Experimental Investigation on Influence of Molding Methods on Properties of Pervious Concrete

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Abstract. Despite the common use of pervious concrete (PC), there is no standard way of producing the test specimens, which undergo testing to infer the behaviour of PC in the field. Vibrating table is the most common method but greatly reduced in vibration time compare with normal concrete in the laboratory. Marshall compaction and superpave gyratory compactor (SGC) are recommended standard molding methods for porous asphalt mixtures manufactured in the laboratory environment. Three kinds of pervious concrete samples with three target porosities were prepared by the above three methods, and the effects of the molding method on the physical properties, mechanical properties and durability of the samples were investigated in the study. Experimental results showed, with different molding methods adopting, pervious concrete with the same mixture design exhibits slightly different physical and mechanical properties. After analysis and comparison, SGC is the best choice to obtain concrete with high permeability, good freeze-thaw resistance and high strength, followed by Marshall compaction molding, and vibration molding is the last one. As a result, a win-win situation of the hydraulic characteristics and mechanical properties of pervious concrete can be achieved due to both optimized mix-design and appropriate molding method.

1. Introduction

Perious concrete, a kind of mixture with continuous voids, in which coarse aggregates with a specific particle size gradation are cemented into concrete by cementitious material, with little or no fine aggregate added. Compared with conventional concrete, this material is light and porous, and requires less energy to put into production [1], so it is a leader in emerging environmentally friendly products. Its characteristics make it as good sound-absorbing and heat-insulating material, a bed material for vegetation and sewage purification. Of course, the most widely and longest-lasting material applied as permeable pavement [2-10]. It is preferred by engineers to use it in road engineering with the following benefits: precipitation enters the soil through multi-porous while filtering for contaminants in water [11], allow more water to evaporate from the soil and natural recharge of groundwater [12, 13], effectively effectively suppress the loss of surface water [14], reduce the urban heat island effect [15], limit the budget cost of building road drainage systems [12], and at the same time, porous materials can effectively absorb noise [16]. Just as everything has two sides, compared with ordinary concrete, the durability and strength of pervious materials are not high. It is limited to areas with light traffic or low levels of congestion such as local roads, streets, parking lots, shoulders of heavy pavements etc. [17, 18]. Overcoming the performance bottlenecks of pervious concrete, especially its
low strength, which is an inspiring but challenging task. Fortunately, since the advent of permeable concrete, many scholars have done a lot of work to improve its mechanical properties on the basis of firmly retaining the hydraulic properties of permeable concrete. Such as varying aggregate particle size gradation curve [17, 19], the type and amount of fine sand added to the mixture [20-22], the content of cement and water, admixtures, especially for some certain types of fibers [20, 21, 23], various polymer modified water-permeable concrete materials [24-28] and so on. In addition to the above studies of the materials that make up concrete, construction techniques adopted is another key factor affecting the performance of pervious concrete [29-31]. Therefore, both researching proper molding methods in the laboratory and full scale applications is still a topic of constant discussion. As mentioned above, PC is a non-skeleton structure formed by a special gradation aggregate cemented with reduced cementitious material, which has poor fluidity and large frictional resistance between aggregates. Therefore, the choice of molding process has a significant impact on the mechanical properties and destructiveness of the PC. At present, vibration molding is a molding method commonly used in laboratories. Unfortunately, the low fluidity and high viscosity of fresh pervious concrete and the formation of high-quality voids during the forming process make it unsuitable for long-term vibration consolidation like ordinary concrete mixtures. On the other hand, vibration molding also creates local large cavities in some areas of the material, while low voids appear in some areas around it, making the distribution of voids very uneven. Fortunately, the strength of the fresh infiltration mixture is very low when initially placed and low compaction energy can be immediately applied. Accordingly, Marshall compaction and superpave gyratory compactor (SGC) commonly used in permeable asphalt can be adopted for pervious concrete. Some scholars have been committed to the research and achieved certain results. Sengün et al. [32] compared and analyzed the effects of four molding methods including SGC on the properties of roller compacted concrete (RCC) and revealed the correlation of mechanical properties with compaction ratio of RCC, cementitious materials and w/c. It is concluded that the permeable void is affected by the compaction method but hardly affected by the content of the cementing material, but its mechanism needs to be further studied. Lang et al. [33] studied the influence of three kinds of molding methods on the permeability of magnesium phosphate cement steel slag permeable concrete (MSPC): vibration molding (VM), tamping molding (TM) and hydrostatic molding (HM). The comparative analysis shows that the mechanical properties of MSPC first increase and then decrease with the porosity, and the compressive strength of the sample formed by vibration molding is the largest, but the reason is unknown. Bonicelli et al. [31] used Marshall compactor with different blows to simulate compaction tools with different impact forces in the field, and tested and evaluated the performance of the samples. The results show how three factors including compaction energy affect the indirect tensile strength and porosity of the mixture without hydrological properties of PC. Kevern et al. [34] evaluated and analyzed the performance of Marshall-formed pervious concrete under different compaction energy by Marshall with its mixture design with no or small addition of fine sand. Prediction formulas related to the correlation between porosity (Vc), permeability coefficient (k), stiffness (E), strength (ITS), particle loss (CL) and bulk density (ρ), but their application needs to be studied. There are differences in the impact of molding methods on the performance of permeable concrete, and the molding methods are uncertain and diverse. In summary, the existing research on pervious concrete molding method and its effect on its properties is not comprehensive enough. At present and to the author's best knowledge, superpave gyratory compactor (SGC) only used for RCC but scarcely for pervious concrete. This article uses different molding methods to make samples, compares the effects of different methods on the performance of permeable concrete, analyzes the causes of the effects, and tries to find out the best molding method and proportion to achieve the best balance of mechanical and hydraulic performance. That has practical guiding significance for on-site construction.

