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Experimental Investigation of Water Temperature on Mixing of Concrete

Reiann Rose U. Villafranca[1], Kyla Mae O. Sazon[2], Glenny Faith G.Wanta[3], Brian Joseph D. Villacurza[4], Neo Raed M. Velasco[5],

[1-5 Student], Don Honorio Ventura State University, Pampanga/College of Engineering and Architecture/Department of Civil Engineering. Cabambangan, Bacolor, Pampanga, Philippines, 2001

Franco Remo B. David[6], Francis Cayanan[7]
2020100393@dhvsu.edu.ph [1], 2020100331@dhvsu.edu.ph [2], 2020100394@dhvsu.edu.ph [3], 2020101191@dhvsu.edu.ph [4],

[6-7 Faculty], Don Honorio Ventura State University, Pampanga/College of Engineering and Architecture/Department of Civil Engineering. Cabambangan, Bacolor, Pampanga, Philippines, 2001

2020101188@dhvsu.edu.ph [5]
Frbdavid@dhvsu.edu.ph [6], engrkikocayanan2@gmail.com [7]

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Abstract:
Due to the Philippines' high temperatures, this study investigates the effect of water temperature on concrete's compressive strength. Researchers examined concrete behavior at different mixing water temperatures (low and high). The focus was on compressive strength, setting time, and workability. Results showed that lower water temperatures increased compressive strength while higher temperatures decreased it. Additionally, colder water extended setting time, while warmer water accelerated it. Finally, all tested mixtures had a medium workability, suitable for construction. This research highlights the importance of water temperature control in achieving optimal concrete performance in hot climates.

Keywords — **Concrete, Water Temperature, Compressive Strength, Workability, Setting Time**

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I. INTRODUCTION

Concrete is a preferred material for various uses because of its numerous applications and desirable features, such as its capacity to withstand large amounts of compression, long-lasting durability, cost-effectiveness, easy availability of its components, and its compatibility with reinforcing bars and the ability to be moulded into various sizes and shapes [1], [2]. Regrettably, concrete is exceedingly susceptible to cracking and other forms of damage, such as degradation, which facilitates the ingress of harsh substances, including acid rain and salts into the concrete [3].

The temperature of water plays a vital role in determining the characteristics of concrete, especially its compressive strength. These factors are essential in assessing the ability of concrete to bear loads and resist cracking, which ultimately affects the durability and longevity of concrete structures [4]. When water encounters cement and other cementitious materials, a chemical reaction occurs, known as hydration. This process leads to the merging of water molecules with the minerals in Portland cement, which results in the release of thermal energy. The products of this chemical process dissolve in water and subsequently crystallize, creating a solid framework [5].

When the water is warmer, chemical reactions happen faster, resulting in quicker initial setting and early strength development [4]. It is important to note that although gaining strength early on is advantageous, it is crucial to avoid extremely high-water temperatures as they can cause uncontrolled and rapid hydration. This can lead to a flash set which results in a porous structure that has reduced long-term strength and may lead to durability issues such as cracking and shrinkage [6]. Moreover, when the water is cold, the absorption process is hindered, resulting in a postponement in the hardening and starting to gain strength. As a result, it can increase the construction time and make it more vulnerable to frost damage [7].

In tropical climates like the Philippines, where hot weather conditions are commonly experienced, understanding and managing these temperatures are crucial in understanding the behaviour of concrete [8].

Review of Related Literature

The formation of cracks in concrete is primarily due to extreme temperature variations. When the temperature of the concrete surface drops, it contracts more, leading to a higher tensile strength than the temperature difference itself. These cracks are observed in large concrete structures, road surfaces, and in warm environments [9]. The quality of concrete, which must meet international standards to be free of contaminants and chemicals, is crucial for its strength and longevity [10]. The performance of concrete made from Portland cement is greatly affected by the manufacturing process under harsh conditions with fluctuating temperatures. Elevated outdoor temperatures speed up the setting of concrete, diminishing its durability and affecting both technical and economic aspects [11]. Type I Portland Cement, also known as Ordinary Portland Cement, is ideal for constructing basic concrete structures without the inclusion of sulphates [12].

Selecting the appropriate sources for aggregates is crucial for enhancing the compressive strength of concrete [13]. The role of these aggregates in determining the strength and longevity of concrete is significant, as they often make up a large portion of the concrete mixture [14]. Incorporating angular aggregates into concrete boosts its compressive strength and permeability, but these properties decrease as the aggregate size diminishes [15]. Fine aggregates are used to bridge the gap between coarse aggregates and improve the workability of the concrete, making it easier to pump [16]. The expansion of the construction sector and the depletion of river sand have led to the need for alternative materials to M-sand, which not only increase the strength of concrete but also promote environmental sustainability [17]. Over time, the transportation of water by water has been greatly impacted by temperature. Moreover, the ability of cementitious materials to retain water has been found to vary with temperature [18].

Water plays a crucial role in the processes that create strength and resilience, yet, despite its significant chemical properties, its major drawback in making concrete is its low density. In comparison to other materials used in making concrete, a small quantity of water transforms into a considerable amount, with water making up 10% or less of the concrete's weight but taking up nearly 20% of its space [5]. In general, comparative tests necessitate that, where the quality of the water is unknown, the strength of concrete produced with that water should be compared to that of concrete produced with water of known suitability [19]. High or low temperature conditions in concrete mixing, transportation, casting, or curing significantly impact structure behaviour, performance, and qualities, affecting technical and economical construction, affecting concrete producers and end users [20]. High temperatures or unintentional fires can significantly alter the structural characteristics of concrete surfaces. Heat is created on free surfaces via convection and radiation. A study looked at the structural characteristics of concrete sections and found that those exposed to high temperatures, mass concrete will lose some of its structural characteristics [21]. Hot weather conditions can negatively affect concrete structures.

These impacts include a higher need for water, a greater loss of slump, a slower setting time, increased plastic cracking, early hardening, reduced ability to control air, long-term deterioration, and a higher risk of thermal cracking [22]. According to ACI, it is recommended to use cold-ice water when the temperature exceeds 35°. The most significant disadvantages of cold weather curing of concrete are extended setting time, premature deterioration, delayed hydration, decreased strength, and the formation of thermal cracking. When fresh concrete is exposed to cold temperatures, the mixing water within the concrete typically turns into ice, thus altering its setting properties [23].

The average temperature in the Philippines except for Baguio is 26.6 °C with January being the coldest month and May is the warmest month [24]. Water undergoes state changes due to temperature variations. At 32°F (0°C), pure water goes from its solid to its liquid form. At 212 °F (100 °C), pure water boils [25]. Curing is essential for preserving the moisture and temperature content of concrete for desired characteristics, increasing its strength, increasing its volume stability, reducing its permeability, and increasing its durability, including resistance to abrasion and resistance to frost and thaw [26]. ACI 301's minimum water temperature for mixing concrete is 4°C while maximum temperature is 32°C [27]. The temperature of water used to cure concrete affects its strength. The strength of high-performance concrete is affected by the combination of water temperature. High temperatures increase strength and cure faster, while lower temperatures can cause shrinkage and decrease compression strength [28] Additionally, cold water curing reduces the compressive strength of the concrete by delaying cement hydration, which makes it a poor choice for concrete curing [29]. Using hot water in the concrete mix raises the temperature during production and speeds up the setting time due to the quick hydration of the concrete [30]. According to the study, using cold mixing water enhances the workability, reduces cracks, and boosts the compressive strength of concrete constructions.

Effect of Water Temperature on Concrete Properties

The study indicates that the quality of water used significantly influences the concrete's workability, setting time, compressive strength, tensile strength, and flexural strength. For standard slump requirements, drinking water is still the best option; seawater shortens the initial setting time. While wastewater tends to acquire more tensile strength, potable water is the best choice for achieving the desired compressive strength [31].

Portland cement, aggregate, water, and chemical admixtures are the main components of the composite building material known as concrete. In contrast to hardened concrete, which is solid and strong, fresh concrete can be moulded since it is in a malleable state. Controlling variables including the water-cement ratio, temperature, aggregates, cement type, and admixtures are necessary for producing high-quality concrete [32]. Water-cement ratio (WCR) is one of the most significant determinants of Plain Cement Concrete (PCC) strength and durability. Lower WCRs mean stronger, more durable Portland Cement. The WCR is determined by the ACI method and is determined by compressive strength. In most state DOTs, the WCR is set at 0.40 to 0.50 [33]. Studies have demonstrated that initial concrete freezing can reduce compressive strength by as much as 50%. At -4°C water freezes in the concrete capillaries and expands by as much as 9%, resulting in cracking. To prevent damage, it is recommended to maintain a temperature between 10°C and 50°C for a period of 48 hours [34]. The amount of water in fresh concrete can greatly influence the spacing between particles and the amount of empty space within the hardened mixture. Typically, more water per cubic meter (w/cm) leads to concrete that is more permeable but has less strength when compressed [5]. The elasticity of the structure may be the most significant factor in the construction of roads and runways, and a thorough understanding of elastic modulus plays an essential role in the calculation of deflections [35]. Temperature and vice versa at 40° C, enhancing compressive and flexural strength [30]. The temperature of the water used in the mix affects how the concrete sets, which can lower its strength and cause small cracks due to too much water during the setting process, but this doesn't significantly affect how the cement pastes dissolves [36].

