

FINAL PROJECT

**THE EFFECT OF USING FLY ASH AS SUPPLEMENTARY
CEMENTITIOUS MATERIAL ON CONVENTIONAL
CONCRETE**

**Submitted to Universitas Islam Indonesia Yogyakarta in Fulfillment for
Bachelor of Civil Engineering**



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FACULTY OF CIVIL ENGINEERING & PLANNING
UNIVERSITAS ISLAM INDONESIA
YOGYAKARTA
2024**

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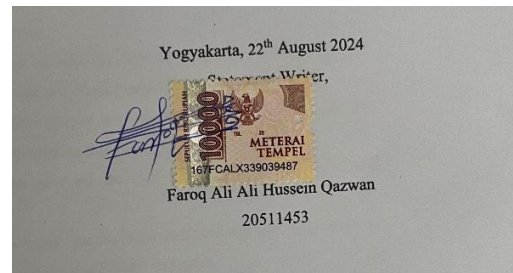


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PLAGIARISM-FREE STATEMENT

I, the undersigned, hereby acknowledge and seriously that the research that I compiled as a requirement for the Civil Engineering Study Program, Faculty of Civil Engineering and Planning of the Islamic University of Indonesia is the result of my work. Certain sections in writing the research that I quoted from the work of other people have written references to the norms, rules, and ethics of writing scientific papers. If later found that all or part of this research is not my work or there is plagiarism in certain parts, I am willing to accept sanctions by the applicable laws.



FOREWORD

Assalamu'alaikum Warrahmatullahi Wabarakaatuh,

Praise the author goes to Allah ` SWT because the author could complete the Final Project Research titled " The Effect of Using Fly Ash as Supplementary Cementitious Material on Conventional Concrete". This Final Project Research is one of the academic requirements for completing undergraduate studies in Civil Engineering Study Program, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.

Many challenges had to be overcome to prepare this Final Project Research, but thanks to feedback, recommendations, and encouragement from a variety of sources, this Final Project Research may now be finished. Related to this, the author would like to express his deepest gratitude to:

1. Mrs. Ir. Yunalia Muntafi., S.T., M.T., Ph.D as the Head of the Civil Engineering Study Program,
2. Mr. Jafar, S.T., M.T. as he was the supervisor of the Final Project and assisted me in carrying out this Final Project Research,
3. My beloved parents who always pray for me, gave encouragement and support so that I could complete this Final Project Research,
4. My beloved sister who gave me the motivation when writing the Final Project Research,
5. Friends in arms and other parties who collaborated and discussed to facilitate the writing of this Final Project Research.

Yogyakarta, 22th August 2024

Statement Writer,

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DEDICATION

This final project is presented to Allah SWT as a form of worship of the author as His servant, to both parents of the author who continue to provide moral and material support to the author, as well as all parties who have accompanied the author's learning process during his undergraduate education.

ABSTRACT

Fly Ash Class C, which is rich in calcium and has strong pozzolanic properties, is commonly used as an additive in concrete to improve its workability and early strength. Typically, fly ash can replace up to 35% of the cement in concrete, depending on the desired performance. This makes it an attractive option, reducing the amount of cement needed while also preventing fly ash waste. In this study, we explored the use of Fly Ash Class C in concrete mixtures, substituting cement at rates of 0%, 20%, 25%, 30%, and 35%, based on the guidelines from SNI-03-2834-2000. The fresh concrete was tested to measure the slump value. The samples were tested at the Construction Material Laboratory of Universitas Islam Indonesia (UII) to measure compressive strength, tensile strength, and elasticity. The concrete was formed into 150 x 300 mm cylindrical specimens for these tests. The results showed that the optimal substitution rate was 20%, which led to the best balance of workability, compressive strength, tensile strength, and elasticity. While adding 20% fly ash enhanced these properties, increasing the fly ash content beyond this point actually weakened the concrete in terms of strength and elasticity.

Keywords: Compressive Strength, Fly Ash Clas C, Modulus of Elasticity, Tensile Strength

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LIST OF NOTATIONS AND ABBREVIATIONS

FA	= Fly Ash
GFA	= Ground Fly Ash
SCM	= Supplementary Cementitious Material
ACI	= American Concrete Institute
SNI	= Standar Nasional Indonesia
CS	= Compressive Strength
GGBFS	= Ground Granulated Blast Furnace Slag
OPC	= Ordinary Portland Cement
STS	= Split-Tensile Strength
SSP	= Steel Slag Powder
ME	= Modulus Elasticity
FS	= Flexural Strength
PCC	= Portland Composite Cement
SSD	= Saturated Surface-Dry
ASTM	= American Society for Testing and Materials
IS	= Indian Standard
USCS	= United States Customary System
SI	= International System

CHAPTER I

INTRODUCTION

1.1 Background

According to American Concrete Institute, 2021. Sustainable concrete is a type of concrete designed to have a reduced environmental impact throughout its lifecycle. It aims to minimize resource consumption, reduce carbon emissions, and promote the use of recycled materials. Sustainable concrete can be achieved through various methods, such as using alternative cementitious materials like fly ash, incorporating recycled aggregates, optimizing mix designs to reduce cement content, and implementing efficient production and construction practices.

One way to achieve sustainable concrete is by substituting a portion of the cement content with supplementary cementitious materials (SCMs) such as fly ash. Fly ash is a by-product of industrial processes, such as coal combustion. It has pozzolanic properties, meaning it reacts with calcium hydroxide in the presence of water to form additional cementitious compounds. By incorporating fly ash into concrete, the reliance on cement, which is a major contributor to carbon dioxide emissions during production, can be reduced.

Effective curing uses a continuous watering method for at least 14 days due to using sika additive is used to accelerate the hardening of concrete by reducing water by up to 15%. Sika has a solution to close cracks in concrete that is practical and easy to apply. Based on research from Maeijer et al (2020), the duration of the concrete curing process is 14 days with variations. The purpose of the treatment is to keep the water from being lost immediately, because the concrete maturation process requires water for its chemical process. It is recommended to let your new concrete slab and beam cure properly for at least 14-21 days after pouring for a long-lasting and solid construction.

According to Metha, 2020, the use of fly ash in concrete offers several benefits. Firstly, it improves the workability and cohesiveness of the concrete mixture, leading to easier placement and compaction. Secondly, it enhances the

long-term strength and durability of concrete by reducing permeability and increasing resistance to chemical attack. Additionally, the incorporation of these SCMs can help mitigate the heat of hydration, reducing the risk of thermal cracking in large concrete structures. The substitution ratio of cement by fly ash can vary depending on the desired properties and performance requirements of the concrete. Generally, fly ash can replace the cement content. However, these ratios may vary depending on factors such as the specific application, mix design, and local regulations.

According to Neville, 2019, the incorporation of fly ash in concrete not only reduces the environmental impact but also offers several technical benefits. These include improved workability, reduced heat of hydration, increased strength, and enhanced resistance to sulfate attack and alkali-silica reaction. Overall, while cement plays a crucial role in concrete construction, its disadvantages necessitate the use of SCMs. These materials offer numerous benefits, including mitigating heat of hydration, reducing costs, enhancing long term strength, improving durability, addressing environmental concerns, and adjusting setting time and workability.

Based on the explanation before, fly ash is the right solution as an alternative material substitute cement. It would be very unfortunate if this fly ash is just wasted without any utilization. Therefore, a study was conducted on the use of fly ash as supplementary cementitious material on conventional concrete.

1.2 Problem Formulation

Based on the background described previously, the problem formulation of this research is as follows.

1. What are the optimal substitution ratios of fly ash in concrete to achieve the desired properties and performance, such as slump test, modulus of elasticity, compressive strength, and tensile strength?
2. What is the influence of fly ash as supplementary cementitious material for conventional concrete on slump test, modulus of elasticity, compressive strength, and tensile strength?

1.3 Research Objectives

Based on the problem formulation, the research objectives are as follows.

1. To determine the optimal fly ash substitution ratio in concrete to achieve the desired properties and performance, such as slump test, modulus of elasticity, compressive strength, and tensile strength.
2. To evaluate the influence of fly ash as supplementary cementitious material for conventional concrete on slump test, modulus of elasticity, compressive strength, and tensile strength compressive strength, and tensile strength.

1.4 Research Benefits

This research aims to develop sustainable concrete mixes using fly ash, which will have several benefits, including:

1.4.1 Benefits for Sustainable Concrete Development

1. Reduced environmental impact:
Fly ash can be used to replace a portion of cement in concrete, which can significantly reduce the environmental impact of concrete production.
2. Conserved natural resources:
Fly ash is a by-product of other industrial processes, so using it in concrete reduces the need to extract and process new natural resources.
3. Improved concrete performance:
Fly ash can improve the workability, durability, and strength of concrete.
4. Reduced costs:
Fly ash is often less expensive than cement, so using it can reduce the cost of concrete production.

1.4.2 Benefits for the Development of Science

1. This research can be used as a theoretical reference regarding the effect of using fly ash as Supplementary cementitious material.

2. This research is a development of insight into the mix design of fly ash as an experimental method.
3. This research can be used as a reference in future research related to the fly ash as supplementary cementitious material.

1.5 Research Limitation

Based on the problem formulation, objectives, and benefits, the research limitations are as follows.

1. The research will be carried out using an experimental method to find the optimum value of compressive strength, tensile strength, and modulus elasticity on the replacement percentage of fly ash for cement.
2. Variability of fly ash:

Fly ash is a by-product of industrial processes, so their availability and quality can vary depending on the region and the specific industry. This can make it difficult to develop and use concrete mixes that consistently achieve the desired properties and performance. When used in portland cement, Class C fly ash can be used as a portland cement replacement ranging from 20-35% of the mass of cementitious material. Hence, this research will use fly ash Class C.

3. According to American Concrete Institute (ACI) Committee 226, "Guide to the Use of Fly Ash in Concrete," ACI 226R-19, the specimen shape is a cylinder measuring 150 x 300 mm. The specimens tested in 14 days old, because of using chemical additive (sika) that accelerates time setting. Class C fly ash replaces 15%-35% of Portland cement in concrete (up to 50% for use in mass concrete placements.), making it stronger and eco- friendly. The substitution ratio is typically 1:1 to 1.5:1 (fly ash to cement by weight).
4. The methods that are used for mix design is SNI 03-6468-2000 for water, cement, fine aggregate, fly ash, and coarse aggregate. Compressive strengths were tested according to the ASTM C109 at the 14 days old. Tensile strengths were determined according to ASTM C109 at the 14 days old by applying a

load over the diameter of the concrete cylinder Concrete durability is defined according to Concrete Terminology by American Concrete Institute (ACI) 562.

5. The coarse and fine aggregate is used from Pusat Inovasi Material Vulkanis Merapi UII.

CHAPTER II

LITERATURE REVIEW

2.1 Previous Research

There are many similarities and differences between the research carried out and previous research, including research methods, objects studied, and variables studied. Previous research is consulted to prevent current research from failing, and the following studies are used as references in this research.

1. Influence of a steel slag powder-ground fly ash composite supplementary cementitious material on the chloride and sulphate resistance of mass concrete by Han et al., (2020)

In this research the authors explained about Ground Fly Ash (GFA) and Steel Slag Powder (SSP) were applied to bulk concrete to investigate its durability, temperature rise during cement hydration, and resistance to sulfate and chloride attack. This study replacing SSP with GFA increases the hydration degree of concrete, reduces the $\text{Ca}(\text{OH})_2$ (CH) content and its carbonization, and refines the pore structure of concrete, especially under high temperature curing conditions.

Replacing OPC with SSP has a negative effect on the strength and durability of concrete, but replacing SSP with GFA can offset this negative effect due to the higher pozzolanic activity of GFA. The improvement effect is better under high temperature curing conditions and subsequent aging (Pan et al., 2019). The five concrete mix ratios are shown in Table 2.1. The specific samples were designated C1, C2, C3, C4, and C5.

Table 2. 1 Mix Proportions of GFA and SSP

Mix Proportions (Kg/m³)	C₁	C₂	C₃	C₄	C₅
OPC	400	240	240	200	200
SSP	0	160	100	200	120
Fly Ash	0	0	60	0	80
Fine aggregate	780	780	780	780	780
Coarse aggregate	1040	1040	1040	1040	1040
Water	1180	1180	1180	1180	1180

Source: Han et al., (2020)

The results show that replacing SSP with GFA increases the 14 day strength of the concrete and can also increase the 90-day strength over that of pure OPC concrete under standard curing conditions. Furthermore, replacing SSP with GFA under high temperature curing conditions could result in 14 day and 90-day strengths higher than that of pure OPC concrete. The composite of SSP and GFA could maintain moderate processability's and GFA effectively reduce the temperature rise during concrete curing.

2. Influence of slag and fly ash as supplementary cementitious materials on properties of concrete by Adewuyi et al., (2020)

This study concerns the effects of different individual and total contents of fly ash and Ground Granulated Blast Furnace Slag (GGBFS) as CEM-II auxiliary materials on the properties of fresh concrete and hardened concrete. A control mixture without fly ash or GGBFS was used in this study. FA and GGBFS cementitious materials are supplemented by replacing 30% of Ordinary Portland Cement (OPC) individually or in combination.

In this study, the concrete mixture was created with a rotating drum mixer. The aggregate and cement were placed in a drum and partially mixed with water to ensure a good bond between the cement paste and the aggregate.

Here's the mix design in Table 2.2:

Table 2. 2 Mix Proportions of GGBFS

Mix Proportions	C0	C1	C2	C3	C4	C5
Compaction factor	0.89	0.89	0.88	0.85	0.85	0.86
Mean Slump (mm)	55	67	65	62	58	53
Total constituents (kg/m ³)	2465	2465	2465	2465	2465	2465
Coarse aggregates (kg/m ³)	1088	1088	1088	1088	1088	1088
Fine aggregates (kg/m ³)	801	801	801	801	801	801
Water (kg/m ³)	192	192	192	192	192	192
GGBFS (kg/m ³)	0	115	77	57.5	38	0
FA (kg/m ³)	0	0	38	57.5	77	115
Cement (kg/m ³)	384	269	269	269	269	269

Source: Adewuyi et al., (2020)

Concrete mixture C1 consists of mixed cement of 0FA/30GGBFS (0% fly ash and 30% GGBFS), C2 consists of 10FA/20GGBFS, C3 consists of 15FA/15GGBFS, C4 consists of 20FA/10GGBFS C5 was constructed from 30FA/0GGBFS. This study confirmed the potential of fly ash and GGBFS as admixtures in CEM-II mixed concrete in both plastic and hardened states.

The results show, the workability of control concrete and cement-mixed concrete was found to be within the recommended range for ordinary concrete and reinforced concrete. The tensile strength of all blended cement concrete mixtures on day 28 was higher than the control value.

- Investigate the potential use of fly ash, a common industrial by-product, as a cementitious additive in concrete by Li et al., (2022)

This research shows the effect of adding fly ash on the mechanical properties,

particularly compressive strength (CS) and split-tensile strength (STS), durability, and microstructure of cement compounds. In addition, it also discusses the main limitations and factors influencing these characteristics.

Fly ash can enhance material performance and environmental sustainability when used in SCM but using more than the recommended 20% of the compound may risk its overall safety. When FA is added, STS may decrease at lower curing ages but improve at higher curing ages. Lower replacement levels of FA can lead to an improvement in flexural strength (FS), whereas greater levels of FA can have the opposite effect. By reducing interconnecting gaps and reducing chloride ion penetration, FA's smaller particle size can improve cementitious composites' durability.

This study shows, the mechanical characteristics of cementitious composites are influenced by the type, chemical composition, and quantity of fly ash (FA). Using FA as an additional cementitious material might lessen its impact on the environment and promote sustainable construction.

4. Durability and Microstructure Characteristics of Concrete with Supplementary Cementitious Materials by Chari et al., (2022)

The authors studied the microstructural properties of concrete using SCM to improve product durability and extend the service life of concrete structures. The physical properties and chemical composition of OPC, Granulated blast furnace slag (GGBS), and fly ash were identified, and three different experiments were conducted to determine their resistance to chloride ion penetration and corrosion processes.

