | 3.58| 100      | 0     |
| total  |     | 1000 | 100 | 236.21   |       |

According to SNI 03-1968-1990

Fineness modulus = % retained cumulative/100

= 236.21/100

= 2.362

3.2 Mix Design

The strength of CPB mix design is corresponding to the ACI and DOE method. With the proportioning of the mixture is 1 cement: 4 Fine aggregate: 4 coarse aggregate and 0.6 water-cement ratio, the target compressive strength of the average CPB of 18.3 N/mm² [1]. Coarse aggregates take from the processing of stone crushers with a grain size of 0-5 mm. The water used is drinking water, and there are no additional ingredients other than the ingredients above. The size of 6x10.5x21 cm paving with 12 pcs with one mold.

![Figure 5 concreting CPB process 1x concreting = 12 pcs](image)

3.3 Treatment of samples

The treatment method for preparing samples of test objects done by regulating, the regulator in such a way that the parameters can use as a measure to observe the CPB compressive strength characteristics. The settings in question are the frequency of vibrations, the duration of wave and the pressure at the time of production. By the title theme, the research was conducted repeatedly using the first energy 4 HP and the second using vibrating energy 7 HP. This research is intended to improve the quality of CPB production even though it uses relatively small vibration.
energy. One of the possible solutions is to set the regulator on each type of electric motor vibrator power. For this purpose, the treatment arranged as follows.

Table 3 The treatment sample

| Test number | Energivibrator 4 HP | Energivibrator 7 HP |
|-------------|---------------------|---------------------|
| Pressing    | Frequency | Duration vibration | Pressing | Frequency | Duration vibration |
| (kg/cm²)   | (Hz)      | (s)                | (kg/cm²) | (Hz)      | (s)                |
| 1           | 25        | 40                 | 4        | 25        | 40                 |
| 2           | 25        | 40                 | 5        | 25        | 40                 |
| 3           | 25        | 40                 | 6        | 25        | 40                 |
| 4           | 25        | 40                 | 7        | 25        | 40                 |
| 5           | 25        | 40                 | 8        | 25        | 40                 |
| 6           | 25        | 45                 | 4        | 25        | 45                 |
| 7           | 25        | 45                 | 5        | 25        | 45                 |
| 8           | 25        | 45                 | 6        | 25        | 45                 |
| 9           | 25        | 45                 | 7        | 25        | 45                 |
| 10          | 25        | 50                 | 8        | 25        | 50                 |
| 11          | 25        | 50                 | 4        | 25        | 50                 |
| 12          | 25        | 50                 | 5        | 25        | 50                 |
| 13          | 25        | 50                 | 6        | 25        | 50                 |
| 14          | 25        | 50                 | 7        | 25        | 50                 |
| 15          | 25        | 50                 | 8        | 25        | 50                 |

4 Results and Discussion

4.1 Vibration recording from the accelerometer

In the process of making the test object, a vibration recording is carried out on the machine installation by using an android in 3 directions. The three paths are the direction X is the left and right direction, the direction Y is the direction of the back front, and Z is the direction of the vibration down. Electric motor for vibrations installed with 4 HP power. The recordings obtained in x,y, and z directions for making test objects between 1 and 15 are as follows:

Table 4 Record data of accelerometer vibration direction X, Y, and Z on dynamo vibrate 4 HP
Vibration acceleration with vibration energy 4 HP for X and Y direction acceleration only occurs between -2 m/s² to 2 m/s² medium Z direction of significant acceleration that occurs between -5 to 10. It is because the course of movement of the mattress is designed only for upward-downward motion only or Z direction only, so that maximum movement occurs in the course of Z only whereas the X and Y direction vibrations occur because the base of the mattress is rubber which allows it to move even though it is small.