The guidelines for creating concrete mixtures, as outlined by ASTM, recommend using a maximum aggregate size of 20 mm and a slump range of 80 mm to 100 mm for the water-to-binder ratio. The slump of the concrete, or how much it flows, goes up with colder water, but it becomes easier to work with and flows more with warmer water. The concrete's ability to withstand pressure was found to be between 14° and 18°C, with the results showing consistency within this range [34]. The study found that concrete compression resistance increases at higher cure temperatures, becomes smoother at seven days and is nearly linear at 14 days and decreases from 28 to 91 days, suggesting that curing temperature plays a role in concrete compression resistance [30].

Background of the Study

The high ambient temperatures in the Philippines pose a significant challenge to concrete performance, particularly in its compressive strength. Understanding the impact of water temperature on these properties is crucial for achieving durable and long-lasting structures in this tropical climate. Understanding the relationship between workability and strength is essential for designing and producing concrete that meets the specific requirements of different applications. Utilizing appropriate mixed design strategies and construction practices helps achieve the desired balance between these two properties, ensuring the success and durability of concrete structures.

Continued research is vital in developing innovative techniques to ensure the longevity and structural integrity of concrete constructions in the country. For that reason, the researchers will focus on determining the concrete's behaviour on different water temperatures during the mixing process of concrete while considering the water-cement ratio and curing process.

Statement of the Problem

In the construction industry, strength, setting time, and workability of concrete have become critical concerns. Researchers will discuss the experiment of mixing different water temperatures in concrete to determine if it significantly increases the concrete's compressive strength, improves its workability, and affects its setting time. It aimed to respond to the following concerns:

- How does the interaction of water temperature affect the setting time of cement?
- What influence could water temperatures possess on concrete's workability?
- What would be the compressive strength of concrete with varying water temperature if it was left to cure for seven, 14, and 28 days using potable water?

Objectives

General Objective

The objective of the research is to explore how water at certain low and high temperatures impacts the process of mixing concrete in vertical construction that are upright. Moreover, the researcher will demonstrate whether there will be alterations in the mechanical properties of concrete and the duration it takes to set.

Specific Objectives

- To evaluate how changes in water temperature affect the time it takes for cement to set, using the Vicat apparatus.
- To study how various water temperatures impact the ease of workability of concrete, as evaluated through the Slump test.
- To identify the alterations in the compressive strength of concrete when mixed with water at temperatures ranging from 4°C±0.5°C to 32°C±0.5°C, with an emphasis on achieving the highest strength increases over periods of seven days, 14 days, and 28 days

Significance of the Study

This research reconnoitres how different water temperatures impact the process of mixing concrete. The results of this research will be extremely advantageous for the following:

Construction Industries. Concrete mixing is a widely known technique in construction to produce concrete used in the structure's structural composition. Determining the effects of the water temperature in the concrete mixing process can help the construction industry produce improved quality concrete.

Ready Mix Companies. The continuous temperature increases in the Philippines, which results in prolonged hours of delivery, may affect the quality of concrete. After mixing the water, the mixture has a limited time. As such, this study will help the company improve the ingredients they will use in their ready-mix mixture.

Future Researchers. This study will help future researchers fill the gap of the related studies if they wish to conduct further research on this topic.

Scope and Limitation

This study looks into how three different water temperatures (ranging from 4°C to ± 0.5°C, 26.6°C to ± 0.5°C, and 32°C to ± 0.5°C) affect the strength of concrete as it dries over periods of seven, fourteen, and thirty-eight days. Compressive strength, the most widely employed and accepted metric for concrete performance, determines a mixture's capacity to withstand forces exerted upon a structure. The initial phase of the experiment involves subjecting six mixture samples to the Vicat needle test, while three additional samples undergo the slump cone test during the mixing process. Subsequently, nine cylindrical concrete specimens will be cast for each designated temperature. It is important to note that the curing water temperature will not be controlled and will fluctuate based on ambient conditions and typical tap water temperatures in the Philippines, excluding Baguio. Additionally, the current scope of this study is restricted to vertical concrete applications.

Conceptual Framework

To accomplish the researcher's goal of producing an efficient product, the researcher used The Input-Process-Output model was used to improve the relationship between the variables in this study. The input in the left frame showed the data, information gathered, and materials gathered to be used. The process, which was in the middle frame, covered creating and testing the product and interpreting the data gathered. The right frame presented the output and the experimental investigation of water temperature on mixing concrete.

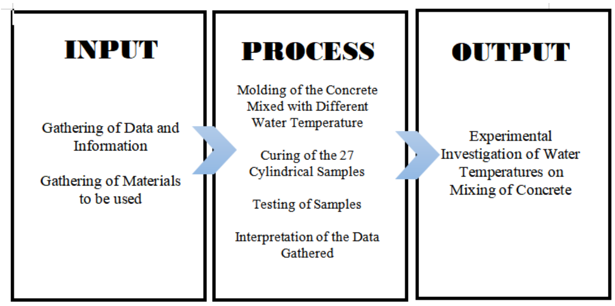


Fig. 1 Conceptual Framework

II. METHODOLOGY

Research Design

The researcher used to employ quantitative research analysis for gathering data. With the goal of observing and examining how water temperature affects the process of mixing concrete, this study will adopt a quantitative approach. It is under the authority of experimental study design to enable researchers to assess the effects of an experimental treatment. The main goal of this study is to assess the validity of any conclusions that can be derived from it. This analysis determined the temperature at which concrete's compressive strength would increase. In addition, several observations of the experiment will be made, particularly before and after the treatment.

Research Instrument

For this study, researchers will conduct experimental research to test materials, including compressive strength and temperature stress tests.

Mixing the concrete will differ from the regular construction method that uses similar materials. The experimental methods used in this study are essential to determine the concrete's quality, strength, and durability at a specific temperature. Researchers will use this data and information to conduct the study effectively

Raw Materials

M-Sand. Sand is a significant material in concrete mixtures. Suitable material for making concrete includes fine aggregate derived from naturally occurring gravel deposits or broken rocks. Manufactured sand, often known as M-Sand, is a synthetic form created by smashing durable stones into small, angular particles of sand. These particles are then washed and meticulously sorted to be utilized as a construction component. The quality of the sand and aggregate utilized in the concrete directly impacts the concrete's strength, characteristics, and durability.

Gravel. Gravel is a widely utilized material in the construction of concrete structures. Gravel is the primary coarse aggregate utilized in concrete, with the remaining part being crushed stone. Aggregate ingredients enhance the density of concrete mixes. Gravel is crucial in cementing the concrete and preventing it from developing cracks.

Cement. Cement is essential to concrete composition and performance. Concrete relies on cement for strength, durability, and binding. Portland cement mixes with water hardens with sand and rock to form concrete.

Potable Water. The condition of the water used in making cement concrete significantly affects its lasting quality. The properties of concrete, including its ease of workability, strength when compressed, permeability, resistance to water, durability, resistance to weathering, shrinkage during drying, and the likelihood of cracking, are all influenced by the water content in concrete. Water that is pure, devoid of impurities, minerals, gases, and certain bacteria significantly enhances the concrete's overall strength.

Ice Block. Ice is the primary ingredient to achieve the desire cold temperature that will be needed in the experiment.

TABLE 1: TOOLS AND EQUIPMENTS USED IN THE STUDY

Hand Tools	
Shovel	Used for transferring sand, gravel, and cement to the designated places.
Sand Sieve	Used to separate fine grained sand.
Trowel	Used to transfer concrete mixture into the concrete cylinder mold during the experimentation.
Alcohol Thermometer	Used in experiments that identified the freezing and boiling points.
Water Digital Thermometer with Long Probe	Utilized to obtain highly accurate measurements of temperatures or variations in temperature.
Tamping Rod	Used for concrete mixture's compaction to eliminate air void.
Rubber Mallet	Used to consolidate materials and release entrapped air in concrete molds and slump cones.
Bucket	Used to store the measured sand, gravel, cement and water that was used in the experiment.
Sack	Used in storing the sand and gravel.
Equipment	
Concrete Cylinder Mold	Used to mold the concrete mixture that was used in testing.
Mixing Board	Used in masonry that served as a platform for combining materials like cement and sand.
Measuring Box	A measuring box is used for measuring the fine aggregates and coarse aggregates
Vicat Apparatus	Used to determine the cement's consistency, initial setting time, and final setting time.
Slump Cone	Used to evaluate a fresh concrete mix's workability in relation to relevant AASHTO and ASTM criteria.
Safety	
Hand Gloves	Used to prevent harm in hands and wrist during the experimentation.
Face Mask	Used to cover face to prevent inhaling the dust from the aggregates.