The results show, that Concrete cubes were tested for accelerated corrosion with rapid onset of the corrosion process over a period of 56 days. Replacing 30% of M40 and M60 grade fly ash and 30% of its GGBS with cement will take longer for corrosion and cracking to occur, increasing the damage period of the samples. Replacement of 20% fly ash and 20% GGBS with cement resulted in high compressive strength. The alternative SCM for OPC was 0, 40, 50, and 60 percent of the cement weight, and the water binder ratio was adopted

as 0.40 for M40 grade concrete and 0.28 for M60 grade concrete. The mix design shown in Table 2.3.

Table 2. 3 Mix Design of Concrete

Grade Name	Water (Kg/ m³)	Cement (Kg/ m³)	Fly Ash (Kg/ m³)	GGBS (Kg/ m³)	Aggregates (Kg/ m³)
M40-0%	157,73	415,07	0	0	691,33
M40-20%	157,73	249,904	83,01	83,01	675,54
M40-25%	157,73	207,54	103,77	103,77	671,60
M40-30%	157,73	166,03	124,52	124,52	604,80
M60-0%	157,73	250,00	208,00	0	580,48
M60-20%	157,73	294,80	131,60	131,60	574,00
M60-25%	157,73	329,00	164,50	164,50	567,50
M60-30%	157,73	263,22	197,42	197,42	567,00

Source: Chari et al., (2022)

5. Effect of ultra-fine fly ash on concrete performance and durability by De Maeijer et al., (2020)

This research investigates the Ultrafine Fly Ash (FA2) and Separated Fly Ash (FA1), a new by-product obtained through a dry seal separation process, was investigated as a cement substitute in concrete. The influence of ultrafine fly ash on material properties was investigated using an upscaling method considering the properties of paste, mortar, and concrete.

Results at the paste and mortar level showed that increasing the ultrafine offly ash (FA2) contributed to improving the workability of the mixture. In the case of CEMI, the compressive strength of the concrete with 25% FA2 replacement was already comparable to that of the reference concrete with 0% replacement after 14 days. In CEMIII, the compressive strength of the concrete mixture with 15% FA1 and 25% FA2 replacement reached the reference concrete value 91 days after construction.

Table 2. 4 Mix Design FA2 and FA1

Category	R4	Cement (Kg/ m³)	Fly Ash1 (Kg/ m³)	Fly Ash2 (Kg/ m³)
CEM-REF	162	360	-	-
CEM-FA1-15%	162	306	54	-
CEM-FA2-25%	162	270	-	90
CEM-FA1+FA2- 25%	162	270	36	54

Source: De Maeijer et al., (2020)

The results show, that regarding durability, replacing cement with ultrafine fly ash (FA2) has a positive impact on resistivity, chloride migration coefficient, and alkali-silica reaction (ASR), but has a negative impact on carbonation resistance.

2.2 Research Review

Based on the five studies that have been explained that there are differences between previous research and this research which is the originality for research. In this study, author developed a mix design according to SNI 03-6468-2000 for water, cement, fine aggregate, fly ash, and coarse aggregate. Based on Han et al., (2020), this study used ground fly ash (GFA) and mix with Steel slag powder (SSP) as replacing the OPC for the mix design. The results showed that replacing OPC with SSP has a negative effect on the strength and durability of concrete, but replacing SSP with GFA can offset this negative effect due to the higher pozzolanic activity of GFA. The other research based on Adewuyi et al., (2020) and Chari et al., (2022) used fly ash and Granulated Blast Furnace Slag (GGBFS) to test the durability of the concrete. The research shows replacement of 20% fly ash and 20% GGBS with cement resulted in high compressive strength.

Based on the previous results, this research will be carried out using an experimental method to find the optimum value of compressive strength, tensile strength, and modulus of elasticity on the replacement percentage of Class C fly ash

for cement with the dimension of concrete shape is a cylinder measuring 150 x 300 mm. Class C fly ash replaces 15%-30% of Portland cement in concrete (up to 50% for use in mass concrete placements.), making it stronger and eco- friendly. The substitution ratio is typically 1:1 to 1.5:1 (fly ash to cement by weight) according to American Concrete Institute (ACI) Committee 226, "Guide to the Use of Fly Ash in Concrete," ACI 226R-19. Compressive strengths were tested according to the ASTM C109. Tensile strengths were determined according to ASTM C109 by applying a load over the diameter of the concrete cylinder Concrete durability is defined according to Concrete Terminology by American Concrete Institute (ACI) 562.

Table 2. 5 Comparison of Previous Research

No	Researchers' Names and Publication's Year	Comparison		Mix Proportion	Results
		Similarities	Differences		
1	Han, X., Feng, J., Shao, Y., & Hong, R. (2020)	1. Ground Fly Ash(GFA) 2. Compressive strength	1. Steel Slag Powder(SSP) 2. Durability	1. OPC (5,88%). 2. SSP (3,53%). 3. Fly Ash (2,35%). 4. Fine aggregate (22,94%). 5. Coarse aggregate (30,59). 6. Water (34,71%).	The results showed that replacing OPC with SSPhas a negative effect on the strength and durability of concrete, but replacing SSP with GFA can offset this negative effect due to the higher pozzolanic activity of GFA. The improvement effect is better under high temperature curing conditions and subsequent aging.

Continued Table 2.5 Comparison of Previous Research

No	Researchers' Names and Publication's Year	Comparison		Mix Proportion	Results
		Similarities	Differences		
2	Adewuyi, A. P., & Mojakgesa, K. T. (2020)	1. Fly ash 2. Tensile Strength	1. Granulated Blast Furnace Slag (GGBFS) 2. Compressive Strength 3. Durability	1. Coarse aggregates (44,14%). 2. Fine aggregates (32,49%). 3. Water (7,79%). 4. GGBFS (1,54%) 5. FA (3,12%) 6. Cement (10,91%).	As a result, the workability of control concrete and cement-mixed concrete was found to be within the recommended range for ordinary concrete and reinforced concrete. The tensile strength of concrete increased with cementitious materials as the elapsed time of curing by immersion in water increased.

Continued Table 2.5 Comparison of Previous Research

No	Researchers' Names and Publication's Year	Comparison		Mix Proportion	Results
		Similarities	Differences		
3	Li, G., Zhou, C., Ahmad, W., Usanova, K. I., Karelina, M., Mohamed, A. M., & Khallaf, R. (2022)	1. Fly Ash 2. Compressive Strength (CS) 3. Split-Tensile Strength (STS)	1. Flexural strength 2. Durability	1. Fly Ash 2. Fine aggregate 3. Coarse aggregate 4. Water	In addition to the environmental benefits, the addition of fly ash as a supplementary cementitious material also has a positive effect on material properties. However, there is an optimal confinement level (up to 20%) above which FA negatively affects the performance of composites.

Continued Table 2.5 Comparison of Previous Research

No	Researchers' Names and Publication's Year	Comparison		Mix Proportion	Results
		Similarities	Differences		
4	Chari, K. B., & Rao, V. R. (2022)	1. Fly Ash 2. OPC	1. Microstructure 2. Granulated Blast-Furnace Slag 3. Durability	1. Water (12,63%). 2. OPC (20,01%). 3. Fly Ash (6,65%). 4. GGBS (6,65%). 5. Aggregates (54,08%).	Replacing 30% of M40 and M60 grade fly ash and 30% of its GGBS with cement will take longer for corrosion and cracking to occur, increasing the damage period of the samples. Replacement of 20% fly ash and 20% GGBS with cement resulted in high compressive strength.

Continued Table 2.5 Comparison of Previous Research

No	Researchers' Names and Publication's Year	Comparison		Mix Proportion	Results
		Similarities	Differences		
5	De Maeijer, Patricia Kara, Bart Craeye (2020)	1. Compressive Strength 2. Durability 3. Density	1. Ultrafine Fly Ash 2. Density	1. Water 2. Separated Fly Ash (FA1) 3. Ultrafine Fly Ash (FA2) 4. Portland cement (CEMI) 5. Slag cement (CEMII)	Regarding durability, replacing cement with ultrafine fly ash (FA2) has a positive impact on resistivity, chloride migration coefficient, and alkali-silica reaction (ASR), but has a negative impact on carbonation resistance.

Table 2. 6 Research Scheme to Be Carried Out

Research Title	Research Objective	Research Methodology
The Effect of Using Fly Ash as A Supplementary Cementitious Material on Conventional Concrete	This research was carried out to evaluate the influence of fly ash as supplementary cementitious material on conventional concrete, and determine the optimal substitution ratio of fly ash in concrete to achieve the desired properties and performance, such as slump test, compressive strength, tensile strength, modulus of elasticity tests.	This research was carried out in a mixed manner between cement, fine aggregate and coarse aggregate of 1:2:3 and CWF 0.54. Variations in the substitution of class C of fly ash for cement were carried out at levels of 0%, 20%, 25%, 30% and 35%. The tests carried out were compressive strength, tensile strength and modulus of elasticity and were carried out when the concrete cylinder were 14 days old.

2.3 Authenticity of Research

Based on the results of previous research according to Table 2.1, this research will carry out several differences attached in Table 2.6, including the use of fly ash in this research by substituting class C of fly ash for cement carried out simultaneously in the concrete mixture with a variation of 0%, 20 %, 25%, 30%, 35% for class C of fly ash as cement. The tests carried out were compressive strength, tensile strength and modulus of elasticity and were carried out when the concrete cylinder were 14 days old.

CHAPTER III

THEORETICAL BACKGROUND

3.1 Introduction To Fly Ash

3.1.1 Definition of Fly Ash

According to Yousuf, 2020, Fly Ash is ash from coal burning residue that is widely used to help soil stability. Sondakh et al., 2020, stated that the high calcium content in fly ash can help the soil structure become denser, so it is also called a substitute for cement because it has the same content. Fly Ash is divided into two types of classification, namely Fly Ash Class C and Fly Ash class F. Class C Fly Ash is coal combustion ash that has a minimum content of 70% silicon dioxide, aluminium oxide, and ferroxide. Class F Fly Ash is coal combustion residual ash that has a minimum content of 50% silicon dioxide, aluminium oxide, and ferroxide.

In Alterary, 2021, Fly ash is part of the residue burning coal in the form of particles smooth amorphous. The ash is a material inorganic formed from changes in materials minerals (mineral matter) due to processes combustion. The process of burning coal in steam generating unit (boiler) will form namely fly ash and bottom ash. The composition of fly ash consists of 10-20% base ash and 80-90% in the form of fly ash. Fly ash captured with electric precipitator before discharging to air through the chimney.

3.1.2 Physical Properties

According to ACI Committee 226, it is explained that Fly ash has details that smooth, sieve No. 325 (45 milli micron) 5-27 %. Fly Ash is generally shaped solid or hollow ball. Fly ash has density 2.23 gr/cm³, with ambient moisture content 4%. Based on Nayak, 2022, Fly ash has a specific gravity between 2.15-2.6 and gray black in color. Particle size of fly ash from combustion Bituminous coal smaller than 0.075 mm. Fly ash has a specific area of 170-1000 m²/kg. Average particle size of fly ash coal sub bituminous type 0.01 mm – 0.015 mm, the surface area is

1-2 m²/g, The particle form is mostly spherical, i.e. partial large spherical shaped, thus producing better squeezing.

3.1.3 Chemical Properties

According to Alterary, 2021, the chemical properties of fly ash are influenced by the type of coal burned, storage techniques, and handling. Lignite coal burning and Sub-bituminous produce fly ash with more calcium and magnesium oxide. The main Component of fly ash coal is silica (SiO₂), alumina (Al₂O₃), iron oxide (Fe₂O₃), calcium (CaO); and magnesium, potassium, sodium, titanium, and Sulphur in the amount that little.

3.1.4 Fly Ash Mix Design

According to Nayak, 2022, Fly ash is used as a supplementary cementitious material (SCM) for producing Portland cement concrete. The use of fly ash as SCM contributes to the properties of hardened concrete through pozzolanic and/or hydraulic activity. Fly ash is used in concrete at mass fractions of 15–25% and high doses of 40–60% for structural purposes.

According to Yousuf, 2020, Fly ash inclusion can have a significant impact on the properties of fresh concrete and the durability of hardened concrete. The extent to which fly ash influences the properties of concrete depends on the composition and proportions of other components in the mixture, the type and size of the concrete, the exposure conditions during and after pouring, and the method of construction. Therefore, there is no single-level replacement that is best suited for all applications. Fly ash consists of fine powder particles, mainly spherical, solid, or hollow, and mainly amorphous in nature. Generally, the specific gravity of coal ash is around 2.0, but it varies widely between 1.6 and 3.1. This variation is due to a combination of several factors, including particle shape, gradation, and chemical composition. Here are the formulas for mix design proportion.

$$\text{Margin (M)} = 1.64 \times \text{Standar Deviation (Sd)} \quad (3.1)$$

$$\text{Average Compressive Strength of Concrete (f'cr)} = f'_c + M \quad (3.2)$$

$$\text{Free Water Content} = \frac{2}{3}W_h + \frac{1}{3}W_k \quad (3.3)$$

$$\text{Used Percentage of fine aggregate} = \frac{\text{Upper Limit} + \text{Lower Limit}}{2} \quad (3.4)$$

$$\begin{aligned} &\text{Specific gravity of the combined aggregate} \\ &= \left(\frac{\text{Used percentage of fine aggregate}}{100} \times \text{Specific gravity of fine aggregate} \right) + \\ &\left(\frac{\text{Used percentage of coarse aggregate}}{100} \times \text{Specific gravity of coarse aggregate} \right) \quad (3.5) \end{aligned}$$

$$\begin{aligned} &\text{Combined aggregate proportions} = \text{Concrete weight} - \text{cement content} - \text{water} \\ &\text{content} \quad (3.6) \end{aligned}$$

3.1.5 Mechanical Properties

Based on the study by Fode et al., 2023, partial replacement of fly ash in usually Portland cement has a positive effect on the mechanical and durability properties of cement composites. Here's the mechanical properties of fly ash, shown in Tabel 3.1:

Table 3. 1 Mechanical Properties of Fly Ash

Dose Range	W/C	Curing Time	Optimum Compressive Strength (Age, days)	Optimum Split Tensile Strength (Age, days)	Optimum Flexural Strength(Age, Days)	Durability (Water Absorption)
0, 5, 10, 15, 20	-	28, 60, 90	28, 60, 90	-	-	-
0, 10, 20, 30	0.45	7, 28	7, 28	-	-	-
0, 10, 20, 30, 40, 50	-	7, 24, 21, 28	7, 14, 21, 28	7, 14, 21, 28	-	-
0, 10, 30	0.45	3,7,28	3, 7, 28	7, 28	7, 28	-
0, 15, 30, 45	0.55	3, 7, 14, 28	3, 7, 14, 28	3, 7, 14, 28	-	-
0, 10, 20	0.34	7, 28	7, 28	7, 28	7, 28	-
0, 5, 10, 15	0.50	7, 28, 56, 90	7, 28, 56, 90	6, 90	-	-
0, 10, 30, 50, 70	0.30	28, 56	28, 56	28, 56	-	Decrease
0, 5, 10, 15, 20, 25	0.50	7, 28, 90,	7, 28, 90, 180	7, 28, 90, 180	-	-
0, 5, 10	0.65	28, 100, 130	100, 130	-	-	Decrease

3.2 Introduction To Concrete

3.2.1 Definition of Concrete

According to Zhou et al., 2022, concrete is defined as “a mixture of aggregate, cement, and water that hardens” (ISO 6707 standard) and “a composite material consisting essentially of a binder in which particles or fragments of aggregate are embedded”. Specifically, concrete is made by mixing cement, water, fine aggregate (sand), and coarse aggregate (gravel and crushed stone), and the cement and water harden through a chemical reaction (hydration), and the non-reactive aggregate hardens.

