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Research Article

Effect of Vibration Time on The Mechanical and Durability Properties of Previous Concrete

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ABSTRACT

Pervious concrete is specially designed to allow water to flow through it. This type of concrete has gained attention in recent years due to its ability to reduce runoff and improve water quality. However, the mechanical and durability properties of pervious concrete can be affected by several factors, such as the mix design, compaction, and curing. One of the factors that can affect pervious concrete properties is the vibration time compaction.

Therefore, this research aims to investigate the effect of vibration time on the mechanical and durability property of pervious concrete by performing experimental investigation with an incremental vibration time of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec by using table vibrator on 7th and 28th days of curing age. The water-cement ratio (0.4) was kept constant. By using a crashed coarse aggregate of single size 14 sieve size pass and 12 sieve size retain.

The result of this research indicates that increasing the vibration time will improve the mechanical and durability properties of pervious concrete. This is because longer vibration times can help to improve the compaction of the concrete, resulting in a denser and more durable material. However, Vibration duration beyond the optimum period of 8 sec of vibration causes the separation of coarse aggregates which affects the mechanical properties and durability properties of concrete negatively. The permeability property of pervious concrete was when vibration increases concrete become dense because of the removal of air bubbles and pore inside the concrete but beyond 8 sec of vibration duration concrete coarse aggregate separates and the concrete becomes porous so permeability increases. For durability properties of pervious concrete vibration duration increases the flow of acid into concrete decreases due to the denseness of concrete but after optimum vibration duration of concrete coarse aggregate separates and the cement slurry moves up to the surface of the concrete. Due to these, the acid can flow into concrete easily and the weight of the concrete decreased.

The finding of this research study will be useful for engineers and designers working with previous concrete, to have proper compaction because both under and over-vibration affect the properties of previous concrete. as they will provide insights into how to optimize the casting process for maximum performance. This could lead to the development of more durable and sustainable pervious concrete materials that can better withstand the demands of real-world applications.

Keywords: Pervious concrete; Compressive strength; Permeability; Durability; Transportation

1. Introduction

1.1. Background

Around 150 years have passed pervious concrete, also known as gap-graded concrete, was first utilized in construction in Europe. The first applications for this kind of concrete in Europe included cast-in-place load-bearing walls for single- and multi-story houses, steam-cured blocks, and prefabricated panels. Before World War II, pervious concrete was only utilized for two-story houses, but after the war, the technology had advanced and could be used to construct structures up to ten stories high[1].

Concrete that is designed to contain several gaps to collect water and allow it to permeate through the concrete to the ground below is known as porous concrete. Fine aggregates are not included in the production of this concrete. It has more voids than conventional concrete because of this. To entirely remove the usage of fine aggregates, pervious concrete is only made of coarse aggregates, cement, and water. There are several names for porous concrete, including permeable concrete, porous pavement, and permeable concrete. All of these terms mean the same thing, namely, porous concrete. Porous concrete is made by mixing large aggregates with mortar, which creates many voids in the poured concrete. When water hits the concrete, it flows through the voids and enters the soil. Pervious concrete is an important application for sustainable construction[2].

For permeable concrete mixtures, care should be taken to use the vibrator during sample preparation. Many sample mixes were performed to evaluate the influence of vibration. Based on the results of these mixes, it became clear that vibration is a major factor in the short- and long-term performance of this material in pervious concrete mixes. High vibration causes most of the cement paste to accumulate at the bottom of the cement paste; too little vibration results in more voids than necessary and reduces the compressive strength and cohesion of the mix[3].

Since mix design is one of the main factors that contribute to this wide range of concrete properties, aggregate properties, compaction energy and placement techniques are also important factors in determining the properties and performance of pervious concrete material[5]. Recent research has highlighted the importance of vibrating fresh concrete during casting to ensure high quality. Vibration is the most effective way to consolidate concrete particles into a dense mass. However, concrete placement near sources of vibration during setting and early hardening stages is not uncommon. Recent studies have shown that re-vibration can have positive effects, especially in wetter mixes, by eliminating water that has accumulated under the reinforcing bars and reducing defect locations, ultimately increasing strength. The purpose of this experimental study is to investigate the effects of delaying, revibrating, and repeatedly vibrating concrete to gain a better understanding of the processes involved[6].

The porosity of cement-based materials has been seen as the main accountable for their durability because it controls the movement rate of aggressive ions inside the concrete and may cause its physical/chemical degradation. So, several approaches have been proposed to evaluate this concrete property, having as the main goal the search for an effective, viable, and economic methodology to measure and describe the air permeability of concrete[7].

Pervious concrete is a mixture of cement, coarse aggregate, admixtures, and water. Pervious concrete passes water to percolate through the concrete into the sub-base and recharge the underground water level[7,5]. Pervious concrete usually does not contain sand and its air-void content is between 15 and 30%. A small amount of sand can be used to improve compressive strength, but the air void content will minimize and permeability becomes low. It is important to maintain the proper volume of paste/mortar is evenly coated to prepare the aggregate, but the excess paste/mortar will not fill the void space within the coarse aggregate. The voids within the pervious concrete should be interconnected to form channels through which water can flow freely[8].

Pervious concrete, sometimes concrete with increased porosity, is a new approach to controlling, managing, and treating stormwater runoff. Pervious concrete used as pavement can effectively capture and store stormwater runoff, allowing it to infiltrate into the ground and recharge the water table. Pervious concrete contains no fine aggregate and carefully controlled amounts of water and binders. The paste coats and binds the aggregates together to form a system of highly porous, interconnected voids that promote rapid water runoff[9].

Water permeability of concrete was the main property related to the strength and durability of concrete structures subjected to bad environments, although water acts as the transport medium for aggressive agents like chloride or sulfate ions[10].

Pervious concrete is a unique type of concrete that uses gravel instead of coarse aggregate. Pervious concrete is a heterogeneous mixture of cement, aggregates, water, and no sand that forms an open, concerted structure through which water and air can flow. Voids can range from 18 to 35%, so the permeability of pervious concrete ranges from 80 to 720 liters/minute/square meter. The exact amount of water in the concrete is critical. Too much water will cause segregation, too little water will cause lumping in the mixer and very slow mixing of the material. The water/cement ratios are common values from 0.25 to 0.45 and the cement/aggregate ratio is 1:3.5 to 1:7. The main constituents are cement, water and aggregates, and admixtures are used if necessary[11].

Pervious concrete can be used to minimize stormwater runoff, reduce road pollution, and raise groundwater levels. Due to its high porosity, pervious concrete can effectively capture the "first flush" of stormwater and allow it to infiltrate into the soil where it is filtered and "treated" by soil chemistry and biology. In addition to its many uses, there are also some limitations to the use of permeable concrete. Primarily, water-permeable concrete has generally been used on less heavily travelled roads, although there have been installations on larger facilities and studies are being conducted on the structural behavior of water-permeable concrete slabs. In addition, water-permeable concrete exhibits fabric properties (typically lower paste contents and better void contents) and produces curing characteristics (particularly density and strength) that are significantly different from those of conventional concrete; as a result, the quality control/assurance strategies currently used (e.g., slump, strength, air content) are not applicable in many cases[8].

The permeability of cement-based materials is considered to be the main contributor to their durability, as it controls the rate of movement of aggressive ions within the concrete and can cause its physical/chemical degradation. Therefore, several approaches have been proposed to evaluate this concrete property, the main objective being to find an effective, practical and economical method to measure and describe the air permeability of concrete[12]. During the production of concrete, a considerable amount of air is trapped, and during transportation, there is a possibility that partial segregation may occur. If the trapped air is not removed and the segregation of the coarse aggregate is not corrected, the concrete may be porous, inhomogeneous and of lower strength[13].

Recent research has highlighted the importance of vibrating fresh concrete during pouring to ensure better quality. Vibration is the most efficient method of compacting concrete particles into a dense mass. However, it is not uncommon for concrete to be placed near vibration sources during the setting and early hardening phases. Recent studies have shown that vibration can have positive effects, especially in wetter mixes, by displacing water under the reinforcing bars and reducing voids, ultimately increasing strength. This experimental study will investigate the effects of retardation, post-vibration, and repeated vibration of concrete to gain a better understanding of the processes involved. The study will also consider the influence of the hot, dry climate in Sudan and the optimal timing for favorable vibration. While Allen Hulshize's research indicates that the vibration of fresh and maturing concrete does not affect its properties, his study focused so much on the vibration of concrete that certain time periods may need further study. Bastion studied the effects of vibrated concrete during the setting period[14].