Concrete Mix Design

The researcher used a Class A concrete mix formulation derived from Max Fajardo's "Simplified Construction Estimate" manual. This formulation follows a mix ratio of 1 part Portland Cement, 2 parts fine aggregates, and 4 parts coarse aggregates, aiming for a compressive strength of 3500 psi, to be reached within twenty-eight days. The concrete mix formulation will adhere to ASTM standards, with a limit on aggregate size not exceeding 20 mm and a slump range of 80 to 100 mm being considered as a reference. Regarding the Water to Cement Ratio (WCR), the researcher selects a value of 0.50, which remains compliant with ACI standards.

There are two types of aggregate: fine (FA) and coarse (CA). Coarse aggregate and fine aggregate from Bacolor, Pampanga, were used to prepare concrete using locally accessible materials. By following ASTM C 136 and ASTM 33, the CA and FA grades were achieved.

TABLE 2: SIEVE ANALYSIS OF FINE AGGREGATES

Sample Identification					**Fine Aggregates**
Tare No.					F-05
Weight of Tare, grams					267.0
Weight of Sample with Tare, grams					1,497.7
Weight if Sample, grams					1,230.7
Sieve Size		**Weight Retained (g)**	**Percent Retained**	**Percent Passing**	**Specification (ASTM C 33)**
inches	**mm**				**Size Number 67**
1"	25.4			100	~
¾"	19.4	12.2	0.99	99	~
½"	12.7	2.4	0.20	99	~
3/8"	9.5	5.4	0.44	98	100
No. 4	4.8	31.5	2.56	96	95 to 100
No. 8	2.38	79.5	6.46	89	80 to 100
No. 16	1.19	184.3	14.98	74	50 to 85
No. 30	0.59	347.8	28.26	46	25 to 60
No. 50	0.297	347.8	28.23	18	5 to 30
No. 100	0.149	150.4	12.22	6	0 to 10

TABLE 3: SIEVE ANALYSIS OF COURSE AGGREGATES

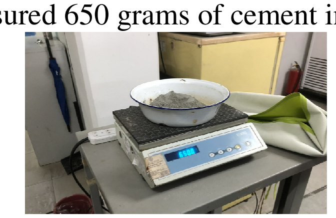
Sample Identification					**3/4" Coarse Aggregates**
Tare No.					TP-3
Weight of Tare, grams					2,236.5
Weight of Sample with Tare, grams					13,648.5
Weight if Sample, grams					11,412.0
Sieve Size		**Weight Retained (g)**	**Percent Retained**	**Percent Passing**	**Specification (ASTM C 33)**
inches	**mm**				**Size Number 67**
1-1/2"	38.1			100	~
1"	25.4	137.3	1.20	99	100
3/4"	19.4	7313.2	64.08	35	90 to 100
1/2"	12.7	3874.7	33.95	1	~
3/8"	9.5	51.4	0.45	0.3	20 to 55
No. 4	4.8	14.1	0.12	0.2	0 to 10
No. 8	2.38	0.7	0.01	0.2	0 to 5

Vicat Needle Test

Procedures for Vicat Needle Test

1. Prepared all the necessary pans needed for measuring the amount of cement. Brush them off if necessary.

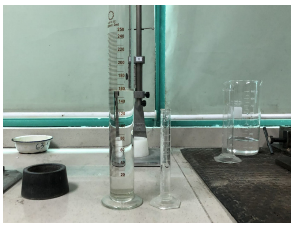
2. Measured 650 grams of cement in every pan.



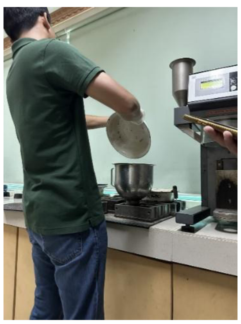
3. After measuring, the pan was covered to avoid unnecessary particles.

4. In a beaker, water was poured, and its temperature was measured.

5. Transferred the water to a measuring cylinder to achieve the desired amount of water.



6. Water was poured into the mixing bowl. Then, the measured cement was added. The bowl was then swirled for 10 seconds until the cement was fully coated with water.



7. The mixture was run in the digital mortar mixer for one minute. After a minute, the mixing bowl was removed from the mixer. A spatula was used to scrape the edges of the mixing bowl, and then it was rerun for another minute.

8. After mixing, with dry hands, mixture was formed into a circle and passed it through with their two hands six times.

9. The mixture was poured into the Vicat Apparatus Conical Mold and the excess mixture on top of the mold was scraped off using a clean spatula.

10. The mold was placed under the apparatus to check its consistency. The weight of the Vicat apparatus was dropped into the mixture and held for 30 seconds. The value should have been between 9 and 11 for normal consistency. If it fell above or below the desired value, the volume of water in the mix would have needed adjustment.

11. The needle of the Vicat apparatus was changed to the initial set needle for the time setting test of the concrete. After one hour had elapsed, the needle was dropped and held in place for 30 seconds. The desired penetration depth was 25mm. If this depth was not achieved, the test continued with checks every 5 minutes, or every 3 minutes, if necessary, until the needle penetrated to the desired depth.

12. After the 25 mm penetration depth was achieved, the needle was switched to the final setting needle to assess the final setting time of the cement. The final setting needle was then dropped onto the cement surface for 30 seconds. To conclude the final setting time, the needle should not have left any mark on the cement surface.

Collection of Raw Materials

For this experiment, the researchers utilized readily available materials to create concrete. These included cement, sand, gravel, and water. The sand and gravel were sourced from a hardware store in Bacolor, Pampanga. The cement, on the other hand, came from Manila. Additionally, ice was incorporated into the mix for the 26.6°C±0.5°C and 4°C±0.5°C experiments. This ice was also acquired in Bacolor.

Preparation of Concrete Mixture
Cleaning the Coarse Aggregates

1. Hosed down the gravel properly to remove unnecessary dirt.

2. Placed the clean gravel on a clean surface and let it dry.

Sand Sieving

1. Subsequently, run the sand on a sand sieve to filter rocks.

Production of Samples
Proportioning

The researcher will measure the raw materials based on the concrete mix design. It is composed of one part of cement, two parts of sand and 4 parts of gravel. This experiment requires 9 samples per temperature. In table 4, shows the quantity of materials used in every mixture.

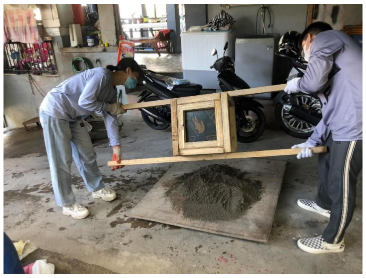
Table 4: QUANTITY OF MATERIALS

Water Temperature	Proportion in Cubic feet (cu. ft)			Water (kg)
	Cement	Sand	Gravel	
4 C	1	2	4	20
26.6 C	1	2	4	20
32 C	1	2	4	20

Making the Samples

The specific procedures for creating the concrete sample in each temperature are. A total of 27 samples were made, 9 per temperature, 3 per curing days and were tested compressive strength.

1. Prepared the measured sand and laid it on the flat and clean surface.



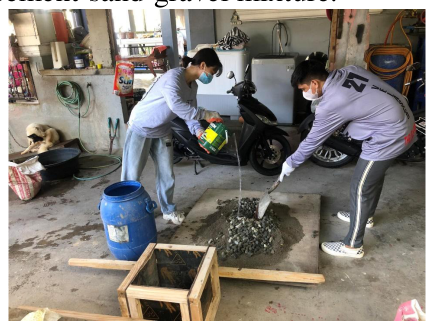
2. Prepared the cement after the sand and gravel preparations were completed.

3. Following that, gently incorporated the cement with the sand.

4. Once the sand and cement have been thoroughly mixed, add the gravel.

5. The water temperature was adjusted manually using a thermometer. If it was 32 °C, hot water was added as needed to reach the desired temperature. Conversely, if the temperature was 4 °C, ice was added to raise it.

6. If the necessary water temperature has already been achieved, carefully mix it into the cement-sand-gravel mixture.



7. When the mixture has been mixed thoroughly, gently put a 4-inch-thick layer of concrete, tap it with a tamping rod, and use a rubber mallet to eliminate any remaining air gaps. Repeat this process 2 more times.