According to Gamal et al., 2021, the materials that are often added to the previous mix are additives, which are fine powders that replace some of the cement, and small amounts of chemicals called admixtures, which primarily improve some properties. The main factors for the widespread use of concrete are formability, early hardening, high initial compressive strength, development of the necessary properties through admixtures for use in complex and adverse situations, and durability.

Furthermore, Bustillo, 2021, mentioned that the properties of concrete can be extensively controlled using appropriate components and special mechanical, physical, and chemical processing techniques. Concrete meets a wide range of requirements in terms of consistency from dry to very fluid or compressive strength from 0.5 MPa to more than 800 MPa. This wide range of value cannot be achieved with other building materials.

3.2.2 Workability of Concrete

Bustillo, 2021, mentioned that concrete is made by mixing cement, aggregate, water, and admixtures or admixtures (if necessary). These carefully measured ingredients are mixed in a mixer. Generally, the mixture is about 10-15% cement, 60-80% aggregate, and 15- 20% water. Air infiltration can be around 5-8% in many concrete mixes.

Abdalla, 2022, mentioned that workability can be defined as the properties of fresh concrete that affect its ease of mixing, placement, setting, and drawing while maintaining homogeneity during operation. When characterizing constructability, the specific conditions of the concrete structure to be manufactured must be considered. The concept of consistency is often used to characterize treatability, as it is a relative parameter primarily defined by consistency. Workability is not an inherent property of concrete and takes into account other factors such as local conditions and how concrete is transported and compacted.

According to Dvorkin et al., 2024, aggregate is the component of concrete that plays the most role in determining its size. Aggregates for concrete are hard mineral granules that are close to round in shape with grain sizes ranging from 0.063 mm to 150 mm. Aggregates according to their origin can be divided into two, namely natural aggregates obtained from rivers and artificial aggregates obtained from broken stones. In concrete mixtures, aggregates are the reinforcing materials (strengter) and filler, and occupy 60% — 75% of the total volume of concrete. Aggregate is a granular material such as gravel, sand, furnace scale, and crushed stone and is used together with a binding medium to form a hydraulic cement concrete or mix. Here's the formula for aggregate.

$$\text{Retained Weight (\%)} = \frac{\text{Retained Weight (gr)}}{\text{Sumation of Retained weight (gr)}} \times 100\% \quad (3.7)$$

$$\text{Cumulative Retained Weight (\%)} = \text{Retained Weight (\%)} + \text{Cumulative Retained Weight (\%)} \quad (3.8)$$

$$\text{Cumulative Passing Weight (\%)} = 100\% - \text{Cumulative Retained Weight (\%)} \quad (3.9)$$

3.2.3 Density of Concrete

According to Bustillo, 2021, measuring concrete density is very important in managing fresh concrete, especially when using light or heavy aggregates. It is also used to check whether the components of concrete are in the required proportions. Fresh concrete density can be defined as the mass (kilograms) per cubic meter of mostly compacted fresh concrete, including any remaining voids. For the same

amount of cement and aggregate, lower fresh concrete density will result in lower concrete strength.

According to Standard EN 206-1 and Sikora et al., 2020, density decreases as moisture and porosity increase. The density of fresh concrete decreases as water content and porosity increase. The density of fresh concrete increases as the cement content increases, the water- cement ratio decreases, and the porosity decreases. hardened concrete can be classified into three main types according to oven dry density.

- a. Regular concrete: concrete with an oven dry density of more than 2000 kg/m³;
- b. Lightweight concrete: concrete with an oven dry density of 800 kg/m³ or more and 2000 kg/m³ or less; and
- c. Weight Concrete: Oven-dried Concrete density not less than 2600 kg/m³.

3.3 The Use and Effect of Fly Ash in Concrete

3.3.1 General Properties

According to Chen et al., 2019, fly ash remains one of the most used cement admixtures (SCMs) worldwide. Fly ash is commonly used to reduce permeability, improve resistance to alkali-silica reactions and sulfate attack, and reduce the heat of hydration of mass concrete elements. The production of concrete is characterized by the high demand for energy and raw materials. The construction, maintenance, and demolition of engineering structures generate excessive amounts of environmentally hazardous waste, which is expensive to dispose of. For this reason, alternative reusable materials are used that improve the mechanical properties of concrete and studied as an effective solution to alleviate problems related to environmental pollution.

According to Munoz., et al, 2023, fly ash is used in concrete were mainly analyzed to study methods and designs to obtain the optimal proportion of 5, 10 and 15%, that fly ash improves the mechanical and physical properties of concrete and the optimal addition level is 10% as a replacement for regular Portland cement in plain concrete.

3.3.2 Compressive Strength

According to Joel, 2020, a good compressive strength of concrete with large quantities of Class C fly ash can be achieved by maintaining a cement density of 400 kg per cubic meter with water-cement ratio (W/C) in the range of 0.35 to 0.45. The strength of fly ash mixed concrete under compression gradually improved over time, but the normal concrete strength ended after 56 days of curing.

Hashmi, 2020, mentioned that by developing green concrete using fly ash, environmental pollution and cement consumption can be minimized. Replacing some of the cement particles in concrete with F-grade fly ash decreased the concrete's 14 day compressive and tensile strength, flexural strength, modulus of elasticity, and abrasion resistance. Concrete optimization means obtaining a concrete mixture that is economical and meets the required concrete properties such as strength, durability, and workability. Differences in water binder ratio, coarse aggregate to total aggregate ratio, and fly ash ratio are important factors that influence the strength of concrete. Higher w/c ratios reduce the strength of concrete, while lower w/c ratios generally result in better strength. For specific optimization, different approaches using experimental, analytical, or statistical methods have been used so far.

3.3.3 Split Tensile Strength

The tensile strength of concrete is approximately one-tenth of its compressive strength. This is determined according to ASTM C109 using UTM (Universal Testing Machine) by applying a load over the diameter of the concrete cylinder. While the compressive strength of concrete is most important in the design of concrete structures, the tensile strength of concrete is a fundamental property in estimating the crack strength of structures and analyzing the failure process of concrete.

3.3.4 Slump Test

The slump test is a widely used method to assess the workability of fresh concrete and is suitable for all types of concrete mixes. The test was performed in accordance with ASTM C143, which outlines the standard procedure for a slump test. In this method, freshly mixed concrete is placed into a slump cone (also known as Abrams cone) in three layers, each layer being tamped 25 times with a tamping rod to ensure proper compaction. Once filled, the cone is carefully lifted vertically, allowing the concrete to slump. The vertical distance between the top of the cone and the displaced original height of the concrete is measured. This slump value indicates the concrete's consistency and workability, essential for ensuring the quality and strength of the mix. The test helps determine whether the concrete mixture meets the desired specifications before it is used in precast manufacturing or delivered to the construction site. The slump test procedure can be seen in Figure 3.1.



Figure 3. 1 Slump Test Using Abrams cone

CHAPTER IV EXPERIMENTAL METHOD

4.1 Object of Study

In this study, the object of research is class C fly ash which will be analyzed on the influence of fly ash as a cement substitute on concrete quality. And calculations regarding optimal substitution ratios of fly ash are in concrete to achieve the desired properties and performance, such as strength, durability, and workability.

4.2 Data Type

4.2.1 Primary Data

Primary data is data obtained directly from observation. The samples production and the samples strength tests are in Construction Material Laboratorium UII. A total of 50 samples were produced for the study. Out of these, 45 samples were tested, with 15 samples allocated for each test of compressive strength, tensile strength, and modulus of elasticity. The remaining 5 samples were reserved as a safety factor, to be used if necessary.

4.2.2 Secondary Data

Secondary data is data collected from previous research, namely literature study data, journals, theses, and information obtained from internet media. Secondary data is useful as a basis for strengthening studies in research utilization of the use of fly ash for concrete materials.

4.3 Data Collection

The data collection method is a way of procuring primary data and secondary data for research purposes. This data collection is carried out to obtain data or information related to the problem to be studied. The research will be carried out using an experimental method to find the optimum value of compressive strength

and tensile strength on the replacement percentage of fly ash for cement. The concrete shape is a cylinder measuring 150 x 300 mm. The materials for data collection in this research are follows.

4.3.1 Class C Fly Ash

The use of fly ash as partial replacement of cement in the production of environmentally friendly concrete is now an established fact. Fly ash is a by-product of industrial processes, so their availability and quality can vary depending on the region and the specific industry. This can make it difficult to develop and use concrete mixes that consistently achieve the desired properties and performance. Class F gains slow strength, high long-term strength, and good workability, while class C of fly ash -based alkali- activate cement in a high-pressure and high-temperature CO₂ environment. Hence this research will use class C of fly ash.

The use of class C of fly ash lowers the workability (slump value) by 26% and entrained air by 33% of the fresh concrete. The substitution ratio is typically 1:1 to 1.5:1 (fly ash to cement by weight) according to American Concrete Institute (ACI) Committee 226, “Guide to the Use of Fly Ash in Concrete,” ACI 226R-19.

Class C of fly ash is specified by ASTM C 618 and is obtained from anthracite and bituminous coals. On the other hand, the use of class C and class F of fly ash enhanced the later age compressive strength of the resulting mixtures by 23% and 35%, respectively in comparison to control concrete mixture. Class C fly ash has a lower calcium content than Class C of fly ash and additional chemical requirements are listed in table 4.1.

Table 4. 1 Chemical Requirement

Property	ASTM C618 Requirements %
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ , min	50
SO ₃ , max	5
Moisture content, max	3
Loss on Ignition, max	6

Source: Alteraty (2021)

In this study, when used in Portland cement, Class C fly ash can be used as a replacement for Portland cement up to 20-35% of the mass of the cementitious material. Class C fly ash is designated in ASTM C 618 and originates from sub-bituminous and lignite coals. Its composition consists mainly of calcium, alumina, and silica with a lower loss on ignition (LOI) than Class F fly ash. As a replacement for Portland cement, Class C fly ash offers the following advantages compared to unmodified Portland cement:

- a. Class C fly ash-based cement.
- b. Increased resistance to alkali silica reaction (ASR) when >15% is added.
- c. Less heat generation during hydration
- d. Increased pore refinement
- e. Decreased permeability.
- f. Decreased water demand.
- g. Decreased cost (\$80/ton for portland cement vs. \$30/ton for fly ash).
- h. This class C of fly ash, in addition to having pozzolanic properties, it has also some cementitious properties.
- i. Some Class C fly ashes may contain lime contents higher than 10%.
- j. High levels of high-calcium (Class C) fly ash have been used to control the temperature rise in mass concrete foundations.

4.3.2 Cement

The OPC (Ordinary Portland Cement) of 43 grades was used in this research. This research used high-volume fly ash concrete as a high structural strength concrete with a significantly higher total amount of binder than ordinary strength concrete. For example: at 14 days testing age, 42 MPa compressive strength of High-Volume Fly Ash Concrete is like 42 compressive strengths of OPC concrete. The 14 days compressive strength and the specific surface of OPC used in this research was 60N/mm³ and 295 m²/kg respectively.

4.3.3 Aggregates

When used in Portland cement, Class C fly ash can be used as a replacement for Portland cement up to 20-35% of the mass of the cementitious material. Class C fly ash is designated in ASTM C 618 and originates from subbituminous and lignite coals. Its composition consists mainly of calcium, alumina, and silica with a lower loss on ignition (LOI) than Class F fly ash. As a replacement for Portland cement, Class C fly ash offers the following advantages compared to unmodified Portland cement:

a. The coarse aggregates

Were combined by the crushed basalt rock of maximum nominal size of 19 mm, conforming to IS: 383 were used. The mix proportions of coarse aggregate for concrete (C1-C5) are 780 Kg/m³. The absorption is 0.5 to 4% with dry rodded bulk density is 1280 to 1920 Kg/m³. Then the surface moisture content for coarse aggregate is 0 to 2%.

b. The fine aggregates

Were by the river sand and crushed sand of maximum nominal size of 4.75 mm, conforming to requirements of IS: 383. The mix proportions of fine aggregate for Concrete (C1-C5) are 1180 Kg/m³. The fineness modulus of fine aggregate in 2.0 to 3.3. The absorption is 0.5 to 4% with bulk specific gravity (relative density) 2.30 to 2.90. Then the surface moisture content for fine aggregate is 0 to 10%.

4.3.4 Water

The water is used for chemical hydration reaction with cement. This is used well water from Pusat Inovasi Material Vulkanis Merapi UII. The performance of concrete with mineral additives was achieved with water curing. Each portion of the concrete mixture was created with a rotating drum mixer. The aggregate and cement were placed in a drum and partially mixed with water to ensure a good bond between the cement paste and the aggregate.

4.4 Mix Design

This study adopts a mix design model. Five variables were used: 0%, 20%, 25%, 30%, and 35% fly ash as a substitution ratios of cement. The mix design shown in Table 4.2 is as follows.

Table 4. 2 Mix Design Proportions

Sample	Volume	Variation Fly ash	Fine Aggregate	Coarse Aggregate	Water	Fly ash	Cement
(pcs)	(m3)	(%)	(kg)	(kg)	(kg)	(Kg)	(Kg)
10	0,05	0%	46,78	64,07	13,04	0,00	24,15
10	0,05	20%	46,78	64,07	13,04	4,83	19,32
10	0,05	25%	46,78	64,07	13,04	6,04	18,11
10	0,05	30%	46,78	64,07	13,04	7,25	16,91
10	0,05	35%	46,78	64,07	13,04	8,45	15,70
Total			233,883	320,35	65,20	26,57	94,19

Source: Personal calculation

4.5 Slump Test

A slump test is a suitable test to determine the workability for all types of concrete mixes; the test was performed according to ASTM C143 (slump test procedure). The tests performed are compressive strength, flexural strength and determining the workability of fresh prepared concrete. The formula for calculating the workability of concrete is as follows. The workability test such as slump cone test is performed for fresh concrete mix. Sample production and the slump test are depicted in Figure 4.1.



Figure 4. 2 Slump Test

4.6 Compressive Strength

The concrete shape is a cylinder measuring 150 x 300 mm were cast with appropriate compaction and demolded after 36 hours. Then, 5 samples of each mix proportions were cured. At the ages of 14 days, the compressive strengths were tested according to the ASTM C109. The formula for calculating the compressive strength of concrete is as follows.

$$\text{Compressive Strength} = \frac{\text{Max load carried by the specimen}}{\text{Top surface area of the specimen}} \quad (4.1)$$

Compressive strength is the measured maximum resistance of a concrete sample to axial loading estimated to be about 88% of the 14-day strength. Good compressive strength of concrete with large quantities of Class C fly ash can be achieved by maintaining a cement density of 400 kg/m³ with water- cement ratio

(W/C) in the range of 0,54. Sample production and the compressive strength are depicted in Figure 4.2.



Figure 4. 3 Compressive Strength

4.7 Split Tensile Strength

The tensile strength of concrete is approximately one-tenth of its compressive strength. This is determined according to ASTM C109 by applying a load over the diameter of the concrete cylinder. While the compressive strength of concrete is most important in the design of concrete structures, the tensile strength of concrete is a fundamental property in estimating the crack strength of structures and analysing the failure process of concrete. The formula for calculating the split tensile strength of concrete is as follows.

$$T = \frac{2P}{\pi Ld} \quad (4.2)$$

Where is,

T = Split tensile strength, KPa

P = Maximum applied load indicated by testing machine, KN

L = Length, M

D = Diameter

The laboratory tests will show that all specimens with nominal dimensions 150x150 mm had higher splitting tensile strength of concrete compared to specimens

with size 150x300 mm, irrespective of the type of aggregate and cement water. Sample production and the split tensile are depicted in Figure 4.3.



Figure 4. 4 Split Tensile

4.8 Modulus of Elasticity

The concrete shape is a cylinder measuring 150 x 300 mm and was determined for modulus elasticity as per IS: 516 (concrete strength testing) at 14 days old. The formula for calculating the modulus of elasticity of concrete is as follows.

$$E_c = \frac{S_2 - S_1}{\epsilon_2 - 0.00005} \quad (4.3)$$

Where is,

E_c = Modulus of elasticity of concrete, lb/in² (MPa)

S_2 = Stress corresponding to ϵ_2 .