It has been found that proper compaction of concrete with adequate workability gives satisfactory results, but that hand-compacted concrete has lower strength because of the higher water-cement ratio required for complete compaction. For applications where high strength is required, stiff concrete with a low water-cement ratio must be used. A mechanical vibrating machine must be used to compact such concrete. Vibrated concrete with a low water-cement ratio offers numerous advantages over hand-compacted concrete with a higher water-cement ratio[15].

1.2. Problem statement

Pervious concrete is a special type of concrete that is specially designed to allow water to flow through it. This type of concrete has gained attention in recent years due to its ability to reduce runoff and improve water quality. However, the mechanical and durability properties of pervious concrete can be affected by several factors, such as the mix design, compaction, and curing. One of the factors that can affect pervious concrete properties is the vibration time compaction. This study aims to determine the effect of vibration time that results in maximum mechanical strength and durability performance of pervious concrete[16-23].

1.3. Objectives

General Objectives

- The main objective of this research study was to investigate the effect of vibration time on the mechanical and durability property of pervious concrete that is produced by using single-sized coarse aggregate and cement only.

Specific Objectives

- To investigate the effect of vibration time on the mechanical property of pervious concrete
- To investigate the effect of vibration time on the permeability property of pervious concrete.
- To investigate the effect of vibration time on the durability property of pervious concrete.
- To determine the optimum vibration time of pervious concrete.

2. Material and Methods

2.1. Introduction

In this chapter, the method adopted to do this research was laboratory investigation, to achieve the goal of the research, and the material used was discussed in detail. And also, ethical considerations should be taken during research work was presented[24-47].

2.2. Material

Pervious concrete is also known as no-fines, permeable, hole-graded, porous concrete. Usually consists of Portland pozzolana cement, single-sized coarse aggregate, and water. It's considered as special type of highly porous concrete.

Aggregates

Pervious concrete is designed to have high porosity, allowing water to pass through it and infiltrate into the ground beneath. The aggregates used in pervious concrete play a significant role in achieving this permeability. Typically, the aggregates used in pervious concrete construction are coarser compared to those used in conventional concrete. They are carefully selected to provide both structural integrity and water permeability. Crushed stone aggregates, typically in the size range of 4.75 to 9.5 mm (No. 4 to 3/8 inch), are commonly used in pervious concrete. They provide stability, strength, and drainage capacity.

The aggregate selection is crucial to maintain the desired void content in the pervious concrete while ensuring adequate strength. The voids between aggregates allow water to infiltrate through the concrete, promoting drainage and reducing storm water runoff. It's important to consult local specifications and guidelines for pervious concrete construction as aggregate selections may vary based on regional availability and requirements.

Aggregate grading used in pervious concrete was crushed coarse aggregate of single-sized 12-sieve passing and 14-sieve retaining. The aggregate used should meet the requirement of ASTM C33/C33M aggregate. Pervious concrete normal aggregate cement ratio was 1:3.5 to 1:7 but the optimum aggregate-to-cement ratio was 1:4 to 1:4.75. However, in this laboratory investigation aggregate cement ratio of 1:4 was used. Coarse aggregate in concrete is a material that is larger than 4.75 mm in size. The properties of coarse aggregate include:

Cement

Portland pozzolana cement (PPC) is a type of cement that is produced by combining pozzolanic materials, such as volcanic ash, fly ash, or silica fume, with Ordinary Portland Cement (OPC). The pozzolanic materials react with the calcium hydroxide released during cement hydration, forming additional cementitious compounds. This enhances the overall strength and durability of the cement.

PPC is known for its improved workability, reduced heat of hydration, and increased resistance to sulfate attacks and alkali-silica reactions. It is commonly used in construction projects where it is necessary to achieve greater longevity, reduced permeability, and enhanced durability of concrete structures. PPC is widely used in applications like dams, bridges, heavy-duty industrial floors, marine structures, and buildings in aggressive environments. The cement used was Portland pozzolana cement (PPC) satisfying Ethiopian standard 1177-1CEM11\B-P 32.5R Grade manufactured by Dangote Cement Factory. Which was available in the local market.

Water

Pervious concrete requires less mixing water compared to conventional concrete. The water-cement ratio should be carefully controlled to ensure the proper strength and porosity of the material. The quality of water used in mixing pervious concrete can have an impact on its durability and longevity. Clean potable water is recommended for the best results. Proper curing is essential for any concrete, including pervious concrete, to achieve optimal strength and durability. Moist curing is typically recommended for pervious concrete to prevent premature moisture loss. Tap water is appropriate for use in concrete. Water quality for pervious concrete is governed by the same requirements as those for conventional concrete. Pervious concrete should be proportioned with a relatively low water cementations material ratio (w/cm) between (0.26 to 0.57). Because an excess amount of water will lead to drainage of the paste. However, in this laboratory investigation water cement ratio of 0.4 was used which is optimum.

2.3 Experimental Program

Properties of pervious concrete are primarily dependent on its porosity, which in turn depends on cementations content, compaction level, and aggregate gradation and quality.

Sample preparation

All laboratory specimens were mixed in the civil engineering laboratory under a controlled environment. All mixing was performed using the mechanical drum mixer. The lab specimens were prepared under ASTM 192. After dry mixing, water was added and the mixing was continued until a uniform mix was obtained. Then the concrete was placed into the molds which were properly oiled. To study the strength-related property such as compressive strength, flexural strength, split tensile strength, and durability was studied. A durability test was conducted by using a sulfuric acid solution. The permeability test was conducted by a falling head. Three mix specimens were tested for each test on the 7th and 28th days with different vibration periods of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec. For the compressive strength test of concrete, a cube size of 150 x 150 x 150 mm was used. All the cubes were tested in saturated condition after wiping out the surface moisture from the specimen. For this investigation cubes were tested by a compression testing machine at the age of 7th and 28th days. For the splitting tensile strength test of concrete, cylinder sizes of 150 mm diameter and 300 mm height were cast. The specimens prepared were de-molded after 24 hours of casting and were kept in a curing tank for curing.

Mix Design

The mix design of pervious concrete typically involves using a combination of coarse aggregates, cementitious materials, water, and sometimes chemical admixtures. Pervious concrete uses a special type of coarse aggregate that comprises uniformly graded particles with void spaces between them. This promotes the permeability of the concrete, allowing water to flow through. The main aim of proportioning the pervious concrete mixture was to have an excellent balance between paste content, strength, porosity, and workability. Its performance was highly influenced by the aggregate cement ratio as coarse aggregate occupies the most of concrete structure which needs sufficient binding (1:4) cement to coarse aggregate which was approximately 85% in the mix was coarse aggregate.

To produce an initial trial batch, ACI 522R-10 is used. The sizes of coarse aggregate used are 12 sieve sizes retain and 14 sieve size pass which is single sized. The water-cementations material ratio (w/cm) was a critical consideration for obtaining desired strength and void structure in pervious concrete (0.4). A high w/cm reduces the strength of the paste to the aggregate and causes the paste to flow and fill the voids even when lightly compacted. The mix design of pervious concrete refers to the specific proportions and components used to create a pervious concrete mixture. Pervious concrete is designed to have high porosity, allowing water to infiltrate and pass through it, making it suitable for applications where storm water management and drainage are important.

Mechanical properties of hardened concrete

Compressive strength test

The compressive strength test of pervious concrete is a measure of its ability to withstand compressive forces. Pervious concrete is a special type of concrete that contains a high void content, allowing water to pass through it. To conduct the compressive strength test, cubic specimens of 150x150x150 mm pervious concrete are typically cast and cured according to standard procedures for the 7th and 28th day. Once the specimens have attained sufficient strength, they are placed in a compression testing machine. The test involves applying a gradually increasing load to the specimen until it fractures or fails under compression. The maximum load that the specimen can withstand, divided by its cross-sectional area, gives the compressive strength of the pervious concrete.

The compressive strength test helps assess the overall quality and structural performance of pervious concrete. It is an important parameter when designing and evaluating pervious concrete pavements, driveways, or any other application where load-bearing capacity is essential.