Slump Cone Test

Procedures for Slump Cone Test

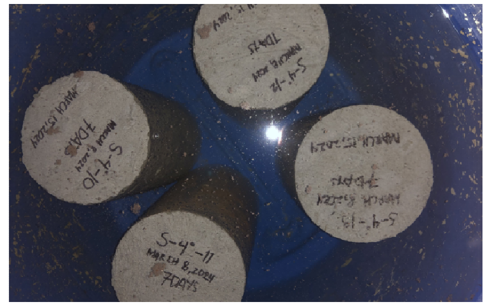
1. The bucket was filled with a specific amount of the mixture for the slump cone test.

2. Then gently place a 4-inch-thick layer of concrete in the slump cone, compacted it with 25 tamping rod blows before repeating the process with additional concrete layers until the cone was full.

3. After reaching the top part of the cone, the cone was lifted gently. The cone is then put beside the mixture and measured its height using a meter tape.

Compressive Strength Test
Procedures for Compressive Strength Test

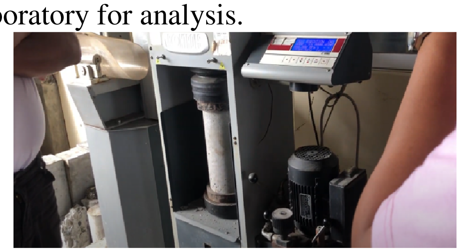
1. After 24 hours, the concrete was carefully removed from the cylinder. Cure the concrete in a bucket full of water for 7, 14, and 28 days.



Note: Particles seen are not from the water, these are reflections of the permanent residues from the inside of the drum.

2. To prevent damage from concrete during transit, the concrete was carefully placed in a bucket filled with rice straws.

3. Since the concrete has reached its designated curing age, the samples were transported to an accredited testing laboratory for analysis.



Data Analysis
Sample Testing

Testing the samples is the central part of the study, so the researchers will do different tests to determine if the water temperature affects concrete production.

Vicat Needle Test – ASTM C191

Using a Vicat needle establish, the hydraulic cement's setting time. There are two test methods available: the automatic Vicat machine (method B) and the manually operated Vicat machine (method A) [38]. A Vicat device is one of the most widely used methods for determining the consistency of cement. This equipment measures a cement paste's initial and final setting times in addition to its standard consistency.

In the summary of test method, after preparing and mixing a paste according to Test Method C 187's guidelines, it is moulded, put in a wet cabinet, and given time to begin setting. This mixture undergoes regular penetration evaluations by permitting a 1-mm Vicat needle to be inserted into it. The interval from when the cement and water first mix, and the penetration depth of 25 mm is referred to as the Vicat initial setting time. The amount of time that passes between first contact and the Vicat final time of setting of cement and water as well as the moment at which the paste surface is not completely circularly imprinted by the needle.

Slump Test – ASTM C143

The slump test is essential for assessing the workability of newly mixed concrete. This test offers a fast and straightforward approach to verify the uniformity of various concrete batches. To ensure the concrete's quality, several techniques will be employed, one of which is the slump test [37]. In this test, three layers of material were incorporated into a mold, with each layer being compacted twenty-five times to ensure an even distribution of the concrete mix. Following this step, the mold was slowly and uniformly removed. At that point, the slump was determined by measuring the distance from the trowel to the top of the material, moving downwards.

Table 5: CONCRETE USE SLUMP IN INCHES

Workability	Slump value	
	mm	inches
Very low workability	0 – 25	0 – 1
Low workability	25 – 50	1 – 2
Medium workability	50 – 100	2 – 4
High workability	100 – 175	4 – 7

There are four distinct levels of workability for concrete: very low, low, medium, and high. Concrete with very low and low workability, also known as tough or unworkable concrete, has very little water and a high degree of aggregate separation, making it difficult to handle. The water-to-cement ratio for this type of concrete is below 0.4. This workability level is commonly used in construction. The next is medium workability, which requires minimal segregation and is easy to mix and pour. For medium workability, the water-to-cement ratio ranges from 0.4 to 0.55. The final type is high workability, which simplifies the mixing and pouring process but may lead to more aggregate separation. In this case, the concrete paste floats to the top, and the coarse aggregates tend to settle at the bottom. This concrete is preferred when a lot of reinforcement is needed, and vibrating the concrete is not an option. Self-compacting concrete is an example of a very workable concrete, with a water-to-cement ratio above 0.55.

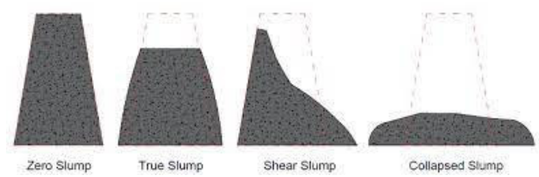


Fig. 2 shows type of slumps.

The figure illustrates four distinct categories of concrete slump: true, shear, collapse, and zero slump, each exhibiting various characteristics. The slump value is the height difference between the mold and the concrete sample after the mold is removed. True slumps raise concerns about concrete workability as they happen when the concrete partially settles but maintains its shape. Shear slumps occur when the top layer of concrete separates and slides horizontally, a result of insufficient cohesion in the concrete mixture. Conversely, a collapse slump typically suggests the concrete is too wet or has a high workability level, while a zero slump usually points to the concrete being too dry or too stiff and uniform.

Compressive Strength Test – ASTM C39

The "Standard Test Method for ASTM C39/C39M-12 a procedures Compressive Strength of Cylindrical Concrete Specimens". Compressive strength testing is among the most essential evaluations for concrete as it reveals the material's strength and its ability to bear the load of the structure, given the particular blend. The following formula can be used to find the concrete sample specimen's compressive strength:

$$CS = F/A$$

Where:
CS = the compressive strength
F = the maximum force applied before the point of failure
A = the initial cross-sectional surface area.

In this study, the test specimen underwent curing for periods of seven, 14, and 28 days prior to determining its compressive strength. The compressive strength of the specimens was evaluated at intervals of seven, 14, and 28 days to achieve the objectives of the study. Subsequently, the obtained results were contrasted with each sample that had the same cured days but a different water temperature. For their 28-day mix design, this study used Class A with a minimum compressive strength of 3500 psi. The average compressive strength was then calculated by the researcher using the formula in each set up, which consists of three samples. The three computed values were then added and dived into one to get the average compressive strength.

III. RESULTS AND DISCUSSIONS

The computations, tests, and experiments conducted for this research are presented in this chapter. This chapter will discuss the findings from the tests that the researcher conducted on all experimental samples from the 7th, 14th, and 28th days with varying water temperatures of 32°C±0.5°C, 26.6°C±0.5°C, and 4°C±0.5°C. These tests included the slump cone test, compressive strength test, and Vicat needle test.

Vicat Needle Test and Results

ASTM C 191, or the "Time of Setting of Hydraulic Cement Using Vicat Needle" method, serves as the foundation for this analysis. The Department of Public Works and Highways (DPWH Regional III) in Sindalan, the City of San Fernando, Pampanga, hosted the Vicat needle experiment. This experiment aims to find out how long cement takes to set when mixed with different temperatures of water.

Table 6: INITIAL TIME SETTING OF CEMENT TEST RESULTS WITH 4°C

INITIAL SETTING									
TRIAL	TIME MADE	TIME						INITIAL SET, min	AVE. min
1	12:24 P.M.	(2:30 P.M.) 39 - 6 = 33	(2:33 P.M.) 39 - 8 = 31	(2:40 P.M.) 39 - 10 = 29	(2:45 P.M.) 39 - 12 = 27	(2:50 P.M.) 39 - 17 =22		2:47 P.M. 143	138
2	12:41 P.M.	(2:31 P.M.) 39 - 7 =32	(2:36 P.M.) 39 - 8 = 31	(2:41 P.M.) 39 - 10 = 29	(2:47 P.M.) 39 - 13 = 26	(2:52 P.M.) 39 - 12 = 27	(2:54 P.M.) 39 - 14 = 25	2:54 P.M. 133	

Table 6 shows the result of initial setting time of cement with 4°C of water temperature. Trial 1 was made at 12:24 p.m. and obtained 27 mm at 2:52 p.m., and 22 mm at 2:50 pm, but the standard of initial setting time of cement is 25mm. The researcher used an interpolation method to acquire the 25mm at an average time of 2:47 p.m. with a 143 in minutes. Trial 2 was made at 12:41 p.m. and obtained 25 mm at 2:54 p.m. with 133 minutes. The average initial setting time of cement with 4°C of water temperature is 138 minutes.