S_1 = Stress value corresponding to a strain of 0.00005.

ϵ_2 = Strain value at which S_2 is measured.

The mixes of the five variables were used: 0%, 20%, 25%, 30%, and 35% fly ash as a substitution ratios of cement for modulus elasticity.

Sample production and modulus of elasticity the are depicted in Figure 4.4.



Figure 4. 5 Modulus of Elasticity

4.9 Research Flowchart

The flow of the research activities is presented in Figure 4.5.

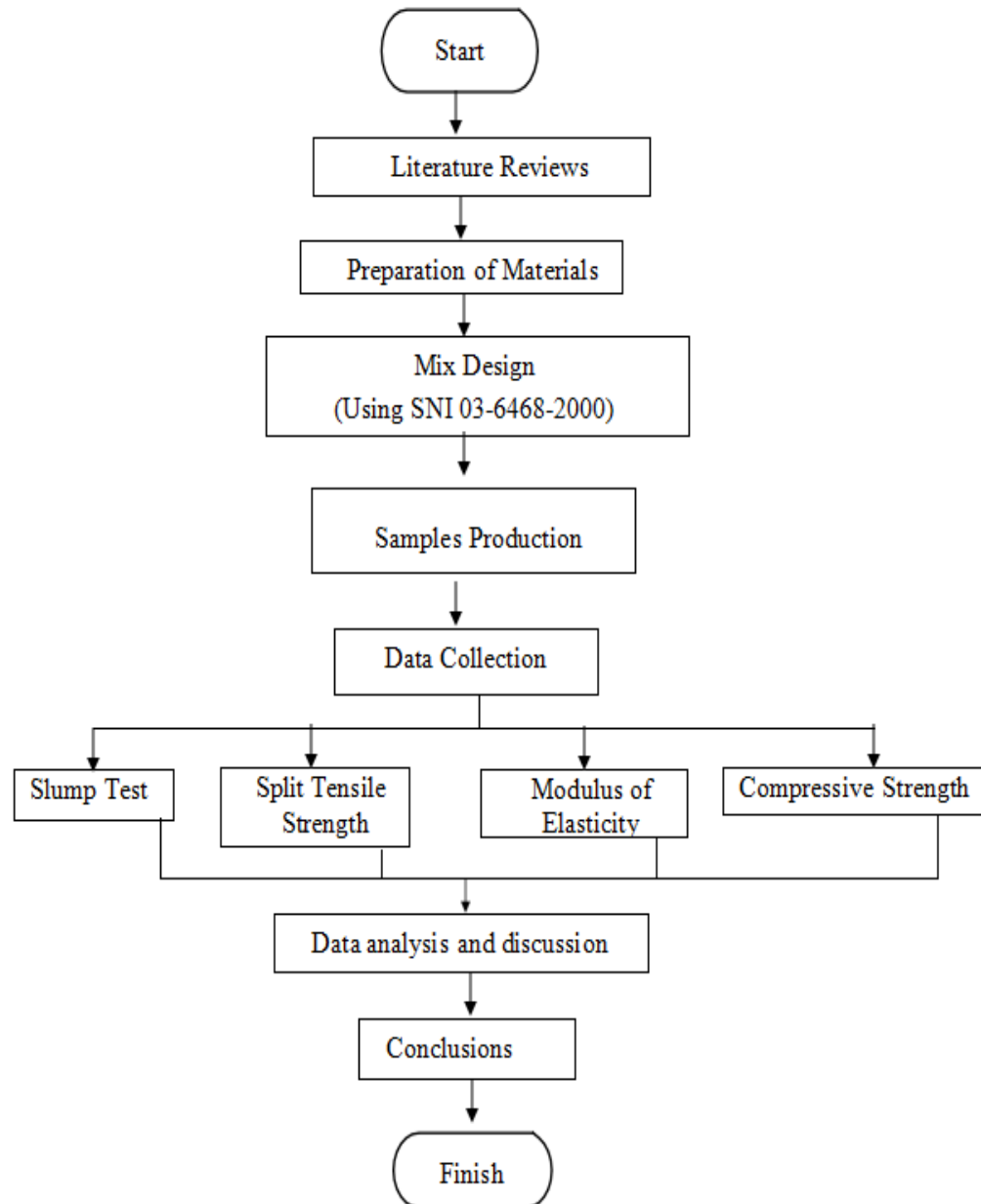


Figure 4. 5 Research flowchart

CHAPTER V

RESULTS AND DISCUSSIONS

5.1 Aggregate Test

Aggregate is the component of concrete that plays the most role in determining its size. Aggregates for concrete are hard mineral granules that are close to round in shape with grain sizes ranging from 0.063 mm to 150 mm. Aggregates according to their origin can be divided into two, namely natural aggregates obtained from rivers and artificial aggregates obtained from broken stones. In concrete mixtures, aggregates are the reinforcing materials (strengter) and filler, and occupy 60% — 75% of the total volume of concrete (Dvorkin et al., 2024). Aggregate is a granular material such as gravel, sand, furnace scale, and crushed stone and is used together with a binding medium to form a hydraulic cement concrete or mix.

5.1.1 Fine Aggregate

Fine aggregate, one of the primary constituents of concrete along with cement, water, and coarse aggregates, is a term used to describe small, inert materials, whether granular or crushed stone. These fine aggregates are essential components in concrete mixtures and play a crucial role in determining the properties of the resulting concrete. The absorption test of fine aggregates aims to determine the weight gain of an aggregate due to water seeping into the pores, but does not include water retained on the outer surface of the particles, the absorption value is expressed as a percentage of its dry weight. In this section, table 5.1 shows the Specific Gravity and Water Absorption, table 5.2 shows the Sand Clay Containt Test Result, tables 5.3 and 5.4 show the loose and dense densities, table 5.5 shows the sieve analysis test and table 5.8 shows the fine aggregate for zone I, zone II, zone III, and zone IV.

Table 5. 1 Examination of Specific Gravity and Water Absorption

Description	Observation Result	Unit
Absolute dry weight of sand, (Bk)	495.5	gram
Saturated surface dry (SSD) weight of sand,	500	gram
Weight of picknometer containing sand and water, (Bt)	1004	gram
Weight of picknometer filled with water, (B)	696	gram
Bulk specific gravity, $(Bk/(B+500-Bt))$	2.581	
Surface dry saturated specific gravity, $(500/(B+500-Bt))$	2.604	
Apparent specific gravity, $(Bk/(B+Bk-Bt))$	2.643	
Water absorption, $((500-Bk)/(Bk \times 100\%))$	0.908	%

Table 5. 2 Sand Clay Containt Test

Description	Observation Result	Unit
Dry aggregate weight (W1)	500	gram
Oven-dry aggregate weight after washed (W2)	491	gram
No.200 sieve passing weight	1.8	%

Table 5. 3 Loose Density

Description	Observation Result	
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram
Cylinders + oven-dry aggregate weight (W2)	15738	gram
Aggregate weight (W3)	6842	gram
Cylinders volume (V)	5301.438	cm ³
Loose Density, $(W3/V)$	1.291	gram/cm ³

Table 5. 4 Dense Density

Description	Observation Result	
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram

Cylinders + oven-dry aggregate weight (W2)	17516	gram
Aggregate weight (W3)	8620	gram
Cylinders volume (V)	5301.438	cm ³
Dense Density, (W3/V)	1.626	gram/cm ³

Table 5. 5 Sieve Analysis Test

Sieve Hole (mm)	Retained Weight (gr)	Retained Weight (%)	Comulative Retained Weight (%)	Comulative Passing Weight (%)
40		0	0	100
20		0	0	100
10		0	0	100
4.8	42	2.10	2.10	97.90
2.4	173	8.66	10.76	89.24
1.2	282	14.11	24.88	75.13
0.6	524	26.23	51.10	48.90
0.3	534	26.73	77.83	22.1
0.15	355	17.77	95.60	4.40
Remaints	88	4.40		ZONE II
Sumation	1998	100.00	262.26	

Table 5. 6 Aggregate Zone

Sieve Hole (mm)	Aggregate			
	Zone I	Zone II	Zone III	Zone IV
10	100	100	100	100
4,8	90-100	90-100	90-100	95-100
2,4	60-95	75-100	85-100	95-100
1,2	30-70	55-90	75-100	90-100
0,6	15-34	35-59	60-79	80-100
0,3	5-20	8-30	12-40	15-50
0,15	0-10	0-10	0-10	0-15

Table 5. 7 Cumulative Passing Weight

Sieve Hole (mm)	Comulative Passing Weight		
	Upper Limit	Sample 1	Lower Limit
4,8	100	97,90	90
2,4	100	89,24	75

1,2	90	75,13	55
0,6	59	48,90	35
0,3	30	22,17	8
0,15	10	4,40	0

Table 5. 8 Fine Aggregate

Sieve Hole (mm)	Zone I		Zone II		Zone III		Zone IV	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
4,8	90	100	90	100	90	100	95	100
2,4	60	95	75	100	85	100	95	100
1,2	30	70	55	90	75	100	90	100
0,6	15	34	35	59	60	79	80	100
0,3	5	20	8	30	12	40	15	50
0,15	0	10	0	10	0	10	0	15

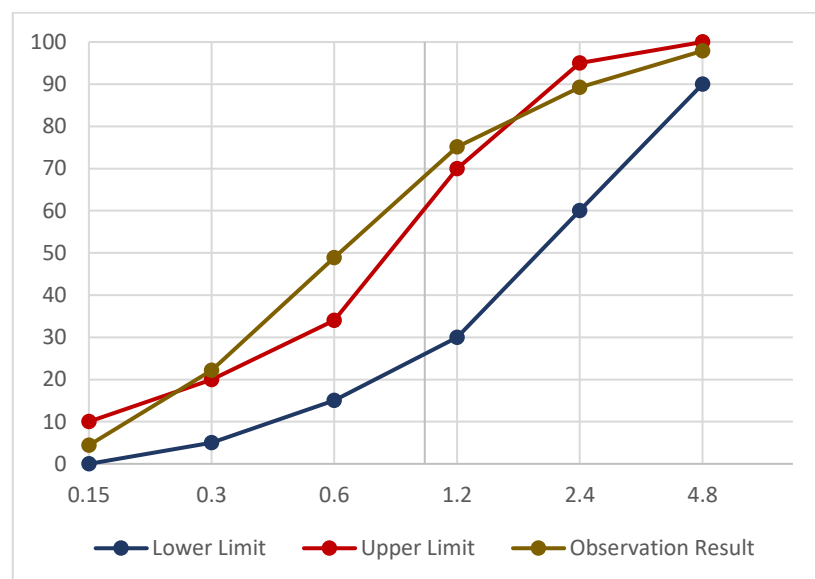


Figure 5. 1 Fine Aggregates Zone I

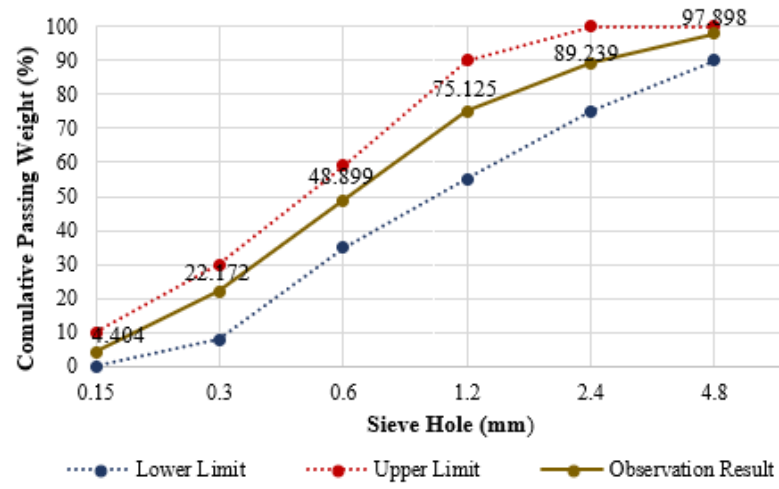


Figure 5. 2 Fine Aggregates Zone II

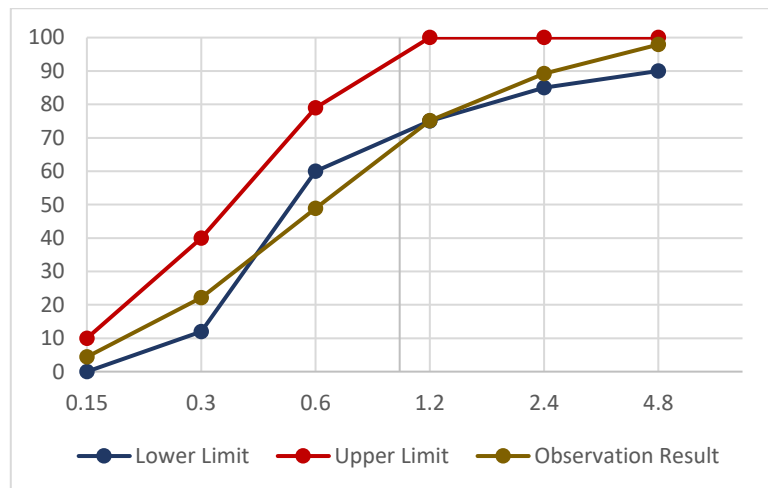


Figure 5. 3 Fine Aggregates Zone III

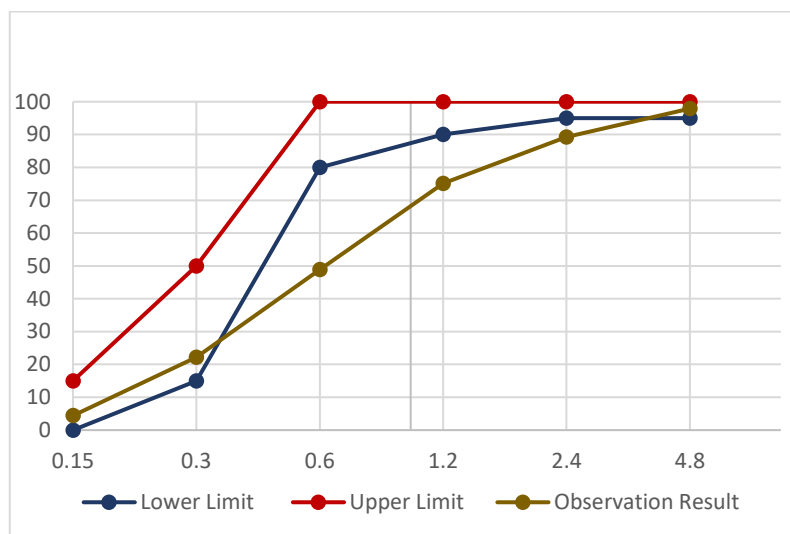


Figure 5. 4 Fine Aggregates Zone IV

The test results are described in Figures 5.1 to 5.4 in zones I, II, III, and IV with fractions from 0.15 mm to 4.8 mm. For the six sieve holes, the lower limit and upper limit values are different from each zone. In this study, a sieve hole was used with the calculation of retained weight and cumulative retained weight described in Table 5.4. The cumulative retained weight value is 262.26% with the cumulative passing weight at 0.15 mm is 4.40 and 4.8 is 97.90. From the results of the tests carried out, it was shown that the gradation for fine aggregate was within the limits required in the SNI 03-2834-2000 specification, where based on the cumulative passing weight value, the gradation was included in Zone II which is a rather fine sand gradation area. So the level of roughness or fineness of this sand is still within the required limits.

Based on the Table 5.1 – Table 5.5, absolute dry weight of sand is 495.5 gram with SSD 500 gram, weight of pycnometer contained sand and water is 1004 gram and weight of pycnometer filled with water is 696 grams. For sand clay content test, Dry Aggregate weight (W1) is 500 gram and Oven-Dry aggregate weight after washed (W2) is 491 gram. The specific gravity obtained is 2.643 and water absorption is 0.908%.