The most common of all tests on hardened concrete is a compressive strength test because many of the desirable characteristics of concrete are qualitatively related to its strength for structural design. A compressive strength test was conducted under ASTM C39/C39 M in Arbaminch university laboratory of having cement to a crushed aggregate of 1:4 ratios by using three 150x150x150 mm cube test samples in a vibration period of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, 12 sec, at 7th and 28th days total of 42 samples to determine the effect of vibration time on the strength of pervious concrete. The specimen was taken out 24 hours before testing to be dried because of the high void content in pervious concrete.

Flexural Strength Test

The flexural strength test of pervious concrete is a mechanical test performed to evaluate the ability of pervious concrete to withstand bending or flexural stresses. Flexural strength measures the maximum tensile or compressive stress that the concrete can withstand before it breaks or fails in a bending scenario.

During the test, a sample of pervious concrete in the form of a beam or a prismatic shape is subjected to a load at its midpoint, creating a bending moment. The applied load causes tension on the bottom surface and compression on the top surface of the specimen. The flexural strength is determined by monitoring the load-deflection behavior of the sample until failure occurs.

The test results provide valuable information about the quality and performance of the pervious concrete mixture. It helps in assessing its resistance to cracking, ability to support loads, and overall durability. A flexural strength test was performed under ASTM C293/C293M. Three 50 x 10 x 10 slabs were tested for flexural strength with different vibration periods 0 sec,2 sec,4 sec, 6 sec, 8 sec, 10 sec, and 12 sec for the 7^{th} and 28^{th} day of a total of 42 samples to determine the effect of vibration time for flexural strength using the universal machine. The specimen was taken out 24 hours before testing to be dried because of the high void content in pervious concrete.

Splitting Tensile Strength Test

The splitting tensile strength test is a standard mechanical test conducted on pervious concrete to evaluate its resistance to tensile forces. Pervious concrete is a special type of concrete that allows water to pass through, typically used for storm water management and drainage applications.

During the test, a cylindrical specimen of pervious concrete is placed on a testing machine. A compressive force is applied diametrically across the specimen, causing it to crack and split. The force is gradually increased until the specimen breaks completely. The maximum force applied to fracture the specimen is recorded as the splitting tensile strength.

This test helps to assess the integrity and durability of pervious concrete, as well as its ability to withstand tensile stresses. It is a crucial parameter for evaluating the structural performance of pervious concrete pavements, sidewalks, and other applications subjected to load-bearing requirements. This test was conducted under ASTM C496/C496 M in the Arbaminch University laboratory of having cement to a crushed aggregate of 1:4 ratios by using three 50x10 cm cylinders for each vibration period of 0 sec, 2sec, 4 sec, 6 sec, 8 sec, 10 sec, 12 sec, at 7^{th} and 28^{th} days of total 42 sample to determine the optimum vibration period and strength. The specimen was taken out 24 hours before testing to be dried because of the high void content in pervious concrete.

Permeability

The permeability test of pervious concrete is a procedure used to determine the rate at which water can flow through the material. Pervious concrete is designed to have high permeability, allowing water to pass through and infiltrate into the ground, reducing storm water runoff.

To conduct a permeability test, a cylindrical sample of pervious concrete is prepared in the laboratory for the 7^{th} and 28^{th} day. The sample is placed within a permeability testing apparatus, such as a constant head. In the constant head permeability test, a steady flow of water is maintained through the sample at a constant head. The rate of flow is measured at 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibration duration for the 7^{th} and 28^{th} day of a total of 42 samples and the permeability coefficient, known as the hydraulic conductivity, is determined.

The results of the permeability test provide crucial information about the porosity and connectivity of voids within the pervious concrete. This data helps engineers and designers assess the suitability of the material for specific applications, such as storm water management systems, pavements, or retaining walls.

Durability test

A durability test of pervious concrete is conducted to evaluate its ability to withstand the effects of long-term exposure to various environmental conditions. Pervious concrete is known for its porous nature, which allows water to pass through and infiltrate the ground. However, it is important to ensure that the concrete retains its structural integrity and functionality over time.

Durability tests typically assess the following factors

Chemical resistance: Pervious concrete must resist deterioration caused by exposure to various chemicals like chloride ions and sulfates, commonly found in wastewater or road salts. This is important to prevent degradation and maintain the long-term durability of the material.

Compressive strength: Pervious concrete must maintain its structural strength to withstand loads and prevent premature failure. Testing involves subjecting samples to compressive forces and measuring their ability to withstand pressure.

Durability tests of pervious concrete aim to assess its long-term performance, ensure it can withstand environmental factors, and maintain its intended functionality as a permeable material for sustainable stormwater management. The durability of pervious concrete is its service life under given environmental conditions. Its Physical effects that adversely influence the durability of concrete include exposure to temperature extremes and chemicals such as sulfuric acids attack. In this study sulfuric acid attack was used for vibration of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec on the 7^{th} and 28^{th} day of a total of 42 samples was used. In the laboratory under ASTM C666/C666M test condition.

Density

Density refers to the measure of compactness or porosity of the material. Pervious concrete is specifically designed to be highly porous, allowing water to pass through it easily. The density of pervious concrete is typically lower than that of conventional concrete since it contains interconnected voids or pores that enable water infiltration. This porous nature is what allows the water to drain through the pavement and into the underlying soil or drainage system.

The test method commonly used for determining the density of pervious concrete is ASTM C1688, which is titled "Standard Test Method for Density and Void Content of Pervious Concrete." This method provides guidelines and procedures for measuring the density and void content of fresh and hardened pervious concrete specimens. It involves measuring the mass and dimensions of the specimen and calculating the density based on these measurements.

The density of pervious concrete refers to its mass per unit volume. Pervious concrete is a special type of concrete with high porosity, allowing water to pass through it easily. Since it contains voids or gaps, its density is lower compared to traditional concrete. The density of pervious concrete typically ranges from about 1000 to 2000 kilograms per cubic meter (kg/m^3) depending on the specific mixture and porosity design.

3. Result and Discussion

Introduction

This portion discusses the results obtained from the laboratory tests that were conducted to examine the physical and mechanical properties of pervious concrete for the time of vibration. The samples were compared with each other and the standard to drive conclusions.

Physical Properties of Concrete

Density

The density of previous concrete is determined as per ASTM C1754/C1754M-12. The results of the density test at a different duration of vibration parameters are compared to each other. As the duration of vibration increases from 0 to 8 seconds, the density of the concrete also increases, with the highest density of 1746.4 Kg/M3 occurring at 8 seconds of vibration. However, after 8 seconds of vibration, the density of the concrete decreases slightly, with a density of 1739.0 Kg/M3 at 10 seconds and 1738.35 Kg/M3 at 12 seconds.

This suggests that there is an optimal duration of vibration that results in the highest density of pervious concrete. In this case, the optimal duration appears to be around 8 seconds. The density of pervious concrete slightly increases with increasing vibration time. However, the density values fluctuate within a small range between approximately 1712 kg/m3 and 1747 kg/m3.

The change in density of pervious concrete concerning vibration duration is due to the effect of vibration on the consolidation of the concrete mix. When the sample is on the vibrator, it causes the concrete mix to flow more easily, allowing air pockets to escape, and promoting better compaction. This results in a denser and more uniform concrete structure.

As the duration of vibration increases, more energy is transferred to the concrete, allowing for better consolidation. This leads to an increase in density, as seen in the table. However, after a certain point, further vibration may not lead to a significant increase in density. Excessive vibration can cause segregation of the mix and lead to a decrease in density.

Therefore, it is important to determine the optimal duration of vibration that results in the desired density of the pervious concrete.

Other researchers have also investigated the effect of vibration on the density of concrete and have reported similar findings. For example, a study by Mr. Gaurav et al. (2015) found that an increase in vibration time from 0 to 10 seconds increased the density of concrete. However, they also found that further increases in vibration time did not result in a significant increase in density.

Overall, these findings suggest that vibration can be an effective method for improving the density of concrete. However, the optimal duration and frequency of vibration may vary depending on factors such as the type of concrete mix and the characteristics of the vibrator. It is important to carefully consider these factors when designing and implementing a vibration strategy for concrete production (**Figure 1**).