Table 7: FINAL TIME SETTING OF CEMENT TEST RESULTS WITH 4°C

	FINAL SETTING												
TRIAL	TIME MADE	TIME/WITH MARK? Y/N										FINAL SET, min	AVE, min
1	12:24 P.M.	3:32 P.M. Y	3:42 P.M. Y	3:52 P.M. Y	4:02 P.M. Y	4:12 P.M. Y	4:22 P.M. Y	4:32 P.M . Y	4:42 P.M. Y	4:52 P.M. Y	5:02 P.M. N	278	277
2	12:41 P.M.	3:57 P.M. Y	4:07 P.M. Y	4:17 P.M. Y	4:27 P.M. Y	4:37 P.M. Y	4:47 P.M. Y	4:57 P.M . Y	5:07 P.M. Y	5:17 P.M. N		276	

Table 7 shows the result of the final setting time of cement with 4°C of water temperature. Trial 1 was formed at 12:24 p.m. and set at 5:02 p.m. without any trace of final needle of Vicat apparatus. Trial 2 was made at 12:41 p.m. and set at 5:17 p.m. without any trace of final needle of Vicat apparatus. Therefore, the final setting time of cement with a 4°C is 227 minutes (about 4 hours).

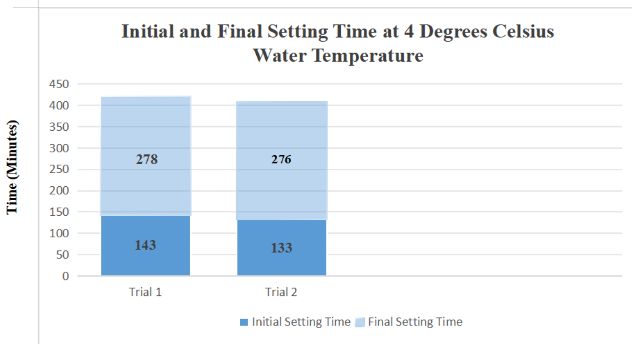


Fig 3.1 Setting Time of Cement Result at 4°C

Table 8:
INITIAL TIME SETTING OF CEMENT TEST RESULTS WITH 26.6°C

INITIAL SETTING													
TRIAL	TIME MADE	TIME										FINAL SET, min	AVE, min
1	10:54 A.M.	(12:15 P.M.) 37 - 3 = 36	(12:20 P.M.) 37 - 5 = 32	(12:25 P.M.) 37 - 5 = 32	(12:30 P.M.) 37 - 6 = 31	(12:35 P.M.) 37 - 9 = 28	(12:40 P.M.) 37 - 10 = 27	(12:45 P.M.) 37 - 13 = 24				12:43 P.M. 109	110
2	11:08 A.M.	(12:18 P.M.) 40 -2 = 38	(12:23 P.M.) 40 -2 = 38	(12:28 P.M.) 40 -5 = 35	(12:33 P.M.) 40 -7 = 33	(12:38 P.M.) 40 -8 = 32	(12:43 P.M.) 40 -9 = 31	(12:48 P.M.) 40 - 12 = 28	(12:53 P.M.) 40 -14 = 26	(12:58 P.M.) 40 -12 = 28	(12:59 P.M.) 40 -17 = 23	12:59 P.M. 111	

Table 8 shows the result of initial setting time of cement with 26.6°C of water temperature. Trial 1 was made at 10:54 a.m. and obtained 27 mm at 12:40 p.m., and 24 mm at 12:45 pm, but the standard of initial setting time of cement is 25mm. The researcher used an interpolation method to acquire the 25mm at an average time of 12:43 p.m. with a 109 in minutes. Trial 2 was made at 11:08 a.m. and obtained 28 mm at 12:58 p.m. and 23 mm at 12:59 p.m., the average time to obtained 25 mm was 12:59 p.m. with 111 in minutes. The average initial setting time of cement with 26.6°C of water temperature is 110 minutes.

Table 9: FINAL TIME SETTING OF CEMENT TEST RESULTS WITH 26.6°C

FINAL SETTING									
TRIAL	TIME MADE	TIME/WITH MARK Y/N						FINAL SET, min	AVE. min
1	10:54 A.M.	2:04 P.M. Y	2:14 P.M. Y	2:24 P.M. Y	2:34 P.M. Y	2:44 P.M. N		230	231
2	11:08 A.M.	2:09 P.M. Y	2:19 P.M. Y	2:29 P.M. Y	2:39 P.M. Y	2:49 P.M. Y	2:59 P.M. N	231	

Table 9 shows the result of the final setting time of cement with 26.6°C of water temperature. Trial 1 was formed at 10:54 a.m. and set at 2:44 p.m. without any trace of final needle of Vicat apparatus. Trial 2 was made at 11:08 a.m. and set at 2:59 p.m. without any trace of the final needle of Vicat apparatus. Therefore, the final setting time of cement with a 26.6 °C is 231 minutes (about 4 hours).

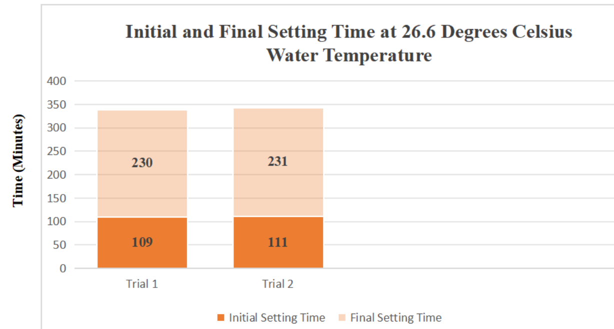


Fig 3.2 Setting Time of Cement Result at 26.6°C

Table 10: INITIAL TIME SETTING OF CEMENT TEST RESULTS WITH 32°C

INITIAL SETTING							
TRIAL	TIME MADE	TIME				INITIAL SET, min	AVE. min
1	11:23 A.M.	(1:01 P.M.) 39 - 10 = 29	(1:06 P.M.) 39 - 14 =25			1:06 P.M. 103	106
2	11:35 A.M.	(1:03 P.M.) 39 - 5 = 34	(1:08 P.M.) 39 - 9 = 30	(1:13 P.M.) 39 - 12 = 27	(1:28 P.M.) 39 - 19 = 20	1:24 P.M. 109	

Table 10 shows the result of initial setting time of cement with 32°C of water temperature. Trial 1 was made at 11:23 a.m. and obtained 25 mm at 1:06 p.m., 103 minutes. Trial 2 was made at 11:35 a.m. and obtained 27 mm at 1:13 p.m. and 20 mm at 1:28 p.m., the average time to obtained 25 mm was 1:24 p.m. with 109 in minutes. The average initial setting time of cement with 32°C of water temperature is 106 minutes (about 2 hours).

Table 11: FINAL TIME SETTING OF CEMENT TEST RESULTS WITH 32°C

FINAL SETTING									
TRIAL	TIME MADE	TIME/WITH MARK Y/N						FINAL SET, min	AVE. min
1	11:23 A.M.	3:09 P.M Y	3:19 P.M. Y	3:29 P.M. Y	3:39 P.M. Y	3:49 P.M. Y	3:59 P.M. N	276	280
2	11:35 A.M.	3:48 P.M. Y	3:58 P.M. Y	4:08 P.M. Y	4:18 P.M. N			283	

Table 11 shows the result of the final setting time of cement with 32°C of water temperature. Trial 1 was formed at 11:23 a.m. and set at 3:49 p.m. without any trace of final needle of Vicat apparatus. Trial 2 was made at 11:35 a.m. and set at 4:18 p.m. without any trace of the final needle of Vicat apparatus. Therefore, the final setting time of cement with a 32 °C is 280 minutes.

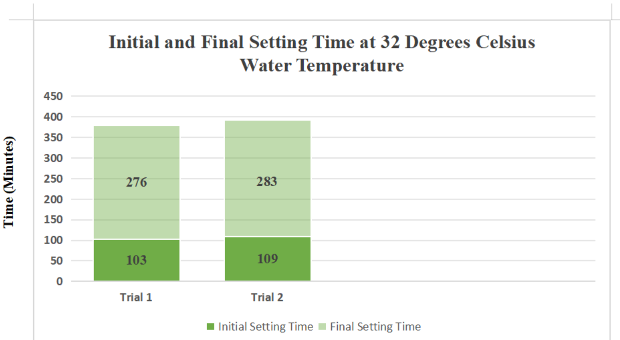


Fig 3.3 Setting Time of Cement Result at 32°C

Slump Cone Test Results The "Standard Test Method for Slump of Hydraulic Cement Concrete" described in ASTM C 143 serves as the foundation for this investigation. The scientists in Villa Elisa, San Agustin, Betis, Guagua, Pampanga, carried out the slump cone experiment. With an allowable error of ± 0.5°C, the experiment aims to ascertain the ease of workability of samples tested at water temperatures ranging from 32°C±0.5°C, 26.6°C±0.5°C, to 4°C±0.5°C.