Cylinder used for loose density has diameter 15cm, weight 30 cm and weight 8896 gram. For Cylinder + Oven-dry aggregate weight (W3) is 15738 gram. The

Loose density obtained is 1.291 gram/cm³ and cylinder used for dense density has diameter 15cm, weight 30 cm and weight 8896 gram. For Cylinder + Oven-dry aggregate weight (W2) is 17516 gram. The Dense density obtained is 1.626 gram/cm³.

5.1.2 Coarse Aggregate

Coarse aggregate or commonly called gravel is the result of natural deintegration of rocks or or in the form of crushed stone produced by stone crushers with grain sizes ranging from 4.76 mm to 150 mm. This coarse aggregate is the component of concrete that plays the most role in determining its size. Just like fine aggregates, coarse aggregates based on their origin are also divided into two, namely natural aggregates obtained from natural sources and artificial aggregates obtained from the products of the stone crushing industry. Table 5.9 shows the Specific Gravity and Water Absorption, tables 5.10 and 5.11 show the loose and dense densities, table 5.2 shows the Sand Clay Containt Test Result

Table 5. 9 Examination of Specific Gravity and Water Absorption

Description	Observation Result	Unit
Absolute dry gravel weight, grams (Bk)	4873	gram
Weight of gravel in saturated dry face condition (SSD), grams (Bj)	5000	gram
Weight of gravel in water, grams (Ba)	3124.5	gram
Bulk specific gravity (Bk/(Bj-Ba))	2.598	
Face dry specific gravity (Bj/(Bj-Ba))	2.666	
Apparent specific gravity (Bk/(Bk-Ba))	2.787	
Water absorption ((Bj-Bk)/(Bk x 100%))	2.606	%

Table 5. 10 Loose Density

Description	Observation Result	
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram
Cylinders + oven-dry aggregate weight (W2)	16586	gram
Aggregate weight (W3)	7690	gram
Cylinders volume (V)	5301.438	cm ³
Loose Density, (W3/V)	1.451	gram/cm ³

Table 5. 11 Dense Density

Description	Observation Result	
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram
Cylinders + oven-dry aggregate weight (W2)	17347	gram
Aggregate weight (W3)	8451	gram
Cylinders volume (V)	5301.438	cm ³
Dense Density, (W3/V)	1.594	gram/cm ³

Table 5. 12 Sand Clay Containt Test

Description	Observation Result	Unit
Dry aggregate weight (W1), grams	2000	gram
Oven-dry aggregate weight after washed (W2), grams	1986	gram
No.200 sieve passing weight	0.7	%

Table 5. 13 Sieve Analysis Test

Sieve Hole (mm)	Retained weight (gram)	Retained weight (%)	Comulative Retained Weight (%)	Comulative Passing Weight (%)
40		0	0	100
20		0	0	100
10	3600	72	72	28
4,8	1321	26,42	98,42	1,58
2,4	35	0,70	99,12	0,88
1,2	16	0,32	99,44	0,56
0,6	0	0	99,44	0,56
0,3	0	0	99,44	0,56
0,15	0	0	99,44	0,56
Remaints	28	0,56		
Sumation	5000	100	667,30	

Table 5. 14 Percent of Aggregate Granules

Sieve Hole (mm)	Percent of Aggregate Granules that Pass the Sieve/Maximum Grain Size	
	40 mm	20 mm
40	95-100	100
20	35-70	95-100
10	10-35	25-55
4,8	0-5	0-10

Table 5. 15 Upper and Lower Limit

Sieve Hole (mm)	40 mm		20 mm	
	low limit	up limit	low limit	up limit
40	95	100	100	100
20	30	70	95	100
10	10	35	25	55
4,8	0	5	0	10

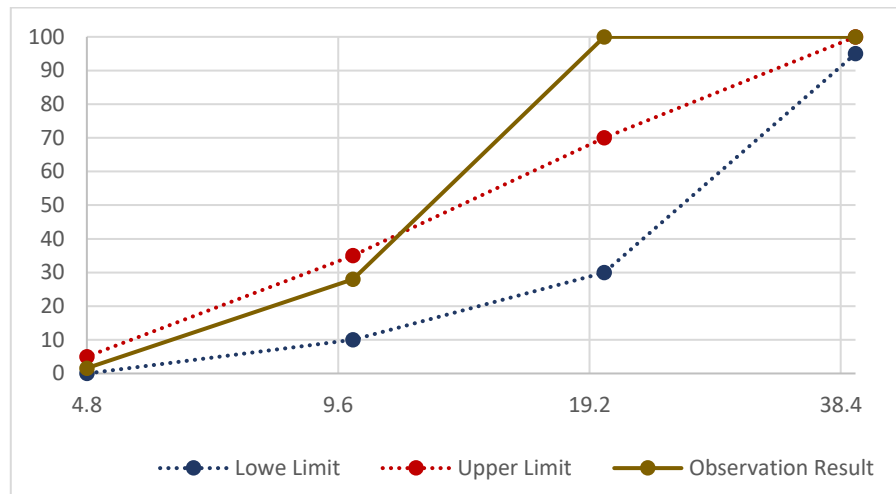


Figure 5. 5 Diameter max 40 mm

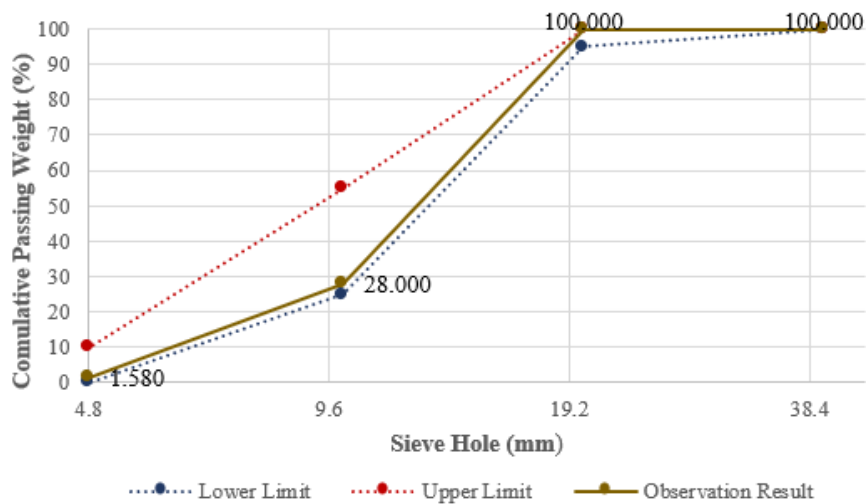


Figure 5. 6 Sieve Hole of Coarse Aggregate Diameter 20 mm

Table 5.15, Figure 5.5, and Figure 5.6 show the sieve test analysis with fractions from 4.8 mm to 40 mm. The aggregate used in concrete mixtures is ≤ 40 by obtaining concrete with good quality. The results of the tests carried out show that the coarse aggregate used in this test is gravel that are included in the grading requirements for coarse aggregate with a maximum grain size of 40 mm. Fine Modulus of Grains is an index used to measure the fineness or roughness of aggregate grains. Modulus of Grain obtained for 20 mm gravel is included in the limit requirements.

Based on the Table 5.9 – Table 5.12, absolute dry weight of gravel is 4873 gram with SSD 5000 gram, and weight of gravel filled with water is 3124.5 gram. For sand clay contain test, Dry Aggregate weight (W1) is 2000 gram and Oven-Dry aggregate weight after washed (W2) is 1986 gram. The specific gravity obtained is 2.787 and water absorption is 2.606%.

Cylinder used for loose density has diameter 15 cm, weight 30 cm and weight 8896 gram. For Cylinder + Oven-dry aggregate weight (W3) is 16586 gram. The Loose density obtained is 1.451 gram/cm³ and cylinder used for dense density has diameter 15cm, weight 30 cm and weight 8896 gram. For Cylinder + Oven-dry aggregate weight (W2) is 17347 gram. The Dense density obtained is 1.594 gram/cm³.

5.2 Mix Proportion Design

Mix design has the goal of obtaining the proportion of material mixture so that the concrete meets the general and technical requirements in accordance with the planning. The methods that are used for mix design is SNI 03-6468-2000 for water, cement, fine aggregate, fly ash, and coarse aggregate. Class C fly ash replaces 15%-35% of Portland cement in concrete (up to 50% for use in mass concrete placements.), making it stronger and eco- friendly. When used in Portland cement, Class C fly ash can be used as a replacement for Portland cement up to 20-35% of the mass of the cementitious material. Class C fly ash is designated in ASTM C 618 and originates from subbituminous and lignite coals.

The substitution ratio is typically 1:1 to 1.5:1 (fly ash to cement byweight) according to American Concrete Institute (ACI) Committee 226, “Guide to the Use of Fly Ash in Concrete,” ACI 226R-19. In this study, a total of 10 samples were used with 5 different variations, namely 0%, 20%, 25%, 30%, and 35%.

Table 5. 16 Form Mix Design (SNI-03-2834-2000)

No	Description	Results	Unit	Information
1	Required compressive strength of concrete (f'c)	20	MPa	Specified
2	Standard deviation value (Sd)	7	MPa	
3	Margin (M)	12	MPa	
4	Average Compressive strength of concrete (f'cr)	32	MPa	(1)+(3)
5	Type of cement	Type 1		Specified
6	Type of fine aggregate	Nature		Specified
	Type of coarse aggregate	Crushed Stone		Specified
7	Free cement water factor	0,54		table 2 and figure 1,2
	Maximum cement water factor value	0,6		
8	Cement water factor Used	0,54		
9	Slump	60-180	mm	Specified
10	Maximum Aggregate size	20	mm	Specified
11	Free water content	205		table 3
12	Cement Content	379,63	kg/m ³	(11):(8)
13	Maximum cement content	-		
14	Minimum cement content	325		table 4
15	Cement grade used	379,63	kg/m ³	
16	Cement water factor adjusted	-		
17	Large arrangement of fine aggregate grains	2		Gradation Zone

18	Specific gravity of fine aggregate	2,58			
	Specific gravity of coarse aggregate	2,60			
19	% Fine aggregate	42,2	%	figure 13 / 14 / 15	
20	Specific gravity of the combined aggregate	2,59			
21	Concrete Weight	2327	kg/m ³	figure 16	
22	Combined aggregate proportions	1742,37	kg/m ³	(21)-(15)-(11)	
23	Proportion of fine aggregate	735,28	kg/m ³	(19)*(22)	
24	proportion of coarse aggregate	1007,09	kg/m ³	(22)-(23)	
No	Description	Cement (kg)	Water (kg)	Aggregate	
				Fine (kg)	Coarse (kg)
25	Theoretical mixture proportions (Aggregate SSD)				
	* Every m3	379,63	205,00	735,28	1007,09
	* Each test mixture (1 samples) : 0,02651 m3	20,13	10,87	38,98	53,39
26	Mix proportions with shrinkage figures (20%)				
	* Every m3	455,56	246,00	882,34	1208,51
	* Each test mixture (10 samples) : 0,053 m3	24,15	13,04	46,78	64,07
	Ratio	1	0,54	1,94	2,65

Table 5. 17 Mix Proportions

Sample	Volume	Variation Fly ash	Fine Agg	Coarse Agg	Water	Class C Fly ash	Cement
(pcs)	(m3)	(%)	(kg)	(kg)	(kg)	(Kg)	(Kg)
10	0,05	0%	46,78	64,07	13,04	0,00	24,15
10	0,05	20%	46,78	64,07	13,04	4,83	19,32
10	0,05	25%	46,78	64,07	13,04	6,04	18,11
10	0,05	30%	46,78	64,07	13,04	7,25	16,91
10	0,05	35%	46,78	64,07	13,04	8,45	15,70
Total			233,883	320,35	65,20	26,57	94,19

Table 5. 18 Volume of Materials

VOLUME	
Dimension	Unit
0.3	m
0.15	m
1 cylinder	10 cylinder
0.0053 m ³	0.0530 m ³

5.3 Samples Production Processes

After determining the mix design, the next step is to make the samples. The materials used are fine aggregate, coarse aggregate, cement, water, and Class C fly ash. Fly ash is a by-product of industrial processes, so their availability and quality can vary depending on the region and the specific industry. This can make it difficult to develop and use concrete mixes that consistently achieve the desired properties and performance. In this research, Class C fly ash can be used as a portland cement replacement ranging from 20-35% of the mass of cementitious material. Hence, this research will use Class C fly ash. The concrete shape is a cylinder measuring 150 x 300 mm. The following is the sequence of the production process of concrete.

1. Prepare The Materials

In this study, material preparation is carried out for the manufacture of concrete which includes the following.

a. Chemical addition (sika)

In this study, Sika is used to accelerate the hardening of concrete by reducing water by up to 15%. Sika has a solution to close cracks in concrete that is practical and easy to apply. The use of Sika additives in concrete mixtures has several advantages, namely improving the workability of concrete and reducing heat hydration. It can be seen in figure 5.7.



Figure 5. 7 Sika Chemical

b. Class C Fly Ash

Fly ash is a by-product of industrial processes, so their availability and quality can vary depending on the region and the specific industry. This can make it difficult to develop and use concrete mixes that consistently achieve the desired properties and performance. In this study, when used in portland cement, Class C fly ash can be used as a portland cement replacement ranging from 20-35% of the mass of cementitious material. Hence, this research will use Class C fly ash. It can be seen in figure 5.8.



Figure 5. 8 Fly Ash Class C

c. Coarse Aggregate

Coarse aggregate or commonly called gravel is the result of natural deintegration of rocks or or in the form of crushed stone produced by stone crushers with grain sizes ranging from 4.76 mm to 150 mm. It can be seen in figure 5.9.



Figure 5. 9 Coarse Aggregate

d. Fine Aggregate

Fine aggregate, one of the primary constituents of concrete along with cement, water, and coarse aggregates, is a term used to describe small, inert materials, whether granular or crushed stone. These fine aggregates are essential components in concrete mixtures and play a crucial role in determining the properties of the resulting concrete. It can be seen in figure 5.10.



Figure 5. 10 Fine Aggregate

e. Cement OPC

The OPC (Ordinary Portland Cement) of 43 grades conforming to IS: 8112 was used in this research. This research used high-volume fly ash concrete as a high structural strength concrete with a significantly higher total amount of binder than ordinary strength concrete. It can be seen in figure 5.11.



Figure 5. 11 Cement OPC

f. Water

The water is used for chemical hydration reaction with cement. This is used well water from Pusat Inovasi Material Vulkanis Merapi UII. The performance of concrete with mineral additives was achieved with water curing. Each portion of the concrete mixture was created with a rotating drum mixer. It can be seen in figure 5.12.



Figure 5. 12 Water

2. Sieve the sand

Before mixing the raw material, it is necessary to sort the sand first.

3. Mixing Materials

All raw materials are mixed using a mixer until all ingredients are well mixed according to Table 5.17 Mix Design of the proportion 0%: 20%: 25%: 30%: 35%.

4. Slump Test

Next, a slump test was carried out to test the consistency of the concrete. Concrete slump is the level of viscosity of concrete dough that can affect permeability, workability and the work process.



Figure 5. 13 Slump Test

5.4 Slump Test

The Slump Test has become the most frequently performed due to the practicality of the recommended equipment and the experiment protocol. The slump test involves the cone's behavior under the action of gravitational forces. The slump check is a realistic way to gauge the workability. The concrete slump test and compaction factor test are used to determine the consistency of fresh concrete before it sets. In this study the Slump test is explained by Table 5.19 and Figure 5.14 with 5 variations of 0%, 20%, 25%, 30%, 35%.