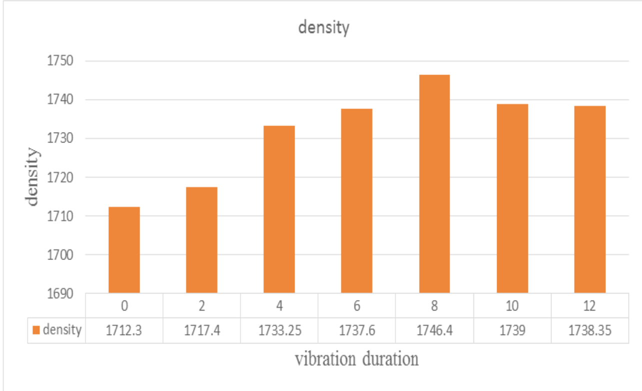

Figure 1: Effect of vibration time on density properties of pervious concrete.

Mechanical Properties of Concrete

The strength and durability of pervious concrete directly depend on the w/c ratio, shape of aggregate, type of aggregate, duration of vibration, and type of vibration. So, to produce strong concrete, it is necessary to reduce the amount of air trapped inside the concrete, which is conducted by vibrating the concrete during the casting stage but extended vibration results in segregation on the coarse aggregate of concrete.

Compressive strength

At the age of 7th days, the observed rate of compressive strength development of pervious concrete that casts at 0 sec was 2.1 MPa. While the Concrete compacted by table vibration for 2 sec has a compressive strength of about 3.1 MPa. This result indicated that the rate of compressive strength development increased by 1 Mpa (32.25%) from the Concrete with 0 sec vibration time.

At 4 sec vibration of concrete, compressive strength development was 4.5 MPa, which was increased by 1.4 MPa (31.11%) from the 2 sec. At 6 sec vibrations of concrete, the observed rate of compressive strength development was 5.25 Mpa, which was increased by 0.75 Mpa (14.28%), while at 10 sec there was a decrease in strength of - 0.8 Mpa (-17.02%) and at 12 sec there was a decrease in a strength -1.3 Mpa (-38.23). The results showed that for 0 sec and 12 sec vibration time duration, it was under and over vibration because of its low development of strength. The compressive strength of low vibration became weak when compared to another cast with the same specimen. This was because more pores are present in concrete in another way when the time of vibration is beyond 8 sec the compressive strength decreases. This may be due to the separation of paste from aggregate during over-vibration.

The laboratory test was extended up to 28 days. The result showed that the rates of compressive strength development of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec and 12 sec vibration time duration of concrete were 3.2 MPa, 5.82 MPa, 6.3 MPa, 9.5 MPa, 11.4 Mpa, 10.8 Mpa and 10.3 MPa, respectively. These values indicated the rate of compressive strength development of 2 sec increased by 2.6 MPa (44.82%) from 0 sec vibrated concrete. For the 4 sec vibrated concrete increased by 0.5 MPa (7.93%) based from 2 sec. For 6 sec of vibration concrete increased by 3.2 Mpa (33.68%) from 4 sec. Likewise for 8 sec vibration concrete increased by 1.9 Mpa (16.66%). Similar observations were done on the 7th day by extending the time duration beyond 8 sec. In this test at 10 sec, there was decreased of -0.6 Mpa (-5.5%), while at 12 sec, -0.5 Mpa (-4.85%) decreased in compressive strength. The results show that there was a significant increase in compressive strength by increasing the vibration time up to 8 sec when tested at the age of 28th days.

This study is similar to the study done at jimma university by using conventional concrete at 0 sec, 1 sec, 2 sec, 3 sec, 4 sec, and 5 sec of vibration duration that as a vibration duration increases the compressive strength of concrete increases up to optimum but after optimum vibration duration the coarse aggregate starts to segregate.

Other researchers have also investigated the effect of vibration duration on the compressive strength of concrete and have reported similar findings. For example, a study by Tewfik et al. (2017) found that increasing the vibration duration from 0 to 10 seconds resulted in a significant increase in the compressive strength of concrete. However, they also found that further increases in vibration duration did not result in a significant increase in compressive strength. Another study by Ossa-lopez et al. (2021) investigated the effect of different vibration durations on the compressive strength of concrete. They found that increasing the vibration duration from 10 to 30 seconds resulted in a significant increase in the compressive strength of concrete.

Overall, these findings suggest that vibration can be an effective method for improving the compressive strength of concrete. However, the optimal duration of vibration may vary depending on factors such as the type of concrete mix and the characteristics of the vibrator. It is important to carefully consider these factors when designing and implementing a vibration strategy for concrete production.

The big difference attributed to concrete bond strength at the age of 28th days was due to complete the hydration reaction which makes the results more deviated according to each vibration time (**Table 1**) (**Figure 2**).

Table 1: Effect of vibration time on compressive properties of pervious concrete.

No.	Vibration period (sec)	Average Compressive strength (Mpa)	
		7th day	28th day
1	0	2.1	3.2
2	2	3.1	5.8
3	4	4.5	6.3
4	6	5.25	9.5
5	8	5.5	11.4
6	10	4.7	10.8
7	12	3.4	10.3

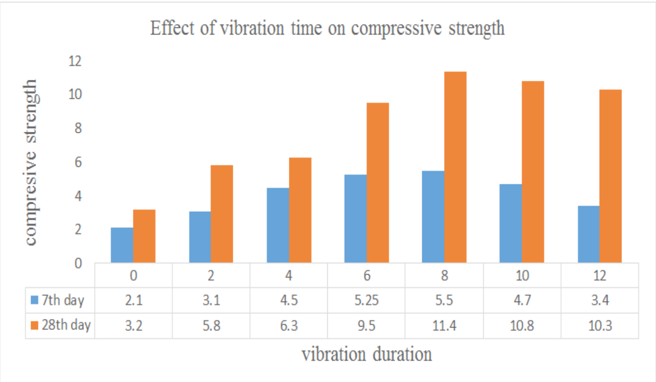

Figure 2: Compressive Strength Properties At 7th And 28th Day of Curing.

Flexural strength of concrete

At the age of 7th days, the flexural strength development for 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibrated concrete was 0.21 MPa, 1.1 MPa, 1.5 MPa, 2.25 MPa, 2.26 Mpa, 2.17 Mpa and 1.4 Mpa of flexural strength respectively. These results indicated that the flexural strength development increased up to 8 sec but decreases beyond 8 sec. According to the test results, the flexural strength development for 2 sec vibrated concrete improved by 0.89 MPa or 80.9% when compared with the flexural strength for 0 sec vibration.

For 4 sec and 6 sec vibrated concrete the rate of flexural strength development enhanced by 0.75 MPa or 33.33% and 0.01 MPa or 0.44%, but it reduced by 0.09 Mpa or 4.17%, -0.77 MPa or -55% from 10 sec and 12 sec vibrated concrete.

On the other hand, in the specimen tested on the 28th day, the rate of flexural strength development of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec vibrated concrete was 0.42 MPa, 1.8 MPa, 1.83 MPa, 3.5 MPa, 4.4 Mpa, 1.8 Mpa, and 1.43 MPa, respectively. These values indicated the rate of flexural strength development increased when the time of vibration increased but it decreases beyond the optimum vibration duration. The test results show that the rate of flexural strength development of 2 sec vibrated concrete was improved by 1.38 MPa or 76.66% from 0 sec vibrated concrete. For 4 sec vibrated concrete the rate of flexural strength development, improved by 0.03 MPa or 1.64%. For 6 sec vibrated rate of flexural strength development was 1.67 MPa or 47.71%, and at 8 sec flexural strengths was 0.9 Mpa or 20.45%. however, it reduced by 2.6 Mpa or 144%, 0.37 MPa or 25.87% from 10 sec and 12 sec vibrated concrete. According to the observed test results, it indicated the rate of flexural strength development increased when the time of vibration increased. According to the data, as the vibration period increases from 0 to 12 seconds, there is an overall increase in the average flexural strength of concrete on both the 7th and 28th days. The highest flexural strength on the 7th day is observed for a vibration period of 6 seconds, which is 2.25 MPa, and the highest flexural strength on the 28th day is observed for a vibration period of 8 seconds, which is 4.4 MPa (**Table 2**) (**Figure 3**).

Table 2: Flexural strength for 7th days and 28th day.