Table 12: FINAL TIME SETTING OF CEMENT TEST RESULTS WITH 32°C

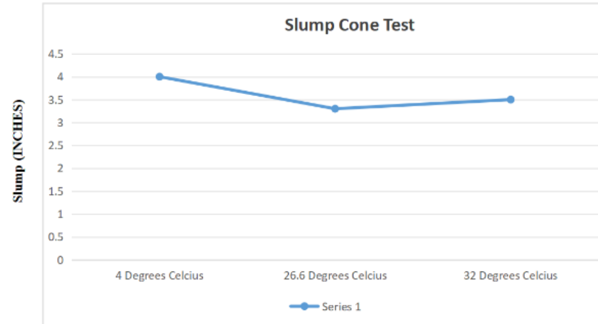


Fig 4: Slump Cone Test Results

Compressive Strength Test Results

Compressive testing investigates the behaviour of a material under pressure. It predicts how a material will behave when subjected to crushing forces by examining how it flows under stretch and how much bending it can take before breaking. Understanding how materials will respond to stretching or compression requires this kind of testing, particularly for hard or difficult-to-bend materials. These characteristics are crucial for determining whether a material is appropriate for a given application or whether it might malfunction in particular circumstances [38].

Three distinct setups are used in this study: the first is at 26.6 °C Celsius, with an error margin of ± 0.5 °C, which is comparable to the average water temperature in the Philippines; the other two are the experimental setups, which use partially mixed concrete water. The results of the compressive tests performed on the seventh day are shown in the information below.

Table 13: COMPRESSION STRENGTH TEST RESULTS ON THE 7TH DAY

SAMPLE IDENTIF-ICATION	DIMENSIONS HEIGHT	DIAMETER	GROSS AREA	MACHINE READING	COMPRESSIVE MPA	AVERAGE MPA	PSI	AVERAGE PSI
	(mm)	(mm)	(mm)	(kN)				
32 ° C - 1A	305	152	18242	296.2	16.23		2353.96	
32 ° C - 1B	305	152	18242	241.5	13.22	14.92	1917.4	2163.48
32 ° C - 1C	305	152	18242	279.1	15.3		2219.08	
4 ° C - 1A	305	152	18242	317.7	17.41		2525.11	
4 ° C - 1B	305	152	18242	338.1	18.53		2687.55	2622.29
4 ° C - 1C	305	152	18242	334.2	18.3		2654.2	
26.6 ° C - 1A	305	152	18242	420.16	23.52		3410	
26.6 ° C - 1B	305	152	18242	444	24.18	23.49	3510	3406.67
26.6 ° C - 1C	305	152	18242	412.37	22.76		3300	

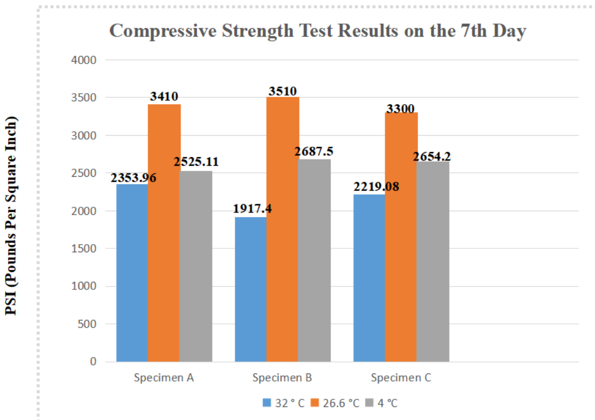


Fig 5.1: Compressive Strength Test Result on 7th Day

In this figure, it shows that the highest compressive strength is the temperature of (± 0.5°) 26.6 °C Celsius, and the lowest compressive strength is (± 0.5°) 32 °C Celsius in the 3 specimens.

Table 14: COMPRESSION STRENGTH TEST RESULTS ON THE 14TH DAY

SAMPLE IDENTIFICATION	DIMENSIONS HEIGHT	DIAMETER	GROSS AREA	MACHINE READING	COMPRESSIVE MPA	AVERAGE MPA	PSI	AVERAGE PSI
	(mm)	(mm)	(mm)	(kN)				
32 ° C - 2A	305	152	18242	375.8	20.58		2984.9	
32 ° C - 2B	305	152	18242	273.4	14.97	17.19	2171.2	2492.73
32 ° C - 2C	305	152	18242	292.1	16.01		2322.1	
4 ° C - 2A	305	152	18242	445.7	24.43		3543.28	
4 ° C - 2B	305	152	18242	413.6	22.65	22.33	3285.11	3238.7
4 ° C - 2C	305	152	18242	363.2	19.91		2887.71	
26.6 ° C - 2A	305	152	18242	426.51	25.31		3670	
26.6 ° C - 2B	305	152	18242	499.82	28.28		4100	
26.6 ° C - 2C	305	152	18242	416.77	22.52	25.37	3270	3680

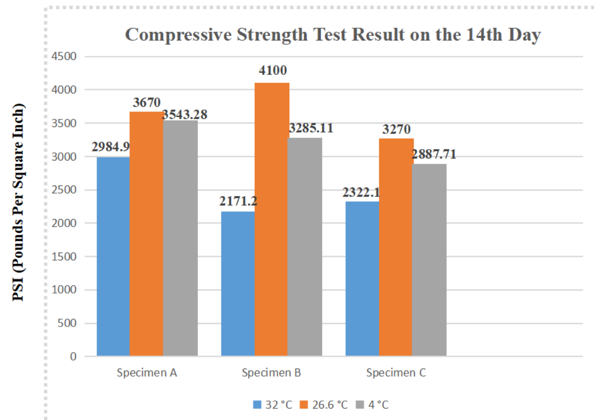


Fig 5.2: Compressive Strength Test Result on 14th Day

In this figure, it shows that the highest compressive strength is the temperature of 26.6 °C Celsius ±0.5°C, and the lowest compressive strength is the 32 °C Celsius ±0.5°C in the 3 specimens.

Table 15: COMPRESSION STRENGTH TEST RESULTS ON THE 28TH DAY

SAMPLE IDENTIFICATION	DIMENSIONS		GROSS AREA	MACHINE READING	COMPRESSIVE			
	HEIGHT	DIAMETER			MPA	AVERAGE MPA	PSI	AVERAGE PSI
	(mm)	(mm)	(mm)	(kN)				
32 ° C - 2A	305	152	18242	309.7	16.98	21.05	2462.75	3052.57
32 ° C - 2B	305	152	18242	358.9	19.66		2851.45	
32 ° C - 2C	305	152	18242	484	26.5		3843.51	
4 ° C - 2A	305	152	18242	516.7	28.33	27	4108.93	4686.67
4 ° C - 2B	305	152	18242	520.5	28.52		4136.48	
4 ° C - 2C	305	152	18242	440.8	24.14		3501.22	
26.6 ° C - 2A	305	152	18242	568.15	30.82	32.32	4470	3915.54
26.6 ° C - 2B	305	152	18242	528.04	29.53		4280	
26.6 ° C - 2C	305	152	18242	665.38	36.62		5310	

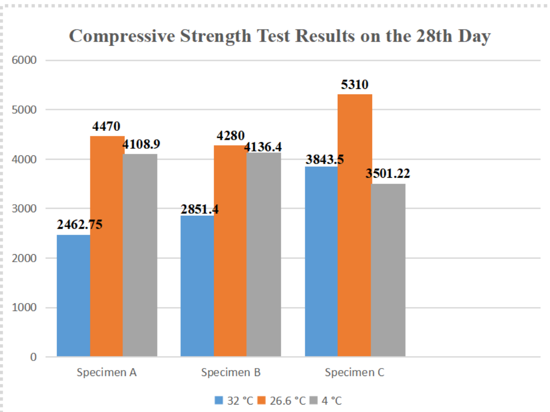


Fig 5.3: Compressive Strength Test Result on 28th Day

As shown in the figure, it shows that the highest compressive strength is the temperature of 26.6 °C Celsius ±0.5°C and the lowest compressive strength is the 32 °C Celsius ±0.5°C in specimen A and B. In Specimen C, the highest compressive strength is 26.6 ±0.5°C and lowest compressive strength is 4 °C Celsius ±0.5°C.

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The researchers investigated different water temperatures to contribute to the information in the engineering field. In addition, the main objective is to see which of these temperatures perform well on slump cone test and compressive strength test. The sample was manually mixed by the researchers. At the same time, the water temperature was obtained manually using laboratory thermometer. The experiment setups were executed based on different water temperatures. These are 4 °C Celsius, 26.6 °C Celsius, and 32 °C Celsius, cement, sand and gravel with a ratio of 1:2:4. As the study goes further, the findings investigated by the researchers are the following:

Vicat Needle Test Result

In the Vicat needle test, it was observed that the 32°C±0.5°C has the fastest initial time setting with the value of 106 min. For the final setting time, the mixture with 26.6°C±0.5°C obtains the fastest final setting time with a value of 231 min.