Table 5. 19 Slump Test

No	Ratios of FA	Slump Test	Unit
1	0%	160	mm
2	20%	95	mm
3	25%	87	mm
4	30%	80	mm
5	35%	78	mm

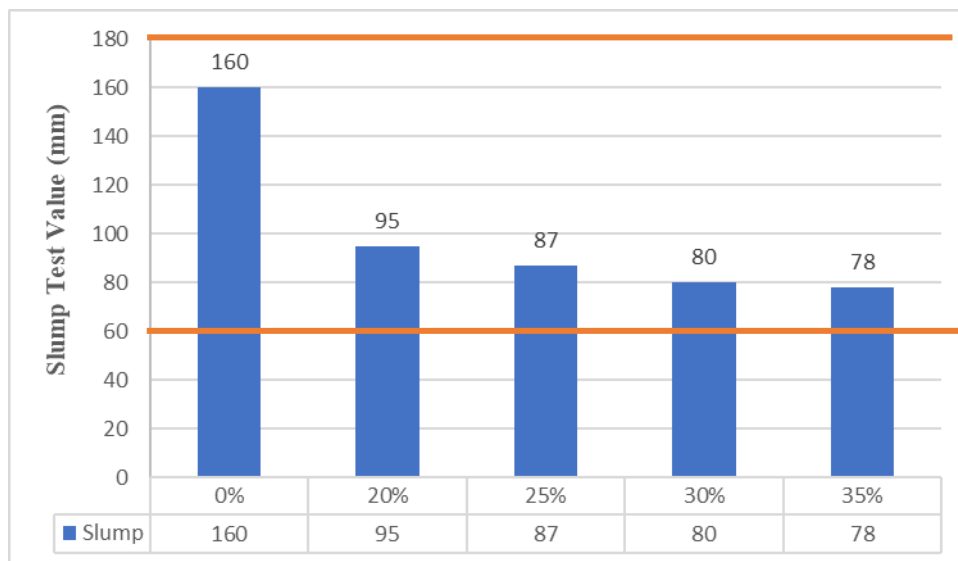


Figure 5. 14 Slump Test Process

The slump test measures the consistency of fresh concrete by determining its workability. The red lines refer to the limits and the boundaries of the slump value which is (60-180) mm. A higher slump indicates higher workability (more fluid concrete), while a lower slump indicates lower workability (stiffer concrete). Slump is the height in the cone mix of the cones that are bent against the height of the slump after the mold is removed. Slump is a guideline used to find out the level of abrasion of a concrete mixture, the higher the level of elasticity, the more low workmanship (high workability value). The stiffness in a concrete slab indicates how much water is used. For this reason, the slump test shows whether the concrete mixture is deficient, excessive, or enough water. Concrete fly ash Class C has good workability and allows to have a lower water-cement ratio, similar slump value compared to ordinary concrete.

Based on the results of the slump test, it was found that the percentage value of fly ash was 0% of 160 mm, 20% of fly ash is 95 mm, 25% of fly ash is 80 mm, 30% of fly ash is 87 mm, 35% of fly ash is 78 mm. The results of the slump were between the boundaries 60-180 mm. This test ensures that concrete has the appropriate consistency for its intended use. Fly ash particles being round and fine improves workability and helps getting desired slump. In a few cases of slump test,

the results varied according to binder content and w/cm ratio. The slump reduction seen higher side in the binder content 35% comparative to others.

The research from Mukherjee et al (2013), was performed by adding 60% of fly ash, and it was noticed that the low slump value. The addition of fly ash to the concrete mixture has an effect on the slump value and viscosity produced. This research a line with Chandio et al (2020), that explained the addition of fly ash for concrete will decrease the slump test value. The effects of the addition of fly ash as replacement of cement show that slump value reduces with increase in fly ash dosage. Research conducted by Hasan et al (2023), the use of fly ash tends to reduce the value of slumps and vice versa, the slump test is used to determine the consistency/strength of the fresh concrete mixture to determine its workability level. Because of the mentioned above, the slump test results showed that the more addition of fly ash can reduced the slump value.

5.5 Curing The Samples

Concrete curing is a concrete maintenance process that must be done periodically. The function of concrete curing is very crucial in order to maintain the quality of concrete even though it has been eaten by age. The water curing method uses water as the main medium. The concrete surface is watered and covered with water with the aim of inhibiting water evaporation in the process of stirring cast concrete.

Cure the fresh samples for 14 days to get maximum results. The reason beyond curing the fresh samples for 14 days not more than that due to using the chemical addition (sika additives) and it has several advantages, namely improving the workability of concrete, accelerate setting time, and reducing heat hydration. /The procedure for making concrete curing is water curing. The application of the water is done to avoid the drying of the concrete surface. Usually, this method applies when the concrete is thinner. The implementation of concrete curing or concrete treatment is carried out when the concrete is in the final setting condition, namely when the concrete has hardened. The implementation of concrete treatment aims to moisture the concrete and avoid excessive evaporation so that the quality

of concrete is obtained in accordance with the plan. The samples can be seen in Figure 5.15.

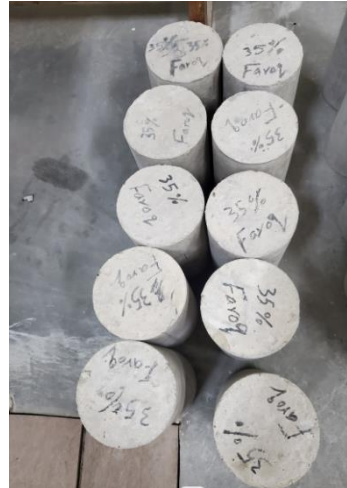


Figure 5. 15 Curing Samples

5.6 Sulfur Capping

The concrete cylinders were capping with molten sulfur. The use of Sulfur in the processing process provides better binding properties, better elasticity, and improved quality of the coating. The top surface of the test piece cylinders are capped or coated with sulfur mortar so that the load can be evenly distributed on the upper surface of the cylindrical test piece. Test Specimen placed centrally against the compressive force machine and then loaded with loading speed adjusted until the test piece is destroyed. Sulfur Capping shows in Figure 5.16.



Figure 5. 16 Sulfur Capping

Sulfur Powder is used as a material for capping the concrete cylinders. The use of Sulfur powder in the processing process provides better binding properties,

better elasticity, and improved quality of the coating. Sulfur Powder can be seen in figure 5.17.



Figure 5. 17 Sulfur Powder

5.7 Strength Test and Modulus of Elasticity Test

5.7.1 Compressive Strength Test

The compressive strength of concrete is the amount of load per unit area, which causes the concrete test piece to collapse when loaded. The compressive strength of concrete was carried out according to ASTM C109. The compressive strength of the resulting concrete is tested using a CTM (Compression Testing Machine) tool. The concrete shape is a cylinder measuring 150 x 300 mm. By developing green concrete using fly ash class C, environmental pollution and cement consumption can be minimized. Replacing some of the cement particles in concrete with fly ash class C decreased the concrete's 14-day compressive strength, split tensile strength, modulus of elasticity, and slump test. Concrete optimization means obtaining a concrete mixture that is economical and meets the required concrete properties such as strength, durability, and workability. Figure 5.18 shown the compressive strength test.



Figure 5. 18 Compressive Test Process

Table 5. 20 Specimen Dimension 0% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	149,7	149,2	150,2	mm
Height	303,9	307	303	mm
Weight of Specimen	12,53	12,85	12,60	kg
Cross-Sectional Area	17600,84	17483,47	17718,61	mm ²

Table 5. 21 Specimen Dimension 20% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,5	150,3	150	mm
Height	303,5	305,9	305	mm
Weight of Specimen	13,00	12,95	12,91	kg
Cross-Sectional Area	17789,46	17742,22	17671,46	mm ²

Table 5. 22 Specimen Dimension 25% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,2	149,67	149,2	mm
Height	298,1	302,3	297,9	mm
Weight of Specimen	12,48	12,64	12,29	kg
Cross-Sectional Area	17718,61	17593,79	17483,47	mm ²

Table 5. 23 Specimen Dimension 30% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,3	150,8	151,2	mm
Height	303	301,89	305	mm

Weight of Specimen	12,997	12,82	12,84	kg
Cross-Sectional Area	17742,22	17860,46	17955,33	mm ²

Table 5. 24 Specimen Dimension 35% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,1	150	149,6	mm
Height	298,5	296,85	299,67	mm
Weight of Specimen	12,181	12,27	12,363	kg
Cross-Sectional Area	17695,03	17671,46	17577,34	mm ²

Calculating the values of compressive strength for each specimen:

1. Compressive strength for 0% fly ash

$$\text{Specimen 1} = \frac{454,19}{17,60} = 25,81 \text{ MPa}$$

$$\text{Specimen 2} = \frac{488,34}{17,48} = 27,93 \text{ MPa}$$

$$\text{Specimen 3} = \frac{466,26}{17,72} = 26,31 \text{ MPa}$$

$$\text{Average} = \frac{25,81+27,93+26,31}{3} = 26,68 \text{ MPa}$$

2. Compressive strength for 20% fly ash

$$\text{Specimen 1} = \frac{480,21}{17,79} = 26,99 \text{ MPa}$$

$$\text{Specimen 2} = \frac{495,56}{17,74} = 27,93 \text{ MPa}$$

$$\text{Specimen 3} = \frac{517,78}{17,67} = 29,30 \text{ MPa}$$

$$\text{Average} = \frac{26,99+27,93+29,30}{3} = 28,08 \text{ MPa}$$

3. Compressive strength for 25% fly ash

$$\text{Specimen 1} = \frac{409}{17,72} = 23,08 \text{ MPa}$$

$$\text{Specimen 2} = \frac{416}{17,59} = 23,64 \text{ MPa}$$

$$\text{Specimen 3} = \frac{410}{17,48} = 23,45 \text{ MPa}$$

$$\text{Average} = \frac{23,08+23,64+23,45}{3} = 23,39 \text{ MPa}$$

4. Compressive strength for 30% fly ash

$$\text{Specimen 1} = \frac{385}{17,74} = 21,70 \text{ MPa}$$

$$\text{Specimen 2} = \frac{397}{17,86} = 22,23 \text{ MPa}$$

$$\text{Specimen 3} = \frac{393}{17,96} = 21,89 \text{ MPa}$$

$$\text{Average} = \frac{21,70+22,23+21,89}{3} = 21,94 \text{ MPa}$$

5. Compressive strength for 35% fly ash

$$\text{Specimen 1} = \frac{301,39}{17,70} = 17,03 \text{ MPa}$$

$$\text{Specimen 2} = \frac{272,23}{17,67} = 15,41 \text{ MPa}$$

$$\text{Specimen 3} = \frac{239,49}{17,58} = 13,62 \text{ MPa}$$

$$\text{Average} = \frac{17,03+15,41+13,62}{3} = 15,35 \text{ MPa}$$

Table 5. 25 Recapitulation of Compressive Strength

No	Specimen	FA Ratio	Dimention	Unit	Max. load	Unit	Compressive Strength (Mpa)	Average	Percentage of decrease
1	1	0%	149,7 x 303,9	mm	454,19	kN	25,81	26,68 MPa	0%
	2		149,2 x 307	mm	488,34	kN	27,93		
	3		150,2 x 303	mm	466,26	kN	26,31		
2	1	20%	150,5 x 303,5	mm	480,21	kN	26,99	28,08 MPa	5,21%
	2		150,3 x 305,9	mm	495,56	kN	27,93		
	3		150 x 305	mm	517,78	kN	29,30		
3	1	25%	150,2 x 298,1	mm	409	kN	23,08	23,39 MPa	12,33%
	2		149,7 x 302,3	mm	416	kN	23,64		
	3		149,2 x 297,9	mm	410	kN	23,45		
4	1	30%	150,3 x 303	mm	385	kN	21,70	21,94 MPa	17,78%
	2		150,8 x 301,9	mm	397	kN	22,23		
	3		151,2 x 305	mm	393	kN	21,89		
5	1	35%	150,1 x 298,5	mm	301,39	kN	17,03	15,35 MPa	42,46%
	2		150 x 296,9	mm	272,23	kN	15,41		
	3		149,6 x 299,7	mm	239,49	kN	13,62		

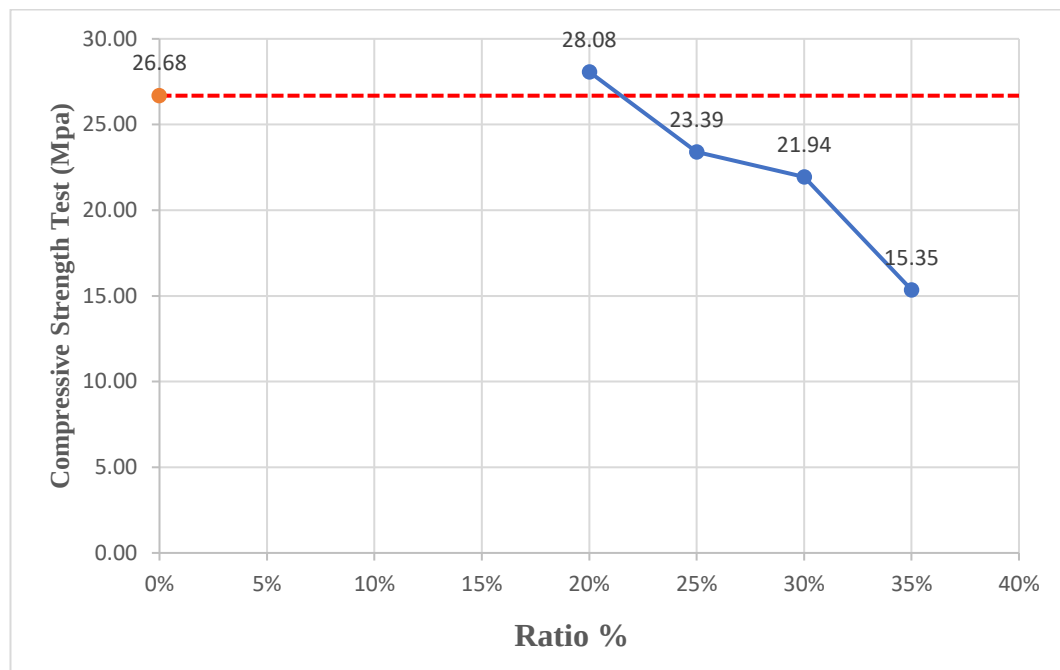


Figure 5. 19 Average Compressive Strength

According to the mix design of this research using SNI-03-2834-2000, required compressive strength of concrete (f'_c) is 20 MPa. Based on Figure 5.19 and Table 5.25 shows that there is a difference in the compressive strength value of each mix proportion. The measured compressive strengths value with various content of Fly Ash for 14 days is given in Table shows that the compressive strength for each material proportion are 26,68 MPa, 28,08 MPa, 23,39 MPa, 21,94 MPa, and 15,35 MPa. The results of the study showed that the effect of adding fly ash to cement increased the compressive strength of concrete compared to normal concrete. The highest increase in compressive strength value occurred in the 20% fly ash variation, while the lowest increase in compressive strength value occurred in the 35% fly ash variation. The low percentage of fly ash makes the compressive strength value increase.

The effect of the use of fly ash can produce a compressive strength higher than normal concrete, but when the addition of fly ash is greater than 20%, it results in an increase in the compressive strength of the mortar to be low. Factors that affect strong values concrete presses, among others, comparison arrangements

between cement, water, coarse and fine aggregates and Various types of additive additives, process mixing and compaction or compacting, as well as the concrete treatment process or curing.

This phenomenon is due to the large amount of calcium compounds (Ca) contained in type C fly ash. Calcium is an element that acts as sites, which is the beginning of the formation of geopolymer chains. The more sites it contains, the shorter the distance between the geopolymerized cores. Meanwhile, the geopolymerization process is considered to stop if the geopolymer chains meet with other cores. The cessation of the process of forming geopolymer chains has an impact on materials that begin to harden. High levels of CaO in high fly ash are not good for development compressive strength in the final days of the test, even recommended a good CaO level in fly ash is 5% - 10%.

Based on the test results, the optimum composition value is 20%, because it is not much different from the control sample (0% fly ash) in terms of compressive strength. However, in accordance with the characteristics of type C fly ash, the compressive strength value of 25% of the sample also showed a modest increase with the age of the specimen. In addition, samples with a composition ratio of 35% or more showed significantly lower compressive strength performance than control samples.