This paper reports a laboratory study conducted to balance the mechanics and hydraulic performance of pervious concrete as a comprehensive result of mixture design and molding method. The experiment program considered three target porosity levels for each of the three molding methods: 12%, 15% and 20%. Then evaluate the properties of pervious concrete produced by three molding
methods: vibrating table, Marshall compaction and superpave gyratory compactor (SGC). The properties of PC involving effective porosity, water permeability coefficient, dynamic elastic modulus, compressive strength and freeze-thaw resistance. At last, comparative analysis the influence of molding method adopted in several pervious concrete mixtures and find the optimization of molding method balance the hydraulic and mechanics properties of pervious concrete.

2. Materials and Methods

2.1. Materials and Mixture Design
A common pavement limestone produced in Jiangxi, with a grain-size distribution of the aggregate is 13.2-9.5 mm, 9.5-4.7 mm, and 4.75-2.23 mm account for 10%, 80% and 10%, respectively. They were preliminary characterized according to ASTM C131-06, EN 933-3, and EN 933-4 resulting in a Shape Index (S.I.) from 4% to 9.8%, Los Angeles Index (L.A.) between 18% and 23% and Flakiness Index (F.I.) between 9.5% and 14.5%. The apparent density and bulk density of the aggregate are 2600kg/m$^3$ and 1600kg/m$^3$, respectively.

Cono brand P.O 42.5 ordinary portland cement was used as cementitious material, with chemical composition and physical properties complying with the requirements of ASTM C150-07, as shown in table 1. SR-5 type ecological concrete reinforcing agent produced by Nanjing Jiuhe Run Technology Co.Ltd., which can participate in cement hydration reaction to form polymer cement cement hydrate. Its quality is 4% of the cement. Samples were produced with three different target porosity with volume method, as shown in table 2. Inspired by the literature [21, 32, 34], the water-cement ratio for all the mixtures remained unchanged at 0.28.

### Table 1. Chemical composition and physical properties of cement.

| Chemical composition (wt%) | Physical properties       |
|----------------------------|---------------------------|
| CaO                        | 62.1                      | Specific gravity 3.10 |
| SiO$_2$                    | 20.3                      | Specific surface blain (m$^2$/kg) 3.45 |
| Al$_2$O$_3$                | 5.1                       | Initial setting time (min) 155 |
| Fe$_2$O$_3$                | 2.9                       | Final setting time (min) 245 |
| MgO                        | 1.6                       | 3 days compressive strength (MPa) 25.9 |
| SO$_3$                     | 2.0                       | 28 days compressive strength (MPa) 50.1 |
| K$_2$O                     | 0.4                       | 3 days flexural strength (MPa) 5.1 |
| Na$_2$O                    | 0.7                       | 28 days flexural strength (MPa) 7.9 |
| Loss on ignition           | 2.36                      |