Table 16: Setting Time of Cement Paste using Vicat Apparatus (ASTM C191)

VICAT APPARATUS SETTING TIME	EXPERIMENTAL TEST RESULTS (MINUTES)			LIMITS
	4°C±0.5°	26.6°C±0.5°C	32°C±0.5°C	
Initial setting time, Min	138	110	106	≥ 45
Final setting time, Max	277	231	280	≤ 374

Slump Cone Test Result

This experiment is based on the "Standard Test Method for Slump of Hydraulic Cement Concrete" ASTM C-143. This Concrete Mixture test sample's consistency result was obtained at three different temperatures: 4°C to ±0.5°C, 26.6°C to ±0.5°C, and 32°C to ±0.5°C.

Table17: Slump Cone Test Result (ASTM C143)

SAMPLE IDENTIFICATION	SLUMP RATE (IN)	REMARKS
4°C±0.5°C MIXTURE	4	TRUE SLUMP
26.6°C±0.5°C MIXTURE	3.3	TRUE SLUMP
32°C±0.5°C MIXTURE	3.5	TRUE SLUMP

The slump measurement was taken from the top of the concrete to the base of the tamping rod inserted into the concrete mold. Table # illustrates that the experimental sample with a water temperature of 32°C±0.5°C exhibits a slump of 3.5 inches or 88.9 mm, demonstrating that the concrete retains its form even after the mold is removed. Similarly, the sample with a water temperature of 26.6°C±0.5°C also shows a slump of 3.3 inches or 83.82 mm, indicating that the concrete keeps its shape after the mold is taken out. Lastly, the sample with a water temperature of 4°C±0.5°C displays a slump of 4 inches or 100 mm, showing that the concrete maintains its form even after the mold is removed. All the experimental samples meet the criteria for true slump, which is the anticipated slump behaviour. Additionally, the slump values of all the experimental setups fall within the medium workability range, suggesting that the slump was successfully achieved.

Compressive Strength Test Result

The researchers adhered to the ASTM C39, the official procedure for determining the compressive strength of cylindrical concrete samples, with meticulous attention to detail throughout this study. This involved preparing concrete cylinders according to specified dimensions, applying a gradually increasing compressive load until failure, and calculating the average compressive strength based on the recorded data. By adhering to ASTM C39, the researchers ensured the test results accurately reflect the concrete's inherent compressive strength, a crucial property for guaranteeing the safety and stability of concrete structures.

The compressive strength testing, conducted according to ASTM C39, yielded mixed results at 28 days. While two test cylinders achieved the desired strength, one fell short of the design requirement of 3500 psi (241.32 MPa). The cylinder tested at 26.6 °C Celsius exceeded the minimum with a compressive strength of 4653.33 psi (320.88 Mpa). Similarly, the 4°C cylinder passed with a strength of 3915.54 psi (270.03 Mpa). However, the cylinder tested at 32 °C Celsius only reached 3052.57 psi (210.51 Mpa), indicating it did not meet the design strength criteria.

The cylinder sample with 26.6 °C attained the average highest compressive strength of 32.32 Mpa among all the sample specimens in the 28 days of curing, and the cylinder sample with 4 °C of water had 27 Mpa and lastly, the cylinder with 32.2 °C had the lowest result of 21.05 Mpa.

In conclusion, following ASTM C39's compressive strength testing procedures, we observed variations in concrete cylinder performance at 28 days. While some cylinders surpassed the design strength of 3500 psi, achieving results suitable for the intended application, one cylinder fell below the minimum requirement. This discrepancy warrants further investigation into the cause of the failing cylinder, potentially involving the concrete mix, curing conditions, or even testing procedures. Following ASTM C39's recommendations for investigating test failures will ensure the use of high-quality concrete that meets safety standards in the final construction project.

Conclusions

General Conclusion

At 28 days, Specimen C cured at 26.6°C exhibited the greatest compressive strength, reaching 5310 psi. This value represents a 151.17% increase compared to the 3500-psi design strength specified for a Class A concrete mix. The Vicat test results revealed a significantly faster setting time for the cement paste prepared with 26.6°C water compared to other test specimens. Regardless of water temperatures (4°C, 26.6°C, and 32°C), all samples maintained adequate workability as indicated by passing the slump test.

Specific Conclusions

- The Vicat needle test was conducted to evaluate the setting duration of Kaito cement, which is known for its quick-drying properties. As expected, the experiment revealed a clear correlation between water temperature and setting time. Initial setting times exhibited an inverse relationship with water temperature. Specimens prepared with colder water (4°C ± 0.5°C) exhibited an average initial setting time of 138 minutes (approximately 2.3 hours), compared to 110 minutes (approximately 1.8 hours) and 106 minutes (approximately 1.8 hours) for specimens prepared with water at 26.6°C ± 0.5°C and 32°C ± 0.5°C, respectively. This trend continued for final setting times, with the colder water (4°C ± 0.5°C) resulting in a longer average final setting time of 277 minutes (approximately 4.6 hours) compared to 231 minutes (approximately

3.8 hours) and 280 minutes (approximately 4.7 hours) for the 26.6°C ± 0.5°C and 32°C ± 0.5°C water temperatures, respectively. While the difference in setting time between the extreme temperatures (4°C ± 0.5°C and 32°C ± 0.5°C) is approximately 5 hours, it is crucial to acknowledge the substantial temperature difference itself (28°C). Interestingly, the water quantity used also differed slightly, with the colder mixture requiring a slightly higher volume (163 ml) compared to the warmer mixture (155 ml). However, the observed variations in water quantity are unlikely to significantly influence the setting time compared to the temperature effect. In conclusion, this experiment confirms the established principle that lower water temperatures lead to extended setting times for cement, while warmer to hot water temperatures accelerate the setting process.

- Commonly, concrete with medium workability is utilized in building projects, and the water to cement ratio typically falls between 0.40 and 0.60. The slump cone test results for all the experimental samples indicate that they fall within the medium workability range, with slumps ranging from 3 to 4 inches. As a result, all the samples achieved a consistency that meets the requirements of the mixtures, as determined by the slump cone test with a water to cement ratio of 0.5.
- On the seventh day of curing, 32 °C Celsius, none of the three samples exceeded the standard psi (pounds per square inches) of Class A using compressive test, while the 4 °C and 26.6 °C Celsius surpassed the standard psi. The standard psi of 7 days is 2485 psi, which is 71% of the standard psi of class A, which is 3500 psi. On the fourteen day of curing, 32 °C none of the samples exceeded the standard psi of Class A using compressive test, while the 4 °C and 26.6 °C Celsius surpassed the standard psi. The standard psi of 14 days (about 2 weeks) is 3045 psi, which is 87% of the standard psi of class A, which is 3500 psi. On the twenty-eight day of curing, 32 °C none of the three samples obtained the standard psi of class A using compressive test, while the 4 °C Celsius and 26.6 °C Celsius surpassed the standard psi. The standard psi of 28 days (about 4 weeks) is 3500 psi, which is 100% of the standard psi of class A, which is 3500 psi. The nine samples of 32 °C, none of them surpassed the standard psi of compressive strength of concrete, since the cement is already in high temperature then the water used in the mixture is also in high temperature. Hence, the high-water temperature reduces the concrete's ability to withstand compression. The water temperatures of 4 °C Celsius and 26.6 °C Celsius, which were included in the concrete mix, surpassed the recommended psi for Class A concrete. Therefore, the lower water temperature increases the compressive strength of the concrete.

Recommendations

This experiment was investigated to show the different water temperature used in mixture of concrete has a huge significant in mechanical properties of concrete. The researcher proved that 32 °C of water is not recommended to be used in mixture of concrete, since it failed to surpass the compressive strength of concrete. The future studies can improve and explore other variables of water temperatures:

- To make a sample with controlled condition.
- To make the samples in one batch to have a more accurate result.
- To push through curing with the same temperature as the mixture of concrete and maintain up to 28 days.
- To investigate the compressive strength of concrete by the different quality of water with different water temperatures.
- To ensure sufficient time for monitoring and data collection, the Vicat needle test can be initiated proactively.

- To use one degree interval temperature such as 27-31 degrees or 21-25 degrees.

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REFERENCES

[1] **A. Danish, M. A. Mosaberpanah, and M. Usama Salim,** "Past and present techniques of self-healing in cementitious materials: A critical review on efficiency of implemented treatments," *Journal of Materials Research and Technology*, vol. 9, no. 3, pp. 6883–6899, May 2020, doi: 10.1016/j.jmrt.2020.04.053.

[2] **N. Z. Muhammad, A. Keyvanfar, M. Z. Abd. Majid, A. Shafaghat, and J. Mirza**, "Waterproof performance of concrete: A critical review on implemented approaches," *Constr Build Mater*, vol. 101, pp. 80–90, Dec. 2015, doi: 10.1016/j.conbuildmat.2015.10.048.