No.	Vibration period (sec)	Flexural strength (Mpa)	
		7th Day	28th Day
1	0	0.21	0.42
2	2	1.1	1.8
3	4	1.5	1.83
4	6	2.25	3.5
5	8	2.26	4.4
6	10	2.17	1.8
7	12	1.4	1.43

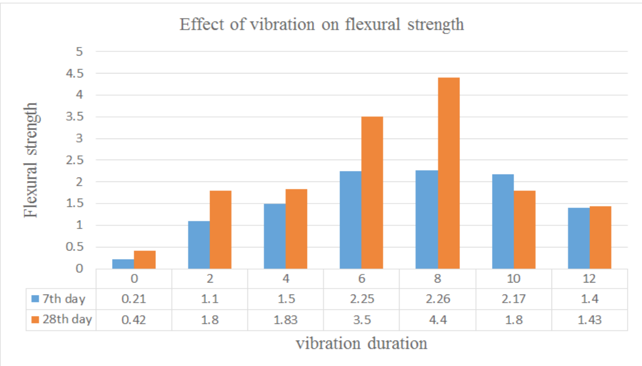

Figure 3: Flexural strength of pervious concrete on the 7th and 28th day.

4.3.4 Correlation between compressive strength and flexural strength

From the obtained results, the flexural strength to compressive strength ratio falls between 10 and 25 percent for the 7 days old concrete and between 13 and 38 percent for the 28 days old concrete aged 28 days. The relation between flexural strength and compressive strength can be predicted by using the following empirical equation (Eqn. 4.1) suggested by the ACI building code.

Equation 1 relation between flexural strength and compressive strength

Ffs = 0.94fc0.5……………………………………… (1)

where Ffs = flexural strength of concrete   fc =compressive strength of concrete

A comparison between the predicted and experimentally obtained results of the flexural strength is shown in (**Table 3**).

Table 3: Comparison of the experimental and predicted flexural strength.

Vibration duration (sec)	Experimental flexural strength		Predicted flexural strength		Experimental/ predicted ratio	
	7 days	28 days	7 days	28 days	7 days	28 days
0	0.21	0.42	1.36	1.68	0.08	0.13
2	1.1	1.8	1.66	2.26	0.07	0.35
4	1.5	1.83	1.99	2.35	0.22	0.43
6	2.25	3.5	2.15	2.89	0.58	0.46
8	2.26	4.4	2.2	3.17	0.73	0.57
10	2.17	1.8	2.04	3.09	0.57	0.48
12	1.4	1.43	1.73	3.01	0.65	0.44

The table shows the experimental and predicted flexural strength of a material at different vibration durations after 7 and 28 days of curing. The experimental/predicted ratio is also provided to compare the accuracy of the predictions. The experimental flexural strength values are generally lower than the predicted values, with the ratio ranging from 0.07 to 0.73. The comparison results indicate that the predicting model for the flexural strength has overestimated the flexural strength at each duration of vibration. The predicted and experimental results started to conform to the increase in duration of vibration at the age of 28 days. This could be attributed either to the overestimation of the predicting model or the effect duration of vibration on the compressive strength used in the calculation of the predicted flexural strength and also it may be due to the predicting formula might have developed for ordinary concrete.

From this prediction model result, it can be obviously under stood the flexural strength is highly affected by vibration duration than compressive strength.

Splitting tensile strength test

At the age of 7th days, the rate of split tensile strength development of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibrated concrete was 0.11 MPa, 0.13 MPa, 0.45 MPa, 1.25 MPa, 1.61 Mpa, 1.17 Mpa, and 1.13 Mpa respectively. These results indicated the rate of spilt tensile strength development increased when the time of vibration increased but decreases when the vibration time was beyond 8 sec. According to the test results the rate of spilt tensile strength development of 2 sec vibrated concrete improved by 0.02 MPa or 15.38% from 0 sec. For 6 sec vibrated concrete the rate of spilt tensile strength development enhanced by 0.8 MPa or 64% and 0.36 MPa or 22.36%, but it reduced by 0.44 Mpa or 37.6%, 0.04 MPa or 3.35% from 10 sec and 12 sec vibrated concrete.

The specimen tested at 28th days, the rate of split tensile strength development of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec vibrated concrete was 0.22 MPa, 0.8 MPa, 1.02 MPa, 1.35 MPa, 1.84 Mpa, 1.5 Mpa, and 1.33 MPa, respectively. These values indicated the rate of split tensile strength development increased when the time of vibration increased. The test results show that the rate of split tensile strength development of 2 sec vibrated concrete was improved by 0.58 MPa or 72.5% from 0 sec vibrated concrete. In 4 sec vibrated concrete the rate of split tensile strength development, improved by 0.22 MPa or 21.15%. In 6 sec vibrated rate of split tensile strength development was 0.33 MPa or 24.44%, and at 8 sec split tensile strength was 0.49 Mpa or 26.63%. But it reduced by 0.3 Mpa or 22.66%, 0.17 MPa or 12.78% from 10 sec and 12 sec vibrated concrete. According to the observed test results, it indicated the rate of split tensile strength development increased when the time of vibration increased.

On the 7th and 28th day after caste, the observed rate of split tensile strength development of pervious Concrete that was cast at 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec increased by the amount of vibration applied as shown in Table. For all the tests as shown, 0 sec and 12 sec vibration time duration Concrete represented under and over vibration because of low and high vibration applied to the concrete. The split tensile strength became weak when compared to other Concrete casts with the same specimens. The segregation of aggregates occurred beyond 8 sec Vibration time as evidence by decreasing split tensile strengths when extended up to 12 sec.

Table 4: Effect of vibration time on split tensile strength on 7th and 28th day.

No.	Vibration period (sec)	Splitting Tensile strength (Mpa)	
		7th Day	28th Day
1	0	0.11	0.22
2	2	0.13	0.8
3	4	0.45	1.02
4	6	1.25	1.35
5	8	1.61	1.84
6	10	1.17	1.5
7	12	1.13	1.33

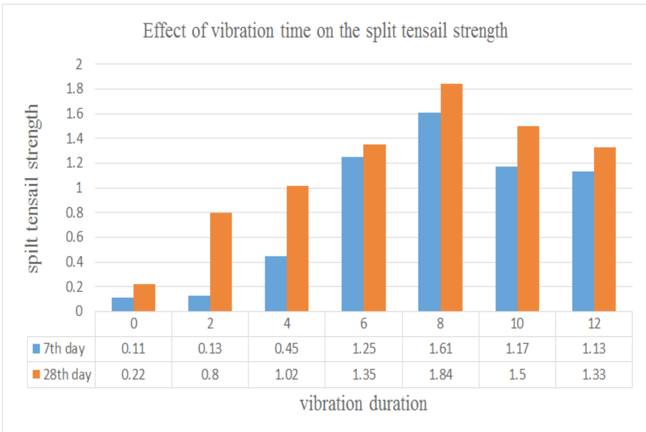

Figure 4: Split tensile strength on the 7th and 28th day.

4.3.5 Correlation between compressive strength and splitting tensile strength

From the obtained results, the splitting tensile strength to compressive strength ratio falls between 4 and 25 percent for the 7 days old concrete and between 6 and 16 percent for the 28 days old. The relationship between splitting tensile strength and compressive strength of concrete can be predicted by using an empirical equation suggested by ACI building code using the following empirical relationship (Eqn. 2).

Equation 2 relationship between splitting tensile strength and compressive strength

$$Ft = 0.59fc^{0.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

where Ft = splitting tensile strength of concrete and fc = compressive strength of concrete

A comparison between the predicted and experimentally obtained results of the split tensile strengths is shown in (**Table 5**).

Table 5: Comparison of the experimental and predicted split tensile strength (MPa).

Vibration duration (sec)	Experimental tensile strength		Predicted tensile strength		Experimental/ predicted ratio	
	7 days	28 days	7 days	28 days	7 day	28 days
0	0.11	0.22	1.04	1.42	0.13	0.20
2	0.13	0.8	1.25	1.48	0.14	0.56
4	0.45	1.02	1.35	1.81	0.92	0.68
6	1.25	1.35	1.38	1.99	1.16	0.74
8	1.61	1.84	1.28	1.93	0.91	0.92
10	1.17	1.5	1.09	1.89	1.03	0.77
12	1.13	1.33	0.85	1.05	0.12	0.70

Experimentally and predictably, the splitting tensile strength was determined from Eq. 4.2, and the results are shown in (**Table 5**). The results indicate that at the early ages of the concrete, the result indicates there is overestimated the splitting tensile strength at each duration of vibration. Furthermore, at the age of 28 days, the experimental results increase with the content duration of vibration up to 10 sec vibration duration. This could be due to more consolidation of the concrete as duration of vibration increases at a later age, and the predicting formula might have developed for ordinary concrete.