### Table 2. Mix proportions of pervious concrete with three target porosity.

| Mix | Target porosity (%) | Water-cement ratio | Cement (kg/m$^3$) | Water (kg/m$^3$) | Coarse aggregate (kg/m$^3$) | Concrete reinforcing agent (kg/m$^3$) |
|-----|---------------------|--------------------|-------------------|-----------------|--------------------------|----------------------------------|
| PC-12 | 12                  | 0.28               | 422               | 118             | 1600                     | 17                               |
| PC-15 | 15                  | 0.28               | 374               | 105             | 1600                     | 15                               |
| PC-20 | 20                  | 0.28               | 294               | 83              | 1600                     | 12                               |

2.2. Specimen Preparation
With comprehensive consideration of the factors involved in the study and its post-experimental requirements, 108 PC specimens (3 molding methods×3 target porosity×12 replicates) need to be prepared. All pervious concrete specimens were cast to the same dimension of $\Phi$100×120mm. The sequence for fabricating the mixture was follows: the weighted aggregates and 1/4 water were mixed for 30 seconds and cement, concrete reinforcing agent and remaining water were added to the mixture with additional 2.5 min.
As aforementioned, the effects of different molding methods on porosity and compressive strength of PC were investigated to obtain the target performance. A steel rod with 14mm diameter, vibrating table, standard Marshall electric compactor, superpave gyratory compactor (SGC) were used to achieve the desired height. Different molding methods were shown as figure 1.

Vibration molding method (VM): 2 layer_ rodding 10 times each layer, then vibrating 10 seconds. Marshall compactor molding method (MCM): 2 layer_ rodding 10 times each layer, then compacting one side of the specimen to the desired height with standard Marshall compactor (determine the number of hits with the desired height by trial experiments. When the sample is compacted to a height of 120mm, the corresponding number of hits were 23, 18, 12 with three porosity levels). Superpave gyratory compactor molding method (SGCM): 2 layer_ rodding 10 times each layer, then compacting to the desired height with superpave gyratory compactor (SGC).

All pervious concrete specimens were immediately moved to the curing room, whose temperature and humidity were maintained at 20℃±2℃ and 95%±5%, respectively. After one day, molds were removed and specimens were cured in water until the days for testing.

2.3. Test Methods

2.3.1. Effective Porosity and Unit Weight Test. Closed pores, semi-connected pores and connected pores were constituted the pore structure of pervious concrete. According to Chinese standard CJJ / T 253–2016, the effective porosity were measured by volumetric drainage method including the latter two.

For each group, after 28 days of curing, effective porosity tests of specimens was measured according to the following procedure. First, the specimen volume V was obtained. After 24 hour of submerging in water, the weight of the sample was recorded as \( m_1 \) as figure 2. Then removed the specimen from the water and wiped with a damping cloth immediately. Then specimen was dried in blast drying oven with temperature maintained at 50 ± 5 ℃until the weight was constant. Then constant weight was recorded as \( m_2 \). After that, the effective porosity and the unit weight PC were calculated according to equation (1) and equation (2), respectively.

\[
P = (1 - \frac{m_2 - m_1}{V \cdot \rho_w}) \times 100\% \quad (1)
\]

\[
\rho = \frac{m_2}{V} \quad (2)
\]
where $\text{P}$ is effective porosity (%), $m_1$ is weight submerged in water (g), $m_2$ is dry weight (g), $V$ is sample volume (cm$^3$), $\rho_w$ is water density (1g/cm$^3$), $\rho$ is the unit weight.

### 2.3.2. Permeability Test

According to Chinese Standard CJJ/T 135–2009, constant head method was used for determination of permeability coefficient in figure 3. All samples were used in effective porosity tests. In the permeability test, The circumferential direction of the cylindrical specimen is tightly sealed with the plastic sleeve to ensure that the water can only pass from the upper and lower surfaces of the specimen. The permeability coefficient $k$ was calculated using equation (3) by Darcy's law:

$$k = \frac{QL}{AHt}$$

where the unit of $k$ is mm/s, $Q$ is the volume of water that flowed out (mm$^3$), $L$ is the height of sample (mm), $A$ is the cross-sectional area of sample (mm$^2$), $H$ is the height of constant water head (mm), $t$ is the time (s).
3. Results and Discussion

3.1. Comparision of Porosity, Unit Weight and Permeability Values of Specimens

Table 3. Unit weight and permeability coefficient of pervious concrete specimens with different molding methods.