[3] **L. Basheer, J. Kropp, and D. J. Cleland,** "Assessment of the durability of concrete from its permeation properties: a review," *Constr Build Mater*, vol. 15, no. 2–3, pp. 93–103, Mar. 2001, doi: 10.1016/S0950-0618(00)00058-1.

[4] "Concrete."

[5] **K. C. Hover,** "The influence of water on the performance of concrete," *Constr Build Mater*, vol. 25, no. 7, pp. 3003–3013, Jul. 2011, doi: 10.1016/j.conbuildmat.2011.01.010.

[6] **T. Harrison,** "Concrete properties: setting and hardening," *Advanced Concrete Technology*, pp. 1–33, Jan. 2003, doi: 10.1016/B978-075065686-3/50251-2.

[7] **A. Kothari, K. Habermehl-Cwirzen, H. Hedlund, and A. Cwirzen,** "A Review of the Mechanical Properties and Durability of Ecological Concretes in a Cold Climate in Comparison to Standard Ordinary Portland Cement-Based Concrete," *Materials*, vol. 13, no. 16, p. 3467, Aug. 2020, doi: 10.3390/ma13163467.

[8] "Abstracts of the 27th Annual Conference of the International Society for Environmental Epidemiology (ISEE), 30 August–3 September 2015, Centro de Convenções Rebouças, São Paulo, Brazil," *Environ Health Perspect*, vol. 123, no. S1, Aug. 2015, doi: 10.1289/ehp.isee2015.

[9] **T. Quoc, B. Le, T. Cuong, and S. Khatir,** "Lecture Notes in Civil Engineering Structural Health Monitoring and Engineering Structures Select Proceedings of SHM&ES 2020." [Online]. Available: http://www.springer.com/series/15087

[10] **N. Su, B. Miao, and F.-S. Liu**, "Effect of wash water and underground water on properties of concrete."

[11] **J. Ortiz, A. Aguado, L. Agulló, and T. García,** "Influence of environmental temperatures on the concrete compressive strength: Simulation of hot and cold weather conditions," *Cem Concr Res*, vol. 35, no. 10, pp. 1970–1979, Oct. 2005, doi: 10.1016/j.cemconres.2005.01.004.

[12] "CHAPTER 2 LITERATURE REVIEW."

[13] **F. A. Aves,** "Impact of Fine and Coarse Aggregates from Distinctive Sources on the Compressive Strength of Concrete," *International Research Journal of Advanced Engineering and Science*, vol. 7, no. 2, pp. 239–242, 2022.

[14] **Y. Esen and A. Kurt,** "Effect of High Temperature in Concrete for Different Mineral Additives and Rates," *KSCE Journal of Civil*

Engineering, vol. 22, no. 4, pp. 1288–1294, Apr. 2018, doi: 10.1007/s12205-017-1224-3.

[15] **J. C. Rikki Reyes *et al.***, "Effects Of Aggregate Shape, Aggregate Size, And Water-To-Cement Ratio on Compressive Strength, Permeability, And Abrasion Resistance of Pervious Concrete Mixture," 2022. [Online]. Available: www.ijprse.com

[16] **A. M. Blash1, A. Altlomate, F. Alatshan, and A. A. A. Al-Sharif,** "Properties of Concrete Produced Using Locally Available Aggregates in Libya," 2017. [Online]. Available: www.ijraset.com1480

[17] **K. Suseela,** "Strength Analysis on Concrete with M-Sand as A Partial Replacement of Fine Aggregate," *International Journal of Civil Engineering and Technology*, vol. 8, no. 12, pp. 583–592, 2017, [Online]. Available: http://iaeme.com/Home/issue/IJCIET?Volume=8&Issue=12http://iaeme.com

[18] **E. Drouet, S. Poyet, and J. M. Torrenti,** "Temperature influence on water transport in hardened cement pastes," *Cem Concr Res*, vol. 76, pp. 37–50, Oct. 2015, doi: 10.1016/j.cemconres.2015.05.002.

[19] **A. Olugbenga**, "Effects of Different Sources of Water on Concrete Strength: A Case Study of Ile-Ife," vol. 6, no. 3, 2014, [Online]. Available: www.iiste.org

[20] **M. A. Assal,** "The effect of mixing water temperature on concrete properties in The effect of mixing water temperature on concrete properties in hot weather conditions hot weather conditions," 2017. [Online]. Available: https://fount.aucegypt.edu/etds/193

[21] **K. Sakr and E. El-Hakim,** "Effect of high temperature or fire on heavy weight concrete properties," *Cem Concr Res*, vol. 35, no. 3, pp. 590–596, Mar. 2005, doi: 10.1016/j.cemconres.2004.05.023.

[22] **R. Farhan Ramadan, H. Ghanem, J. Khatib, and A. Elkordi,** "EFFECT OF HOT WEATHER CONCRETING ON THE MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE-A REVIEW," *BAU Journal – Science and Technology*, vol. 4, no. 1, Dec. 2022, doi: 10.54729/axec5733.

[23] **J. Khan and G. Santha Kumar,** "Influence of binary antifreeze admixtures on strength performance of concrete under cold weather conditions," *Journal of Building Engineering*, vol. 34, Feb. 2021, doi: 10.1016/j.jobe.2020.102055.

[24] "PAGASA." Accessed: Dec. 05, 2023. [Online]. Available: https://www.pagasa.dost.gov.ph/information/climate-philippines?fbclid=IwAR2hjz1XDwJR-xCLKcaFb-LGFRXzSfvOyYOJznRO9eACe8ME3cTraAIf_7c

[25] "Explore – All About Ice – All About Water and Ice Background." Accessed: Dec. 05, 2023. [Online]. Available: https://www.lpi.usra.edu/education/explore/ice/background/allAboutWater/

[26] **N. Ullah,** "EFFECTS OF HOT AND COLD WATER CURRING ON COMPRESSIVE STRENGTH OF CONCRETE," 2020. [Online]. Available: https://www.researchgate.net/publication/342163225

[27] **M. L. Wilson,** "The New ACI 301-20 Goal of Specifications."

[28] **M. H. Naser, F. H. Naser, and A. H. N. Almamoori,** "The effect of water mixing temperature on concrete compressive strength containing different ratios of silica fume," in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing Ltd, Nov. 2020. Doi: 10.1088/1757-899X/928/2/022010.

[29] **S. H. Kosmatka,** "Design and Control of Concrete Mixtures," 2002. [Online]. Available: https://www.researchgate.net/publication/238759453

[30] **Chimdi Gadafa Benti and K. Shantveerayya,** "Experimental Investigation on the Effects of Mixing Hot and Cold Water on the Concrete Properties in Ethiopia," *East African Scholars Journal of Engineering and Computer Sciences*, vol. 3, no. 9, pp. 169–174, Nov. 2020, doi: 10.36349/easjecs.2020.v03i09.001.

[31] **F. Cayanan, O. G. Dela Cruz, A. P. P. Bornales, R. M. Domalaon, and J. B. Marbella,** "A Review of the Effect of Mixing Water Quality on Concrete," in *Lecture Notes in Civil Engineering*, Springer Science and Business Media Deutschland GmbH, 2024, pp. 125–135. Doi: 10.1007/978-981-99-4229-9_12.

[32] **S. Naganathanp and K. N. Mustaphap,** "Effect of Water Temperature on Concrete Properties," 2015.

[33] **S. M. Levy,** "Calculations Relating to Concrete and Masonry," in *Construction Calculations Manual*, Elsevier, 2012, pp. 211–264. Doi: 10.1016/b978-0-12-382243-7.00005-x.

[34] **S. Eskandarsefat,** "Investigation on the effects of mix water temperature on High-Early strength cement concrete properties – An experimental work and a case study," *Journal of Building Engineering*, vol. 20, pp. 208–212, Nov. 2018, doi: 10.1016/j.jobe.2018.07.023.

[35] **R. H. Elvery, E. P. Evans, and A. C. M. I. E. Struct**, "The effect of curing conditions on the physical properties of concrete."

[36] **D. Iskandar, I. Hadijah, S. P. Hadiwardoyo, N. L. Wati, and S. Kurniawan,** "Scrutinizing the Effect of Water Temperature on the Compressive Strength of Recycled Concrete," *Civil Engineering and Architecture*, vol. 11, no. 4, pp. 1668–1678, Jul. 2023, doi: 10.13189/cea.2023.110403.

[37] **N. M. Tuan, Q. Van Hau, S. Chin, and S. Park,** "In-situ concrete slump test incorporating deep learning and stereo vision," *Autom Constr*, vol. 121, Jan. 2021, doi: 10.1016/j.autcon.2020.103432.

[38] **H. Sleiman, A. Perrot, and S. Amziane,** "A new look at the measurement of cementitious paste setting by Vicat test," *Cem Concr Res*, vol. 40, no. 5, pp. 681–686, May 2010, doi: 10.1016/j.cemconres.2009.12.001.