Permeability

At age of 7th day, the effect of permeability for 0 sec, 2 secs, 4 sec, 6 sec, 8 sec, 10 sec and 12 sec of vibrated concrete was 2.05 mm/s, 1.18 mm/s, 1.53 mm/s, 1.22 mm/s, 0.99 mm/s 0.92 mm/s and 0.62 mm/s respectively. These results indicated the rate of permeability decreases when the time of vibration increases.

According to the test results porosity at 2sec of vibration duration decreases by 0.24 mm/s or 13.25% from 0sec. At 4sec of vibration duration porosity decreased by 0.28 mm/s or 18.3%. At 6 sec of vibration duration porosity decreased by 0.31 mm/s or 25.4%. At 8sec, 10 sec, and 12 sec of vibration duration porosity decreases by 0.23 mm/s or 23.23%, 0.07 mm/s or 7.6%, and 0.3 mm/s or 48.38% respectively. In 12 sec vibration of concrete porosity becomes 0.24 mm/s, 0.28 mm/s, 0.31 mm/s, 0.23 mm/s, 0.07 mm/s, 0.3 mm/s for 0 sec, 2 secs, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec respectively.

On the 28th day, the effect of permeability investigated for vibration duration of 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec was 1.72 mm/s, 1.69 mm/s, 0.87 mm/s, 0.56 mm/s, 0.43 mm/s, 0.35 mm/s, 0.22 mm/s respectively. This laboratory result indicates as vibration duration increases the permeability of concrete decreases. At 2sec of vibration duration, the porosity decreased by 0.03 mm/s or 1.77% from 0 sec. at 4sec, 6sec, 8sec, 10sec and 12sec of vibration duration porosity decreased by 0.82 mm/s or 94.25%, 0.31 mm/s or 55.35%, 0.13 mm/s or 30.23%, 0.08 mm/s or 22.8%, 0.13 mm/s or 59.09% respectively.

This laboratory result shows as the duration of vibration increases from 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 seconds on the 7th and 28th day the permeability of the concrete decreases. At 0-sec vibration duration, the permeability becomes 2.05 mm/s which is highly porous but it's not strong and durable. At a 12-sec vibration duration, the permeability become 0.94 mm/s which was little porosity but stronger than 0-sec vibration. The optimum permeability was at 8 sec which was the optimum strength (**Table 6**) (**Figure 5**).

Table 6: Permeability properties for 7th and 28th day.

No.	Vibration on sec	7th day(mm/s)	28th day(mm/s)
1	0	2.05	1.72
2	2	1.81	1.69
3	4	1.53	0.87
4	6	1.22	0.43
5	8	0.90	0.03
6	10	0.92	0.19
7	12	0.94	0.67

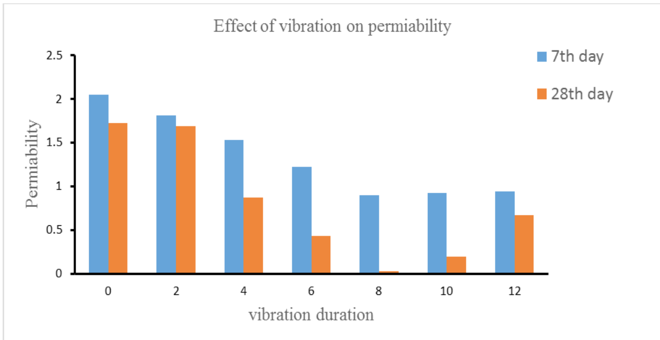

Figure 5: permeability properties of pervious concrete on the 7th and 28th day.

ANOVA Correlation analysis

Using the Pearson correlation coefficient was evident in determining and quantifying a better understanding. The table you provided shows the correlation coefficients between compressive strength, vibration duration, permeability, and density of concrete. The correlation coefficient is a statistical measure that indicates the strength and direction of a linear relationship between two variables. It ranges from -1 to 1, where -1 indicates a perfect negative correlation, 0 indicates no correlation, and 1 indicates a perfect positive correlation.

Compressive strength vs vibration duration

There is a strong positive correlation between vibration duration and compressive strength of concrete with a Pearson correlation coefficient of 0.907**, which is significant at the 0.01 level. This indicates that as the vibration duration increases, the compressive strength of the concrete also increases. It exhibits a directly proportional relationship between concrete's compressive strength and vibration duration. This indicates that there exists a significant positive relationship between concrete compressive strength and vibration duration.

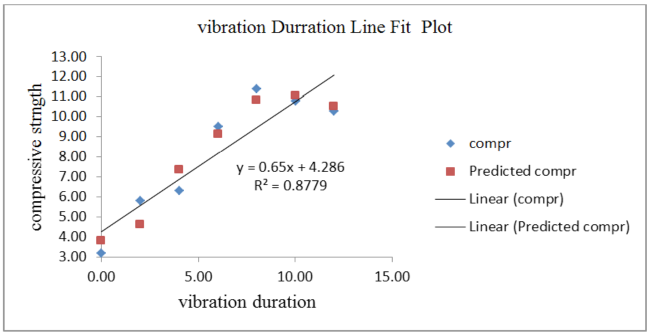

Figure 6: Compressive strength vs vibration duration.

Compressive strength vs permeability

There is also a strong negative correlation between compressive strength and permeability of concrete with a Pearson correlation coefficient of -0.926**, which is significant at the 0.01 level. This means that as the permeability of concrete decreases, its compressive strength increases. This correlation result indicates a negative link between compressive strength and permeability. Because of this, the study showed that concrete compressive strength increases the permeability decreases (**Figure 7**).

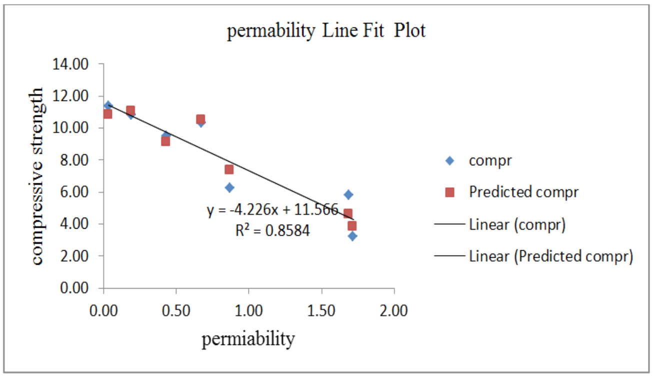

Figure 7: compressive strength vs permeability.

Compressive strength vs density

According to the table, there is a strong positive correlation between compressive strength and density of concrete with a Pearson correlation coefficient of 0.934**, which is significant at the 0.01 level. This means that as the density of concrete increases, so does its compressive strength. It indicates that the concrete compressive strength and density are directly related (**Figure 8).**

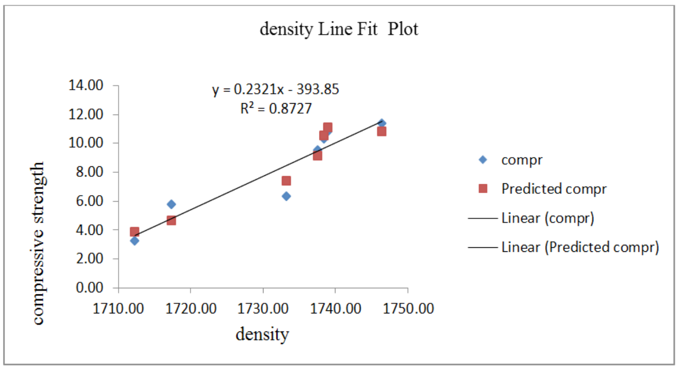

Figure 8: compressive strength vs density.

Permeability vs density

There is a strong negative correlation between permeability and density of concrete with a Pearson correlation coefficient of -0.972**, which is significant at the 0.01 level. This means that as the density of concrete increases, its permeability decreases tending to the association between the variables obtained from these studies.

Table 7: Correlation Analysis.