| Target porosity (%) | VM       |                 | MCM       |                 | SGCM       |                 |
|---------------------|----------|-----------------|-----------|-----------------|------------|-----------------|
|                     | Unit weight (g/cm³) | Effective porosity (%) | Permeability coefficient (mm/s) | Unit weight (g/cm³) | Effective porosity (%) | Permeability coefficient (mm/s) | Unit weight (g/cm³) | Effective porosity (%) | Permeability coefficient (mm/s) |
| 12                  | 2.16     | 10.69           | 0.99      | 2.06            | 12.80      | 2.89            | 2.15            | 10.89           | 1.8                      |
|                     | 2.14     | 11.11           | 1.54      | 2.05            | 13.62      | 3.10            | 2.15            | 11.06           | 2.36                     |
|                     | 2.16     | 11.05           | 1.54      | 2.09            | 13.50      | 2.80            | 2.17            | 11.91           | 4.00                     |
|                     | 2.11     | 13.64           | 2.35      | 2.12            | 11.87      | 2.30            | 2.15            | 12.04           | 2.30                     |
|                     | 2.06     | 15.35           | 3.57      | 2.03            | 16.70      | 3.58            | 2.04            | 16.15           | 5.00                     |
|                     | 2.04     | 16.97           | 4.03      | 2.01            | 17.10      | 6.00            | 2.07            | 16.90           | 5.45                     |
| 15                  | 2.03     | 17.02           | 3.17      | 2.06            | 15.96      | 3.50            | 2.05            | 16.83           | 4.85                     |
|                     | 2.07     | 15.97           | 3.24      | 2.05            | 16.83      | 4.50            | 2.09            | 15.82           | 4.45                     |
|                     | 1.97     | 19.86           | 5.71      | 1.98            | 20.50      | 6.50            | 1.97            | 21.45           | 9.05                     |
|                     | 2.09     | 18.36           | 5.86      | 1.93            | 23.50      | 8.50            | 1.94            | 20.89           | 8.24                     |
|                     | 2.00     | 17.18           | 4.36      | 1.96            | 22.00      | 8.00            | 1.91            | 21.13           | 8.56                     |
|                     | 1.97     | 19.53           | 5.48      | 1.92            | 23.12      | 9.00            | 1.93            | 22.05           | 8.50                     |

The correlation between the unit weight and effective porosity of specimens with different molding methods are plotted in figure 4, figure 5 and figure 6, respectively.

These three plots show that, the unit weight decreases linearly with the effective porosity, as represented by three regression (R²) equations as shown in figures. As the test result in table 3, the relationship between unit weight and effective porosity of pervious concrete formed by three molding methods can be obtained. From figure 4 to 6, some important observations can be identified as follows:

![Figure 4](image1.png)  
**Figure 4.** Correlation between unit weight and effective porosity of pervious concrete by VM.

![Figure 5](image2.png)  
**Figure 5.** Correlation between unit weight and effective porosity of pervious concrete by MCM.

The difference in the relationship between unit mass and effective porosity due to the different porosity generated in different molding methods, the experimental data show that pervious concrete formed by SGCM has the closest relationship, the vibration forming method is the weakest, and Marshall compaction is in the middle.

The difference in unit weight of pervious concrete formed by three different molding methods is
not obvious. When the effective porosity is 12%, pervious concrete formed by SGCM was found to have little higher unit weight than the one formed by the other two molding methods, and the difference became small as the porosity level increased. As table 4 shows, the difference decreased from 0.05 g/cm$^3$ at 12% porosity to 0.008 g/cm$^3$ at 20% porosity.

The rate of decrease of unit weight of pervious concrete formed by SGCM was higher than the two others. Table 4 and figure 4-6 showed that, within the porosity range of this study, the rate of decrease of unit weight with porosity is $0.02114$ g/cm$^3$ per 1% rise in porosity for pervious concrete formed by SGCM. Corresponding the values of the rates of decrease for MCM and VM were $0.01853$ and $0.0143$, respectively. That is, for every 1% increase in effective porosity, pervious concrete formed by SGCM would suffer a higher loss in unit weight than the other two.