This research is in line with previous research by Hang et al (2023) that the addition of fly ash affects the compressive strength of the resulting concrete. In the 20% fly ash variety, it has the highest compressive strength. The use of fly ash waste on concrete can increase compressive strength. Research conducted by Rutkowska et al. (2020), shows that fly ash showing that concrete experiences maximum compressive strength by using a variation of 20% fly ash on a 14-day test. According to Wadhawan et al (2023), the decrease in compressive strength is caused by the decrease in the amount of cement by the replacement of fly ash so that the cement that functions as an adhesive is not enough to glue all the constituent materials of the concrete, so that the bond is not perfect and as a result the strength of the concrete decreases.

5.7.2 Split Tensile Strength Test

Split Tensile of concrete was tested in compression, according to ASTM C109 using UTM (Universal Testing Machine) to determine the compressive strength and split tensile strength, respectively. Split tensile strength is an important parameter in concrete testing, tensile strength testing is done by applying pressure to the test piece evenly up to the strength of the maximum. The Fly Ash class C sample after the split tensile test shown on Tables 5.26 – 5.31.



Figure 5. 20 Split Tensile Test Process

Table 5. 26 Specimen Dimension 0% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	149	150,9	150	mm
Height	304,3	303,5	302	mm
Weight of Specimen	12,78	12,78	12,48	kg

Table 5. 27 Specimen Dimension 20% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	149,7	149,9	151,7	mm
Height	302,5	301	304	mm
Weight of Specimen	13,09	12,81	13,03	kg

Table 5. 28 Specimen Dimension 25% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	149,6	150,3	149,78	mm
Height	304,2	297,7	301,8	mm
Weight of Specimen	12,52	12,38	12,71	kg

Table 5. 29 Specimen Dimension 30% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,8	149,3	150	mm
Height	305,6	302,9	305,7	mm
Weight of Specimen	12,91	12,77	12,78	kg

Table 5. 30 Specimen Dimension 35% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,8	149,3	150	mm
Height	301,2	298,8	298,6	mm
Weight of Specimen	12,46	12,64	12,43	kg

Split Tensile Strength for 0% Fly Ash:

$$\text{Specimen 1(T)} = \frac{2 \times 125}{3,14 \times 149 \times 304,3} = 1,76 \text{ MPa}$$

$$\text{Specimen 2(T)} = \frac{2 \times 128}{3,14 \times 150,9 \times 303,5} = 1,78 \text{ MPa}$$

$$\text{Specimen 3(T)} = \frac{2 \times 116}{3,14 \times 150 \times 302} = 1,63 \text{ MPa}$$

$$\text{Average} = \frac{1,76+1,78+1,63}{3} = 1,72 \text{ MPa}$$

Split Tensile Strength for 20% Fly Ash:

$$\text{Specimen 1(T)} = \frac{2 \times 130}{3,14 \times 149,7 \times 302,5} = 1,83 \text{ MPa}$$

$$\text{Specimen 2(T)} = \frac{2 \times 145}{3,14 \times 149,9 \times 301} = 2,05 \text{ MPa}$$

$$\text{Specimen 3(T)} = \frac{2 \times 142}{3,14 \times 151,7 \times 304} = 1,96 \text{ MPa}$$

$$\text{Average} = \frac{1,83+2,05+1,96}{3} = 1,94 \text{ MPa}$$

Split Tensile Strength for 25% Fly Ash:

$$\text{Specimen 1(T)} = \frac{2 \times 110}{3,14 \times 149,6 \times 304,2} = 1,54 \text{ MPa}$$

$$\text{Specimen 2(T)} = \frac{2 \times 137}{3,14 \times 150,3 \times 297,9} = 1,95 \text{ MPa}$$

$$\text{Specimen 3(T)} = \frac{2 \times 122}{3,14 \times 149,78 \times 301,8} = 1,72 \text{ MPa}$$

$$\text{Average} = \frac{1,54+1,95+1,72}{3} = 1,74 \text{ MPa}$$

Split Tensile Strength for 30% Fly Ash:

$$\text{Specimen 1(T)} = \frac{2 \times 112}{3,14 \times 150,8 \times 305,6} = 1,54 \text{ MPa}$$

$$\text{Specimen 2(T)} = \frac{2 \times 100}{3,14 \times 149,3 \times 302,9} = 1,41 \text{ MPa}$$

$$\text{Specimen 3(T)} = \frac{2 \times 95}{3,14 \times 150 \times 301,8} = 1,32 \text{ MPa}$$

$$\text{Average} = \frac{1,54+1,41+1,32}{3} = 1,42 \text{ MPa}$$

Split Tensile Strength for 35% Fly Ash

$$\text{Specimen 1(T)} = \frac{2 \times 70}{3,14 \times 150,8 \times 301,2} = 0,98 \text{ MPa}$$

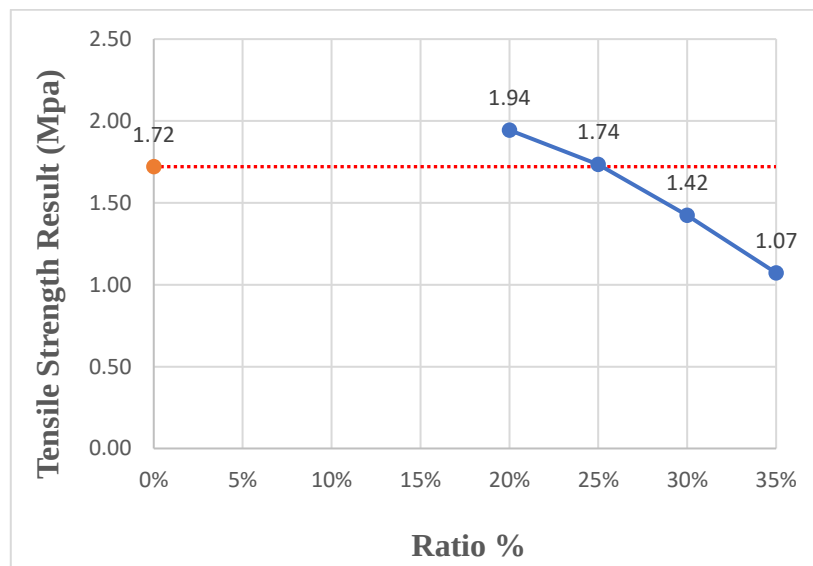
$$\text{Specimen 2(T)} = \frac{2 \times 75}{3,14 \times 149,3 \times 298,8} = 1,07 \text{ MPa}$$

$$\text{Specimen 3(T)} = \frac{2 \times 82}{3,14 \times 150 \times 298,6} = 1,17 \text{ MPa}$$

$$\text{Average} = \frac{0,98+1,07+1,17}{3} = 1,07 \text{ MPa}$$

Table 5. 31 Recapitulation of Tensile Strength

No	Specimen	FA Ratio	Dimention	Unit	Max. load	Unit	Tensile Strength (Mpa)	Average	Percentage of decrease
1	1	0%	149 x 304,3	mm	125	kN	1,76	1,72 MPa	0%
	2		150,9 x 303,5	mm	128	kN	1,78		
	3		150 x 302	mm	116	kN	1,63		
2	1	20%	149,7 x 302,5	mm	130	kN	1,83	1,94 MPa	12.79%
	2		149,9 x 301	mm	145	kN	2,05		
	3		151,7 x 304	mm	142	kN	1,96		
3	1	25%	149,6 x 304,2	mm	110	kN	1,54	1,74 MPa	1.16%
	2		150,3 x 297,7	mm	137	kN	1,95		
	3		149,8 x 301,8	mm	122	kN	1,72		
4	1	30%	150,8 x 305,6	mm	112	kN	1,54	1,42 MPa	17.44%
	2		149,3 x 302,9	mm	100	kN	1,41		
	3		150 x 305,7	mm	95	kN	1,32		
5	1	35%	150,8 x 301,2	mm	70	kN	0,98	1,07 MPa	37.79%
	2		149,3 x 298,8	mm	75	kN	1,07		
	3		150 x 298,6	m	82	kN	1,17		

**Figure 5. 21 Average Tensile Strength**

The measured tensile strength value with various content of Fly Ash for 14 days is given in Table 5.31 shows that the tensile strength for each material

proportions are 1,72 MPa, 1,94 MPa, 1,73 MPa, 1,42 MPa, and 1,07 MPa. The Figure 5.21 shows how the Fly Ash behaved and the graph shows the average tensile strength of the given samples. Based on Figure 5.21 shows that there is a difference in the tensile strength value of each mix proportions. At 35% Fly Ash has the lowest tensile strength value followed by 30% Fly Ash. While the highest tensile strength value is at 20% Fly Ash. On a variation of 25%, 30%, and 35% the tensile strength of concrete decreased. This is due to an increase in aggregates and variation of Fly Ash and can be affected by temperature.

So from the results of the study, it can be concluded that the addition of fly ash with a variation of 20% is still able to increase the value of compressive strength and tensile strength. This phenomenon is due to the large amount of calcium compounds (Ca) contained in class C fly ash. In class C fly ash concrete, it is sensitive to temperature, so the temperature can affect the high and low values of split tensile strength. Therefore, in the activity of concreting large quantities (mass concrete) or when the temperature rises around 200 °C or 400 °F, fly ash does not provide high strength. Class C fly ash has a high percentage of calcium oxide (more than 10%), about 35% silica and a much lower carbon content of less (than less than 2%) than Portland cement. In addition to pozzolan properties, Class C fly ash contains cementitious properties and tends to harden easily; Therefore, the more fly ash is used, the lower the split tensile strength.

However, the research from Zhang et al., (2020) explained the addition of fly ash of more than 20% can reduce the value of compressive strength and tensile strength. This research a line with Simatupang et al., (2022), found that 20% is the optimum split tensile strength and above 20% has decreased. Another study by Smhmlls et al., (2022), shows that the split tensile value for class C fly ash is 0-20%, after 20% there will be a significant decrease. At 35% Fly Ash has the lowest tensile strength value followed by 30% Fly Ash. The research from Munoz et al., (2023) mentioned that fly ash is used in concrete were mainly analyzed to study methods and designs to obtain the optimal proportion of 5%, 10% 15%, and 20% that fly ash improves the mechanical and physical properties of concrete and the

optimal addition level is 10% as a replacement for regular Portland cement in plain concrete.

5.7.3 Modulus of Elasticity Test

The concrete shape is a cylinder measuring 150 x 300 mm and was determined for modulus elasticity at 14 days. The modulus of elasticity is determined by the change in stress to strain, a large modulus of elasticity indicates the ability of concrete to withstand a large load under small strain conditions. So that the higher the compressive strength value of concrete, the higher the value of the elastic modulus. Figure 5.22 shows the Modulus Elasticity Test.



Figure 5. 22 Modulus of Elasticity

Table 5. 32 Specimen Dimension 0% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	151,12	149,5	150,3	mm
Height	306,9	305,1	305,7	mm
Weight of Specimen	12,94	12,62	12,70	kg
Cross-Sectional Area	17936,34	17553,85	17742,22	mm ²

Table 5. 33 Specimen Dimension 20% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150	150,8	149,7	mm
Height	304,2	304,0	303,0	mm
Weight of Specimen	12,95	13,01	13,04	kg
Cross-Sectional Area	17671,46	17860,46	17600,84	mm ²

Table 5. 34 Specimen Dimension 25% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	148,3	149,5	148,9	mm
Height	300,0	300,8	303,1	mm
Weight of Specimen	12,55	12,54	12,65	kg
Cross-Sectional Area	17273,18	17553,85	17413,23	mm ²

Table 5. 35 Specimen Dimension 30% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	150,8	150,8	148,7	Mm
Height	301,9	300,3	300,0	Mm
Weight of Specimen	12,50	12,44	12,61	Kg
Cross-Sectional Area	17860,46	17860,46	17366,48	mm ²

Table 5. 36 Specimen Dimension 35% Fly Ash

Description	Cylinder 1	Cylinder 2	Cylinder 3	Unit
Diameter	148	148,3	148,3	mm
Height	301,9	297,9	296,3	mm
Weight of Specimen	12,47	12,24	12,13	kg
Cross-Sectional Area	17203,36	17273,18	17273,18	mm ²

Modulus of Elasticity for Fly Ash 0%

$$E_{c1} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{10,59 - 2,79}{0,000257 - 0.00005} = 30947,61 \text{ MPa}$$

$$E_{c2} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{10,25 - 2,85}{0,000261 - 0.00005} = 29000,18 \text{ MPa}$$

$$E_{c3} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{11,27 - 2,82}{0,000301 - 0.00005} = 28586,48 \text{ MPa}$$

Modulus of Elasticity for Fly Ash 20%

$$E_{c1} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{13,38 - 3,35}{0,000325 - 0.00005} = 31337,04 \text{ MPa}$$

$$E_{c2} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{13,44 - 5,04}{0,000230 - 0.00005} = 37315,93 \text{ MPa}$$

$$E_{c3} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{14,20 - 2,84}{0,000327 - 0.00005} = 35340,40 \text{ MPa}$$

Modulus of Elasticity for Fly Ash 25%

$$E_{c1} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{9,84 - 2,32}{0,000270 - 0.00005} = 28421,91 \text{ MPa}$$

$$E_{c2} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{9,84 - 4,05}{0,000196 - 0.00005} = 30319,54 \text{ MPa}$$

$$E_{c3} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{9,19 - 5,17}{0,000125 - 0.00005} = 33451,72 \text{ MPa}$$

Modulus of Elasticity for Fly Ash 30%

$$E_{c1} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{8,40 - 3,92}{0,000144 - 0.00005} = 32250,35 \text{ MPa}$$

$$E_{c2} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{8,96 - 3,92}{0,000158 - 0.00005} = 32940,41 \text{ MPa}$$

$$E_{c3} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{8,96 - 2,80}{0,000235 - 0.00005} = 26800,94 \text{ MPa}$$

Modulus of Elasticity for Fly Ash 35%

$$E_{c1} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{6,98 - 2,33}{0,000230 - 0.00005} = 20667,00 \text{ MPa}$$

$$E_{c2} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{5,81 - 1,74}{0,000223 - 0.00005} = 18662,50 \text{ MPa}$$

$$E_{c3} = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} = \frac{6,39 - 2,91}{0,000147 - 0.00005} = 24628,73 \text{ MPa}$$

Table 5. 37 Recapitulation of Modulus of Elasticity

Fly Ash	Specimen	S2	ϵ_2	S1	Ec	Average of Ec	Percentage of decrease
0%	1	10,59	0,000257	2,79	30947,61 MPa	29511,42 MPa	0%
	2	10,25	0,000261	2,85	29000,18 MPa		
	3	11,27	0,000301	2,82	28586,48 MPa		
20%	1	13,38	0,000325	3,35	31337,04 MPa	34664,46 MPa	17,46%
	2	13,44	0,000230	5,04	37315,93 MPa		
	3	14,20	0,000327	2,84	35340,40 MPa		
25%	1	9,84	0,000270	2,32	28421,91 MPa	30731,06 MPa	4,13%
	2	9,84	0,000196	4,05	30319,54 MPa		
	3	9,19	0,000125	5,17	33451,72 MPa		
30%	1	8,40	0,000144	3,92	32250,35 MPa	30663,90 MPa	3,91%
	2	8,96	0,000158	3,92	32940,41 MPa		
	3	8,96	0,000235	2,80	26800,94 MPa		
35%	1	6,98	0,000230	2,33	20667,00 MPa	21319,41 MPa	27,76%
	2	5,81	0,000223	1,74	18662,50 MPa		
	3	6,39	0,000147	2,91	24628,73 MPa		

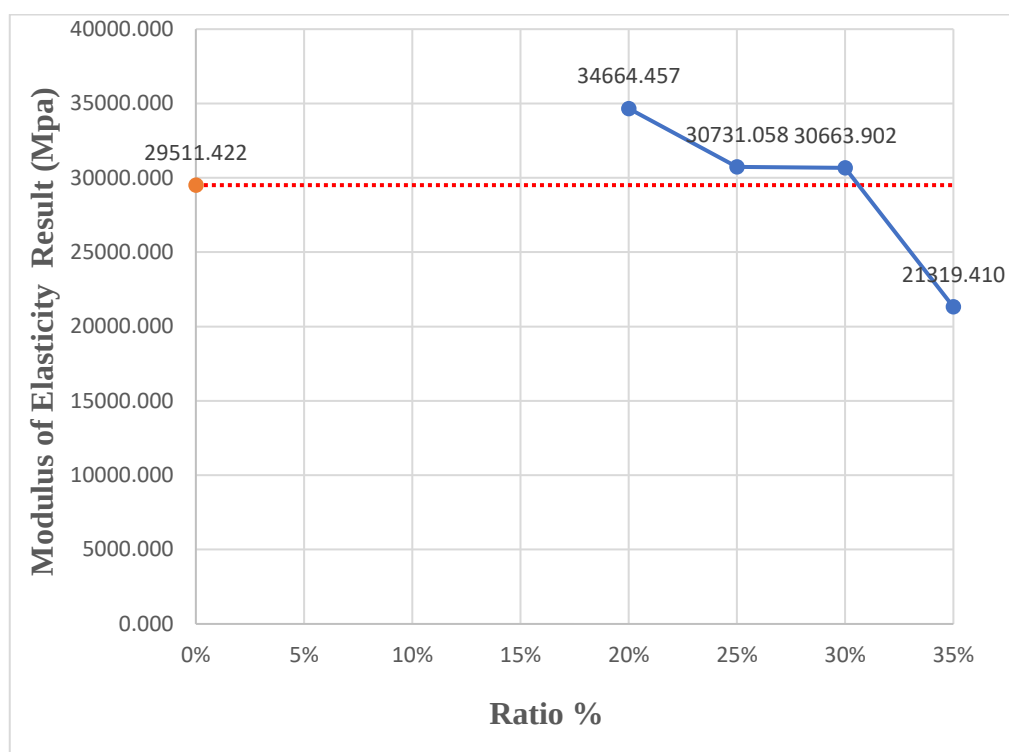


Figure 5. 23 Average of Modulus of Elasticity

The measured modulus elasticity value with various content of Fly Ash for 14 days is given in Table 5.37 shows that the modulus elasticity for each material proportions are different within the percentage of fly ash. The Figure 5.23 shows how the average of modulus elasticity of the given samples.