Variables	Parameters	Compressive strength	vibration duration	permeability	density
compressive strength	Pearson Correlation	1	.907**	-.926**	.934**
	Sig. (2-tailed)		.005	.003	.002
	N	7	7	7	7
vibration duration	Pearson Correlation	.907**	1	-.795*	.833*
	Sig. (2-tailed)	.005		.033	.020
	N	7	7	7	7
permeability	Pearson Correlation	-.926**	-.795*	1	-.972**
	Sig. (2-tailed)	.003	.033		.000
	N	7	7	7	7
density	Pearson Correlation	.934**	.833*	-.972**	1
	Sig. (2-tailed)	.002	.020	.000	
	N	7	7	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.3.1.2. Regression output

Regression analysis can be used to quantify the relationship between the variables more accurately and to predict the value of one variable based on the value of another variable. Prediction models in construction can help determine the strength of concrete at given ages. To effectively and efficiently design concrete building projects, early strength prediction is essential. It could be useful to detect concrete failure risks and enable preventative measures. The regression models developed for this study provided coefficients of determination to predict concrete strength at 28 days. The structure of this model, which is described in Equation 3, is used to forecast the compressive strength of various kinds of concrete.

Compressive strength of concrete

$$Y = ax_1 + bx_2 + cx_3 + d \text{------------------} \quad \text{Equation 3}$$

Where, Y is compressive strength of concrete and:

X_1=vibration duration

X_2= permeability

X_3= density

a, b, c is coefficient of X_1, X_2, X_3 respectively and d is intercept.

The outputs of a regression study that compared concrete's vibration duration, permeability, and density besides compressive strength are revealed in table 4-2. The following regression equation was developed to forecast the compressive strength of concrete with vibration duration, permeability, and density (**Table 8**).

Table 8: Summary of compressive strength regression output.

	Coefficients	Standard Error	t Stat	P-value
Intercept	-44.55	291.18	-0.15	0.00
Durability	0.32	0.19	1.70	0.00
permiability	-2.07	2.80	-0.74	0.01
density	0.03	0.17	0.18	0.00

Equation 43 finding on for Regression Analysis

$$y = 0.32x1 - 2.07x2 + 0.03x3 - 44.55 \ldots\ldots\ldots\ldots eq\ 4$$

Table 4-8 illustrates the findings of a regression analysis showing the relation between the concrete's compressive strength and its vibration duration, permeability, and density. Based on the R^2 value, vibration duration, permeability, and density contribute a significant 93.8% of the total compressive strength of concrete. This suggests that while other variables affect the concrete's compressive strength, vibration duration, permeability, and density are significant contributors. In addition, other variables might be the workability of freshly poured concrete, craftsmanship, adherence to the designs for the engineering, work supervision, and the grade of the coarse aggregate and water, etc.

4.3.1.3. validation of the model

Any model's performance has a significant effect on how reliable it is. Performance analysis uses statistical measures to compare model output data to actual or laboratory outcomes. A reliability test was carried out by assessing the errors related to the regression equations [40]. This is evaluated using the integral absolute error (IAE%), a technique many scholars use to assess the goodness of fit of any proposed relationship. In this case, the proposed regression equation is 4-3 The IAE is computed from equation 4-3.

Equation 44 Equation for Regression Analysis

$$IAE = \sum\sqrt{\frac{[(Oi-Pi)^{\wedge}2]}{\sum Oi}} \times 100 \text{ --------------------5}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|O_i - P_i| \text{ --------------------------6}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - P_i)^2} \text{ --------------------7}$$

The IAE determines the relative departure of the data from the regression analysis using equation 4-5, where Oi is the observed value and Pi is the anticipated value.

Table 9. The IAE for the regression analysis of the equation.

Vibration duration	Actual	Predicted	Residual	Absolute error	Sum of error	Root sum of error
0	3.2	3.769	-0.569	0.569	0.324	0.569
2	5.8	4.622	1.177	1.177	1.385	1.177
4	6.3	7.44	-1.14	1.14	1.300	1.14
6	9.5	9.12	0.378	0.378	0.143	0.378
8	11.4	10.85	0.545	0.545	0.297	0.545
10	10.8	10.93	-0.135	0.135	0.018	0.135
12	10.3	10.55	-0.256	0.256	0.066	0.256
Total	57.3	57.28	0	4.2	3.532	4.2
N	7	7	7	7	7	7
MAE	0.59957					
MSE	0.1352					
RMSE	0.3674					
IAE	0.2294					

The regression equation's predicted and actual values are equivalent only when the IAE is zero, which is an infrequent occurrence. The permissible range for a regression equation is between IAE values of 0 and 10% [40] The actual compressive strength and the compressive strengths computed using the derived regression equations in Mpa are shown in Table 4-9. It is clear from the IAE values found and shown in (**Table 9**), that the regression equations will provide reliable results. This occurs as a result of the IAE value being below 10%. Figure 9 illustrates the relationship between the experimentally observed values for compressive strength and those predicted by the model (**Figure 9**).

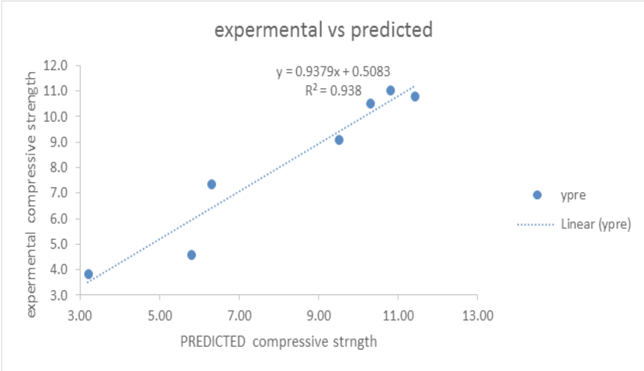

Figure 9: Observed vs predicted compressive strength at 28 days.

As shown from the figure, the observed and the predicted values for the compressive strength of concrete using regression model are in close correlation, indicating the reliability of this model and method for predicting compressive strength.

4.3.5. Durability

4.3.5.1. Sulfate attack

The result of the sulfate attack on previous concrete is given in the table below by considering the loss in weight and decrement in compressive strength.

At the age of 7th days, the durability of pervious concrete after immersion in H2SO4 at 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibration the percentage loss in weight of concrete was 12.3%, 13.4%, 12.0%, 11.82%, 9.53%, 10.42%, and 10.95% respectively. These results indicated that the percentage loss decreases were because of the removal of air bubbles and pores inside the concrete from 0 sec to 6 sec which was 12.3%, 13.4%, 12.02%, and 11.82%. At 8 sec of vibration time duration percentage loss become 9.53% which was the optimum loss and at 10 sec and 12 sec there was an increased vibration results in segregation of course aggregate which results in an increased percentage loss from 10.42% to 10.95% (**Table 10**) (**Figure 9**).

At the age of 28th days, the durability of pervious concrete after immersion in H2SO4 at 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibration the percentage loss in weight of concrete was 21.12%, 20.3%, 18.6%, 18.5%, 18.2%, 20%, and 20.5% respectively. These results indicated that the percentage loss decreases were because of the removal of air bubbles and pores inside the concrete from 0 sec to 6 sec which was 21.12%, 20.3%, 18.6%, and 18.5%. At 8 sec of vibration time duration percentage loss become 18.2% which was the optimum loss and at 10 sec and 12 sec there was an increased vibration resulting in the separation of course aggregate which results in an increased percentage loss from 20% to 20.5%.

Table 10. change in weight after immersion in H2SO4 7th day.

No.	Vibration (sec)	Weight of specimen before immersion in H_2SO4 (7 days) (kg)	Weight of specimen after immersion in H2SO4 (7 days) (kg)	Percentage change in weight of pervious concrete loss	Percentage loss
1	0	5.77	5.02	0.71	12.3%
2	2	5.79	5.01	0.78	13.4%
3	4	5.85	5.3	0.718	12.0%
4	6	5.86	5.39	0.72	11.82%
5	8	5.87	5.5	0.58	9.53%
6	10	5.87	5.3	0.62	10.42%
7	12	5.86	5.2	0.63	10.95%

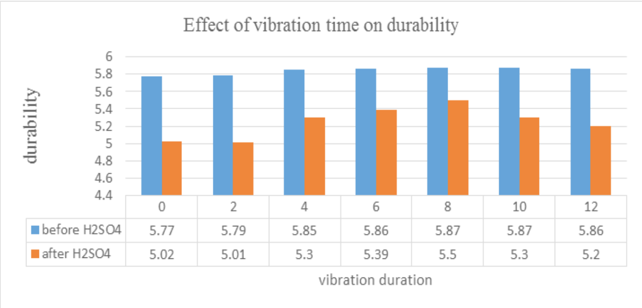

Figure 9: Change in weight after immersion in H2SO4 of 7th days.