| Porosity level, P(%) | VM | MCM | SGCM |
|---------------------|----|-----|------|
|                     | Unit weight, w (g/cm$^3$) | Rate of increase of w per % rise in P | Unit weight, w (g/cm$^3$) | Rate of increase of w per % rise in P | Unit weight, w (g/cm$^3$) | Rate of increase of w per % rise in P |
| 12                  | 2.133 | 0.0185 | 2.099 | 0.0143 | 2.146 | 0.0211 |
| 15                  | 2.077 | 0.0185 | 2.056 | 0.0143 | 2.082 | 0.0211 |
| 20                  | 1.985 | na   | 1.985 | na   | 1.976 | na   |

Different between w of SGCM and VM: 0.013, 0.047
Different between w of SGCM and VM: -0.008, -0.008

The relationship between the permeability coefficient and effective porosity of PC with different molding methods are plotted in figure 7, figure 8 and figure 9, respectively.

The above three plots show that, the permeability coefficient value increases exponentially with the effective porosity level, as represented by three regression ($R^2$) equations as shown in figures.

From the test result on unit permeability coefficient and effective porosity obtained for VM, MCM and SGCM molding method, the following conclusions can be drawn.

Within the porosity range of this study, pervious concrete formed by SGCM had the highest permeability coefficient among the three molding methods at any given porosity. At the three porosity levels tested, the permeability coefficient of pervious concrete formed by SGCM was the largest, MCM was the second one and VM was minimal, and the difference became larger as the porosity value increased. As result shows, the difference between SGCM and VM increased from $0.982$ mm/s at 12% porosity to $1.864$ mm/s at 20% porosity, and the corresponding value between SGCM and MCM increased from $0.367$ mm/s at 12% porosity to $1.153$ mm/s at 20% porosity.

**Figure 6.** Correlation between unit weight and effective porosity of pervious concrete by SGCM.

**Figure 7.** Relationship between effective porosity and permeability coefficient of PC by VM.
Table 5. Rate of increase of permeability with porosity of PC formed by different methods.

| Porosity level p(%) | VM k(mm/s) | Rate of increase of k per % rise in p | MCM k(mm/s) | Rate of increase of k per % rise in p | SGCM k(mm/s) | Rate of increase of k per % rise in p | Different between k of SGCM and VM | Different between k of SGCM and MCM |
|---------------------|------------|--------------------------------------|--------------|--------------------------------------|---------------|--------------------------------------|----------------------------------|----------------------------------|
| 12                  | 1.729      | 0.494                                | 2.344        | 0.424                                | 2.711         | 0.604                                | 0.982                            | 0.367                            |
| 15                  | 3.211      | 0.492                                | 3.617        | 0.553                                | 4.523         | 0.603                                | 1.313                            | 0.906                            |
| 20                  | 5.672      | na                                   | 6.384        | na                                   | 7.536         | na                                   | 1.864                            | 1.153                            |

3.2. Comparative Analysis of Compressive Strength And Permeability Coefficient

Based on many studies [35-37], there is a direct connection between porosity and compressive strength. The result of compressive strength test of PC formed by different methods are shown in figure 10. For the range of porosity values studied, the range of compressive strength of PC mixtures made by SGCM were from 12.85MPa to 32.14 MPa, the ones made by MCM were 17.46 MPa to 27.85 MPa, and the corresponding values of pervious concrete formed by VM were 9.79 MPa to 19.94 MPa. From the test result, the compressive strength decreases as the porosity increases, and the rate of decrease of concrete formed by SGCM was the highest. According to the above analysis, the permeability coefficient and porosity of PC was positively related. With the porosity, the compressive strength and permeability coefficient of PC can be studied.
Table 6. Compressive strength and permeability coefficient of PC with different molding methods.

| Porosity p(%) | VM           | MCM          | SGCM         |
|---------------|--------------|--------------|--------------|
|               | Compressive strength c(MPa) | Permeability coefficient k(mm/s) | Compressive strength c(MPa) | Permeability coefficient k(mm/s) | Compressive strength c(MPa) | Permeability coefficient k(mm/s) |
| 12            | 19.94        | 1.729        | 27.85        | 2.344        | 32.14        | 2.711        |
| 15            | 16.55        | 3.211        | 25.84        | 3.617        | 25           | 4.523        |
| 20            | 9.79         | 5.672        | 17.46        | 6.384        | 12.85        | 7.536        |

As table 6 shows, pervious concrete made by SGCM has good water permeability and high strength, but VM is the worst choice, and MCM is centered. For the same material with the same original ratio, it is necessary to carry out in-depth analysis why different molding methods get such results.