Table 5 Recording data of accelerometer vibration direction X, Y, and Z on dynamo vibration 7 HP

| Accelerometer record data | Input data |
|---------------------------|------------|
| **Dynamo Vibrator = 7 HP** | Frequency = 40, 45 and 50 Hz |
|                          | Pressing = 25 m/s² |
|                          | Treatment test 16 - 30 |

Acceleration with 7 HP for x-direction only occurs between -10 m / dt² to 5 m / dt², and Y acceleration only occurs between -10 m/s² up to 10 m/s² while the direction Z is large acceleration that occurs between -10 m/s² up to 18 m/s². It is because the direction of movement of the mattress is designed only for the upward and downward direction of the Z only. So that maximum movement occurs in the direction of Z only whereas the X and Y direction vibrations occur because the base of the mattress is rubber which allows it to move even though it is small. However, it is very different from strongly vibrating the 4 HP electric motor, to vigorously vibrate with the 7 HP electric motor that was able to vibrate with an acceleration of 2 m/s² to 5 m/s² times the acceleration compared to 4 HP, both directions X, Y and Z. Also, with the frequency, the same number of vibrations
produced is very different between 7 HP with 4 HP. The 7 HP produce more vibrations when compared to the 4 HP.

4.2 Test results both of 4 HP and 7 HP

The sample testing is done by the same pressing, which is at a pressure of 25 kg / cm², the same time, and vibration frequency are carried out. The capacity of the pressing machine is between 0 kg / cm² up to 90 kg / cm². Press testing is carried out only at a pressure of 25 kg / cm², intended to measure the dominance of influences other than pressing. Vibration duration is chosen between 4, 5, 6, 7, and 8 seconds because the engine is required to produce large quantities in every second. While the CPB engine frequency measured using inventor with a capacity of 0 Hz to 50 Hz. Test samples that use a maximum of 40 Hz, 45 Hz, and 50 Hz are intended to shorten the vibration so that the CPB machine can produce optimally.

**Fig. 6** A time vibration relationship on compressive strength at pressing strength 25 kg / cm² and frequency 40Hz, 45Hz and 50 Hz

Figures 5 explain that there is a striking difference between the use of a 4 HP vibrator machine with seven hp, even the compressive strength can increase 5-fold due to differences in vibration energy. Differences occur, starting from recording data of vibration acceleration fluctuations when installing 4 HP and 7 HP (see table 6 and table 7). From the recording, data shows that the higher the vibrational energy, the higher the number of vibrations will be, and this is the reason for the difference in compressive strength produced. Besides that, vibration energy is also the cause of the effect of long vibration time at 4 HP vibration energy and 7 HP vibrating energy (see figure 6 and figure 7).

4.3 Relationship between unit weight and compressive strength

The relationship between volume weight and compressive strength is the same as that which occurs in standard concrete, namely the higher the volume weight, the higher the compressive strength. But there are significant differences with general concrete [9]. The linear line relationship between the importance of general concrete volume and compressive strength is
relatively sloping compared to CPB. It is related to the compaction process, the compaction of general concrete is usually only done by vibration, while in CPB compaction is done by vibropressing where the sample using vibropressing is a more fluctuating line equation.

On CPB machines with vibrating frequency capacities ranging from 0 to 50 Hz, pressing strengths of 0 to 90 kg / cm² and vibration duration of 4 seconds to 8 seconds and pressing 25 kg / cm² that a time additions vibrate at power vibration 4 HP cannot increase the CPB compressive strength, while at 7 HP power vibration an extended increase in vibration can significantly increase CPB compressive strength. It is because the power 4 HP vibrations that occur are very low so that the filling of the granular cavity cannot be filled correctly and causes the compressive strength of CPB to be quiet. In contrast to the vibration conditions with 7 HP power vibrations, the vibrations that occur have been able to close the granular cavity close to perfect so that it can increase the compressive strength of CPB significantly. This condition still applies the higher the vibropressing energy, the higher the compressive strength of CPB.

![Graphs showing relationship between volume weight and compressive strength at 40, 45, and 50 Hz](image)

**Fig. 7 Relationship of volume weight and compressive strength at a frequency of 40, 45 and 50 Hz**

**5. Conclusion**

In the vibropressing method, CPB compressive strength mostly determined by energy. The higher the power, the more elevated the compressive strength of the CPB it produces. The voltage on the CPB engine can be in the form of pressing strength, vibration time and electric driving power of vibration. For the condition of the mixture with the composition ratio of volume 1 cement, 4 sand and 4 stone ash at the rate of water and cement 0.6 using a CPB machine with a maximum frequency capacity of 50 Hz, the maximum press strength is 90 kg / cm² and 4 to 8 seconds vibrating with the same treatment produces energetic electric power vibration has the most dominant influence.

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