As the time of vibration increases (from 0 to 12 seconds), the weight of the specimens before immersion gradually decreases. This implies that the specimens experienced some form of degradation due to vibration alone. The weight of the specimens after immersion in sulfuric acid also decreases for each time interval, indicating further deterioration of the concrete due to acid exposure. The weight change (loss) shows the difference between the weight before and after immersion. The percentage change in mass (loss) calculates the percentage decrease in weight relative to the initial weight. It provides a measure of how much weight was lost during the immersion period. The percentage change in mass generally decreases as the time of vibration increases. This suggests that as the specimens undergo longer periods of vibration, the acid's impact on weight loss becomes less significant (**Table 11**) (**Figure 10**).

Table 11: Change in weight after immersion in H2SO4 on the 28th day.

No.	Vibration (sec)	Weight of specimen before immersion in S2SO4 (28 days) (kg)	Weight of specimen after immersion in H2SO4 (28days)(kg)	Change in weight of pervious concrete loss	Percentage change in mass (loss)
1	0	5.77	4.52	1.21	21.12%
2	2	5.79	4.62	1.17	20.3%
3	4	5.85	4.92	1.1	18.6%
4	6	5.86	4.98	1.13	18.5%
5	8	5.89	4.89	1.19	18.2%
6	10	5.87	4.74	1.18	20%
7	12	5.86	4.64	1.19	20.5%

Comparison of durability before and after H2SO4

The results show that the compressive strength of concrete generally increases with the duration of vibration, both before and after immersion in sulfuric acid. This finding is consistent with other research that has investigated the effect of vibration duration on the compressive strength of concrete.

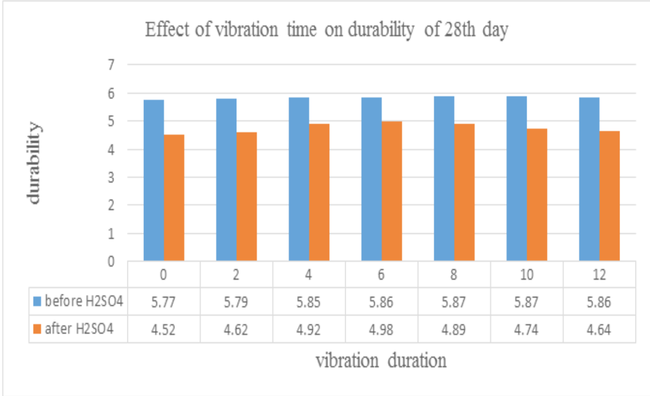

Figure 10: Change in weight after immersion in H2SO4 on the 28th day.

However, it's important to note that immersion in sulfuric acid can significantly reduce the compressive strength of concrete, as seen in the lower values of compressive strength after immersion compared to before immersion. This is due to the chemical reaction between the sulfuric acid and the calcium hydroxide present in concrete, which can weaken the bonds between the concrete particles and reduce the strength of the material.

Overall, it's essential to consider the effects of chemical exposure on the strength of concrete and to follow proper testing and design procedures to ensure that the resulting concrete is strong and durable. At the age of 7th days, the compressive of pervious concrete after immersion in H2SO4 at 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibration the percentage loss in weight of concrete was 17%, 16.5%, 15%, 14.8%, 13%, 16% and 18.5% respectively. These results indicated that the percentage loss decreases were because of the removal of air bubbles and pores inside the concrete from 0 sec to 6 sec which was 17%, 16.5%, 15%, and 14.8%. At 8 sec of vibration time duration percentage loss become 13% which was the optimum loss and at 10 sec and 12 sec there was an increased vibration resulting in segregation of course aggregate which results in an increased percentage loss from 16% to 18.5%.

At the age of 28th days, the durability of pervious concrete after immersion in H2SO4 at 0 sec, 2 sec, 4 sec, 6 sec, 8 sec, 10 sec, and 12 sec of vibration the percentage loss in weight of concrete was 19.8%, 18.65%, 18.25%, 16.88%, 15.73%, 7.66%, and 19.85% respectively. These results indicated that the percentage loss decreases were because of the removal of air bubbles and pores inside the concrete from 0 sec to 6 sec which was 19.8%, 18.65%, 18.25%, and 16.88%. At 8 sec of vibration time duration percentage loss become 15.73% which was the optimum loss and at 10 sec and 12 sec there was an increased vibration resulting in segregation of course aggregate which results in an increased percentage loss from 7.66% to 19.85% (**Table 12**).

Table 12: Comparison for H2SO4 on Compressive strength before and after.

No.	Vibration period (sec)	Average Compressive strength (Mpa) before immersion		Average Compressive strength (Mpa) after immersion	
		7th Day	28th	7th Day	28th
1	0	2.1	3.2	1.74	2.57
2	2	3.1	5.8	2.59	4.72
3	4	4.5	6.3	3.8	5.15

4	6	5.25	9.5	4.47	7.7
5	8	5.5	11.4	4.78	9.61
6	10	4.7	10.8	3.95	9.97
7	12	3.4	10.3	2.77	8.26

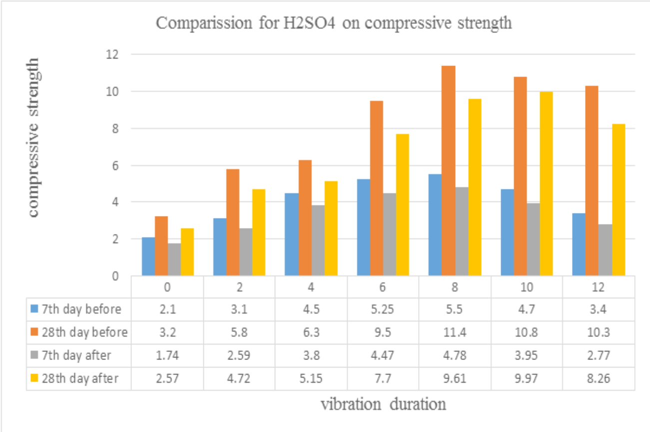

Figure 11: compression for compressive strength before and after.

4. Conclusion and Recommendation

Conclusion

In this research study, the effects of vibration time duration on Concrete strength (compressive, flexural, and split tensile) were experimentally investigated for previous concrete. Based on the finding the following conclusions can be drawn.

When extended Vibration time above the maximum period of vibration on concrete, it revealed a negative effect on the strength of concrete. The reason for this change was the incremental time duration of Vibration above the Optimum time of 8 sec causing the separation of coarse aggregates which affects the (compressive, flexural, and spilt tensile) strength of concrete On the other hand when the vibration of concrete is below the Optimum time duration, also it negatively affects the strength of concrete this is because of the air bubbles from the concrete does not removed.

The effect of vibration time duration on the permeability property of pervious concrete was when vibration increases concrete becomes dense because of the removal of air bubbles and pores up to 6 sec of vibration but after 8 sec of vibration duration concrete coarse aggregate separation that the concrete becomes porous so permeability increases.

The effect of vibration time duration on the durability property of pervious concrete by using sulfuric acid solution (H2SO4) was as vibration duration increases the flow of acid into concrete decreases concrete strength increases but after optimum vibration, concrete coarse aggregate separates and the cement slurry move up to the surface of concrete. Due to these, the acid can flow into concrete easily and the weight of the concrete decreased. But vibration can improve Concrete properties by removal of excess water and voids. The longer time or shorter time of the Optimum decreases the strength of the Concrete. The effect of vibration time duration on concrete permeability was experimentally investigated which indicates as vibration time duration increases permeability decreases but in this experimental investigation the optimum vibration duration for concrete strength was the optimum vibration duration for permeability of concrete.

Recommendation

Based on research finding research draws the following recommendations: -

In the production of previous concrete, it is necessary to have proper compaction because both under and over-vibration affect the properties of previous concrete.

These types of concrete are very useful for areas that are for the construction of rest areas, Parking lots, and for areas where water penetration to the ground is necessary. Therefore, stakeholders who work on such structures should consider the vibration time because both permeability, as well as strength of the concrete, mainly depends on the duration of vibration time.

Recommendation for further studies

It is recommended that further studies should be done for a better understanding of the effect of vibration time on the transportation and durability properties of pervious concrete. Investigations suggested are:

In this research, the study was conducted using the table vibrator method. it is recommended for further research work by using a rodding or spinning tube vibrator.

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