The aggregates with the same original ratio were respectively compacted and rotated by MCM or SGCM for the same number of times as the concrete molding, and then the aggregate was sieved to obtain the new particle size gradation as shown in figure 11.

As shown in figure 11, when pervious concrete manufactured by MCM or SGCM, the particle size gradation of the aggregate changes significantly. Although the particle size distribution is still concentrated in the range of 9.5-2.23 mm, the aggregate of less than 2.23 mm after MCM accounts for 1%, and the corresponding value of SCGM is more than 5%. As revealed in literature [21, 38], the addition of sand into PC would improve the concrete’s strength. It can be speculated that the change in particle size is one of the reasons why the strength and permeability coefficient of pervious concretes formed by MCM and SGCM are higher than that of VM. Second, the materials that make up the concrete move in different forms during different molding processes. Under the action of gravity and vibration, the displacement of aggregate and cement material is mostly concentrated in the vertical direction. There are also vertical and horizontal differences in the gap formed by the accumulation of aggregate and the filling of cement material. In VM process, the distribution of the slurry is also uneven, resulting in low strength and low permeability of PC. In MCM process, aggregate and cement in mixture compacted mutually in vertical and horizontal direction, and vertical was dominant. For this reason, the strength of the pervious concrete formed by this method is significantly higher than that of VM. In process of MCM, the distribution of the cemented material is relatively uniform, and the permeability coefficient is also large. In process of SGCM, each substance in the mixture is centrifuged under vertical pressure. As analyzed in literature [39], at the first 25 gyrations approximately, around 70% vertical displacement and 40% horizontal displacement were produced. Such a process facilitates the mutual compaction of the aggregate and the uniform distribution of the cementitious material. The concrete formed by this method has a compressive strength and a
permeability coefficient which are significantly larger than those of the other two methods at a lower target porosity. Third, during SGCM process, the particle size changes and the surface area of aggregate increases, and the required cementing material should be increased. However, in the mix design, the cement cementing material decreases with the increase of the target porosity, as a result, the strength of PC formed by SGCM is significantly lower than that of MCM.

4. Summary and Conclusions
The properties of pervious concrete formed by different molding methods have been reported and studied in this paper. It compared the unit weight, effective porosity, permeability, compressive strength and freeze-thaw durability of pervious concrete manufactured by three different methods at three levels of target porosity: 12%, 15% and 20%. The three molding methods were vibration molding method, Marshall compactor molding method, superpave gyratory compactor molding method. The causes of different mechanical and hydraulic characteristics of pervious concrete in different molding methods were also detailed analyzed. As a result, the following conclusions can be drawn:

For pervious concrete formed by the three different molding methods studied in this paper, the decrease of unit weight \( (w) \) with effective porosity \( (P) \) can be described by a linear relationship of the form \( w = a + bP \), where \( a \) and \( b \) are positive and negative regression coefficients, respectively. Within the range of porosities studied, the unit weight of pervious concrete formed by SGCM is slightly larger than that of the other two methods, but the gap decreases with the increase of porosity. Unit weight of pervious concrete of the three molding methods tends to be consistent as the porosity approaches 20%.

For the range of porosity values studied, the increase of permeability coefficient \( (k) \) with effective porosity \( (P) \) can be described by an exponential relationship of the form \( k = k_0 + me^{nP} \), where \( k_0 \), \( m \) and \( n \) are regression coefficients. Among the three molding methods, permeability coefficient of pervious concrete formed by SGCM is significantly higher than the other two at the same porosity level, and this gap increases with the increase of porosity, and the gap between SGCM and VM is greater than SGCM and MCM.

In the range of pores studied, the mix ratio design of the same target porosity, SGCM is the best way to obtain concrete with good permeability and high strength, MCM is the second preferred method, and VM is the least one. This advantage of SGCM is even more pronounced at low target porosity. Comparative analysis of the material movement in the three molding methods, the compaction effect of SGCM and MCM is conducive to the improvement of concrete strength and uniform distribution of cementing materials, and the particle size gradation distribution occurs in the process. When the porosity is 20%, the increase in small particle size aggregate during SGCM process and the decrease in cementing materials result in a compressive strength of 12.85 MPa, which is 0.74 for pervious concrete manufactured by MCM.

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