At 0% fly ash, the highest modulus of elasticity value is owned by specimen 1, which is 30947,61 MPa. Then 20% of fly ash has the highest modulus of elasticity value owned by specimen 2, which is 37315,93 MPa. At 25% fly ash, the highest modulus of elasticity value is owned by cylinder 3, which is 33451,72 MPa. Then 30% of the fly ash has the highest modulus of elasticity value owned by specimen 2, which is 32940,41 MPa. Then 35% of fly ash has the highest modulus of elasticity value owned by specimen 3, which is 24628,73 MPa. At 20% Fly Ash has the highest modulus elasticity due to the highest modulus elasticity followed by 25% Fly Ash. It has been demonstrated that when the volume fraction of Fly Ash increased, the values of the elastic modulus, impact strength, and hardness increased as well.

The research from Han et al (2020) explained while the lowest modulus elasticity value is at 35% Fly Ash. The effect of the use of fly ash can produce a strength and modulus elasticity higher than normal concrete, but when the addition of fly ash is greater than 20%, it results in an increase in the compressive strength of the concrete to be low. Nguyen et al (2021) shows the phenomenon of modulus elasticity impact due to the large amount of calcium compounds (Ca) contained in class C fly ash. Calcium is an element that acts as sites, which is the beginning of the formation of geopolymer chains. The more sites it contains, the shorter the distance between the geopolymerized cores.

Meanwhile, the geopolymerization process is considered to stop if the geopolymer chains meet with other cores. The cessation of the process of forming geopolymer chains has an impact on materials that begin to harden. Gerges et al (2024), explained the characteristics of Class C fly ash that hard as cement, the higher the intensity of Class C fly ash, the lower the strength and modulus of elasticity. It contains a higher percentage of calcium oxide with a carbon content of less than 2 percent. This class of fly ash has self-cementing and pozzolanic properties.

CHAPTER VI

CONCLUSION AND SUGGESTION

6.1 Conclusion

Based on the results of the discussion of this study, the following conclusions are obtained.

1. The optimal substitution ratios of fly ash in concrete to achieve the desired properties and performance, such as slump test, modulus of elasticity, compressive strength, and tensile strength is 20% of class C fly ash. In fact, the addition of class C fly ash is more hardening than others with in large portions will actually weaken the compressive strength, split tensile strength, and modulus elasticity of the concrete itself.
2. The influence of Class C Fly Ash as supplementary cementitious material for conventional concrete that the addition of fly ash with a variation of 20% is still able to increase the value of compressive strength, tensile strength and modulus of elasticity. However, the addition of marble ash of more than 20% can reduce the value of compressive strength, tensile strength and modulus of elasticity. The effect of the use of fly ash can produce a strength and modulus elasticity higher than normal concrete, but when the addition of fly ash is greater than 20%, it results in an increase in the compressive strength of the concrete to be low. Fly ash particles being round and fine improves workability and helps getting desired slump. The slump reduction seen higher side in the binder content 35% comparative to others.

6.2 Suggestion

The suggestion for researchers is to maximize the use of Fly Ash by comparing other types of fly ash such as Class F , Class N, and Class C so that they can find the optimal substitution. And in the future, it is hoped that the application of fly ash as a supplementary cementitious material can reduce dust pollution in the environment because fly ash is solid and does not dissolve easily. For future research, can use fly ash with 5%: 10%: and 15% to prove that the use of the mix proportion is optimal compared to 20% fly ash.

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APPENDIX

Appendix 1. Fine Aggregate
Appendix A-1. 1 Comparison of Materials

Description	Observation Result	Unit
Absolute dry weight of sand, grams (Bk)	495,5	gram
Saturated surface dry (SSD) weight of sand, grams	500	gram
Weight of picknometer containing sand and water, grams (Bt)	1004	gram
Weight of picknometer filled with water, grams (B)	696	gram
Bulk specific gravity, $(Bk/(B+500-Bt))$	2,581	
Surface dry saturated specific gravity, $(500/(B+500-Bt))$	2,604	
Apparent specific gravity, $(Bk/(B+Bk-Bt))$	2,643	
Water absorption, $((500-Bk)/(Bk \times 100\%))$	0,908	%

Appendix A-1. 2 Sand Clay Containt Test and Loose Density

Description	Observation Result	Unit
Dry aggregate weight (W1), grams	500	gram
Oven-dry aggregate weight after washed (W2), grams	491	gram
No.200 sieve passing weight	1,8	%

Description	Observation Result	Unit
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram
Cylinders + oven-dry aggregate weight (W2)	15738	gram
Aggregate weight (W3)	6842	gram
Cylinders volume (V)	5301,438	cm3
Loose Density, (W3/V)	1,291	gram/ cm3

Appendix A-1. 3 Sieve Analysis Test

Sieve Hole (mm)	Retained Weight (gr)	Retained Weight (%)	Comulative Retained Weight (%)	Comulative Passing Weight (%)
40		0,000	0,000	100,000
20		0,000	0,000	100,000
10		0,000	0,000	100,000
4,8	42	2,102	2,102	97,898
2,4	173	8,659	10,761	89,239
1,2	282	14,114	24,875	75,125
0,6	524	26,226	51,101	48,899
0,3	534	26,727	77,828	22,172
0,15	355	17,768	95,596	4,404
Remaints	88	4,404		
Sumation	1998	100,000	262,262	

Fineness Modulus	=	2,623
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Appendix 2. Coarse Aggregate

Appendix A-2. 1 Examination of Specific Gravity and Water Absorption

Description	Observation Result	Unit
Absolute dry gravel weight, grams (Bk)	4873	gram
Weight of gravel in saturated dry face condition (SSD), grams (Bj)	5000	gram
Weight of gravel in water, grams (Ba)	3124,5	gram
Bulk specific gravity ($Bk/(Bj-Ba)$)	2,598	
Face dry specific gravity ($Bj/(Bj-Ba)$)	2,666	
Apparent specific gravity ($Bk/(Bk-Ba)$)	2,787	
Water absorption ($((Bj-Bk)/(Bk \times 100\%))$)	2,606	%

Appendix A-2. 2 Loose Density

Description	Observation Result	
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram
Cylinders + oven-dry aggregate weight (W2)	16586	gram
Aggregate weight (W3)	7690	gram
Cylinders volume (V)	5301,438	cm ³
Loose Density, (W3/V)	1,451	gram/cm ³

Appendix A-2. 3 Dense Density

Description	Observation Result	
Cylinder diameter	15	cm
Cylinder height	30	cm
Cylinder weight	8896	gram
Cylinders + oven-dry aggregate weight (W2)	17347	gram
Aggregate weight (W3)	8451	gram
Cylinders volume (V)	5301,438	cm ³
Dense Density, (W3/V)	1,594	gram/cm ³

Appendix A-2. 4 Sand Clay Containt Test

Description	Observation Result	Unit
Dry aggregate weight (W1), grams	2000	gram
Oven-dry aggregate weight after washed (W2), grams	1986	gram
No.200 sieve passing weight	0,7	%

Appendix 3. Preliminary Data for Mix Design

Preliminary data		Units
Required compressive strength of concrete (f'c)	20	MPa
Type of cement	Type 1	
Type of fine aggregate	Nature	
Type of coarse aggregate	Crushed Stone	
Maximum Aggregate size	20	mm
Slump value	60-180	mm
Specific gravity of fine aggregate	2,581	
Specific gravity of coarse aggregate	2,598	
Number of test object 1 variation	10	pcs
Volume of concrete cylinder (D15x30cm) 1 Variation	0,05301	m3

Appendix 4. Compressive Test Conversion Rate

Conversion Rate for the age of specimen		
Specimen Form	Age of specimen	Conversion Rate
Cylindrical 150x300 mm	14 days	0,88

Appendix 5. Split Tensil Strength Test

Splitting Tensil Strength Test		
Date of made specimen is 03/06/2024 and 05/06/2024 Date of tested is 18/06/2024 and 20/06/2024 Splitting Tensil Strength Test: $T = 2P/\pi Ld$ T: Splitting Tensil Strength Test P: maximum applied load indicated by the testing machine(N) l: lenggth(mm) d: diameter(mm)		
Conversion Rate for the age of specimen		
Specimen Form	Age of specimen	Conversion Rate
Cylindrical 150x300 mm	14 days	0,88

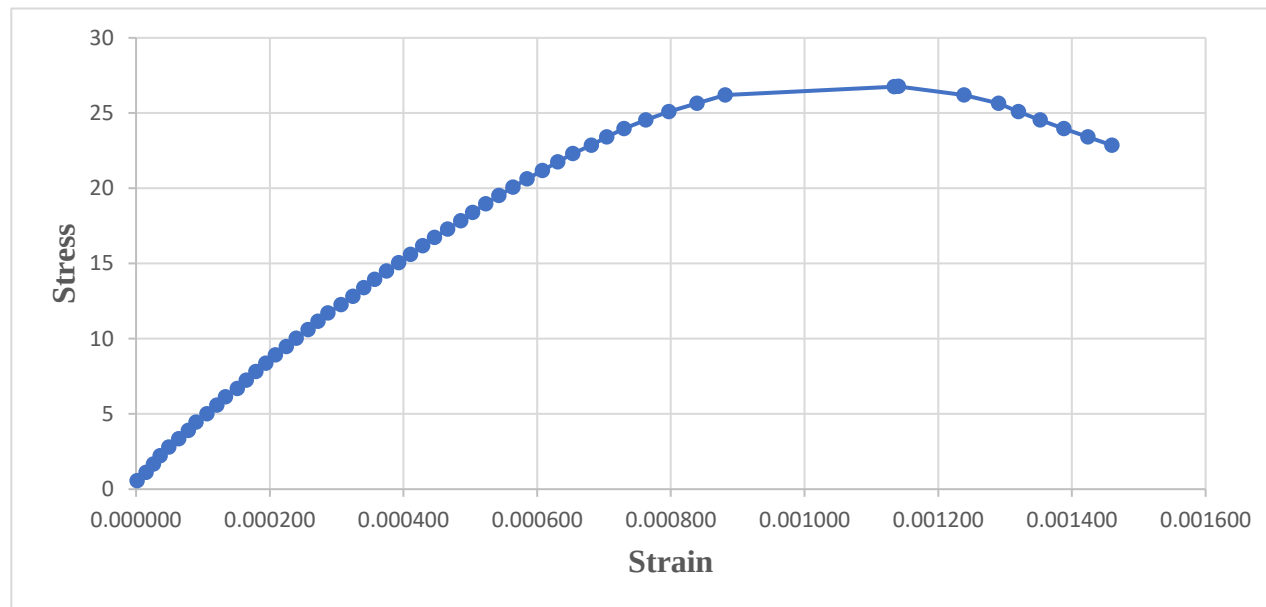
Appendix A-6. 1 Modulus Elasticity 0% Cylinder 1

0% fly ash, cylinder 1					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	1	10000	0,0005	0,000002	0,557527417
20	9	20000	0,0045	0,000015	1,115054833
30	16	30000	0,008	0,000026	1,67258225
40	22	40000	0,011	0,000036	2,230109666
50	30	50000	0,015	0,000049	2,787637083
60	39	60000	0,0195	0,000064	3,345164499
70	48	70000	0,024	0,000078	3,902691916
80	55	80000	0,0275	0,000090	4,460219333
90	65	90000	0,0325	0,000106	5,017746749
100	74	100000	0,037	0,000121	5,575274166
110	82	110000	0,041	0,000134	6,132801582
120	93	120000	0,0465	0,000152	6,690328999
130	101	130000	0,0505	0,000165	7,247856416
140	110	140000	0,055	0,000179	7,805383832

150	119	150000	0,0595	0,000194	8,362911249
160	128	160000	0,064	0,000209	8,920438665
170	138	170000	0,069	0,000225	9,477966082
180	147	180000	0,0735	0,000239	10,0354935
190	158	190000	0,079	0,000257	10,59302091
200	167	200000	0,0835	0,000272	11,15054833
210	176	210000	0,088	0,000287	11,70807575
220	188	220000	0,094	0,000306	12,26560316
230	199	230000	0,0995	0,000324	12,82313058
240	209	240000	0,1045	0,000341	13,380658
250	219	250000	0,1095	0,000357	13,93818541
260	230	260000	0,115	0,000375	14,49571283
270	241	270000	0,1205	0,000393	15,05324025
280	252	280000	0,126	0,000411	15,61076766
290	263	290000	0,1315	0,000428	16,16829508
300	274	300000	0,137	0,000446	16,7258225
310	286	310000	0,143	0,000466	17,28334991
320	298	320000	0,149	0,000486	17,84087733
330	309	330000	0,1545	0,000503	18,39840475

340	321	340000	0,1605	0,000523	18,95593216
350	333	350000	0,1665	0,000543	19,51345958
360	346	360000	0,173	0,000564	20,070987
370	359	370000	0,1795	0,000585	20,62851441
380	373	380000	0,1865	0,000608	21,18604183
390	387	390000	0,1935	0,000630	21,74356925
400	401	400000	0,2005	0,000653	22,30109666
410	418	410000	0,209	0,000681	22,85862408
420	432	420000	0,216	0,000704	23,4161515
430	448	430000	0,224	0,000730	23,97367891
440	468	440000	0,234	0,000762	24,53120633
450	489	450000	0,2445	0,000797	25,08873375
460	515	460000	0,2575	0,000839	25,64626116
470	541	470000	0,2705	0,000881	26,20378858
480	696	480000	0,348	0,001134	26,761316
480.1	700	480100	0,35	0,001140	26,76689127
470	760	470000	0,38	0,001238	26,20378858
460	792	460000	0,396	0,001290	25,64626116
450	810	450000	0,405	0,001320	25,08873375
440	830	440000	0,415	0,001352	24,53120633

430	852	430000	0,426	0,001388	23,97367891
420	874	420000	0,437	0,001424	23,4161515
410	896	410000	0,448	0,001460	22,85862408

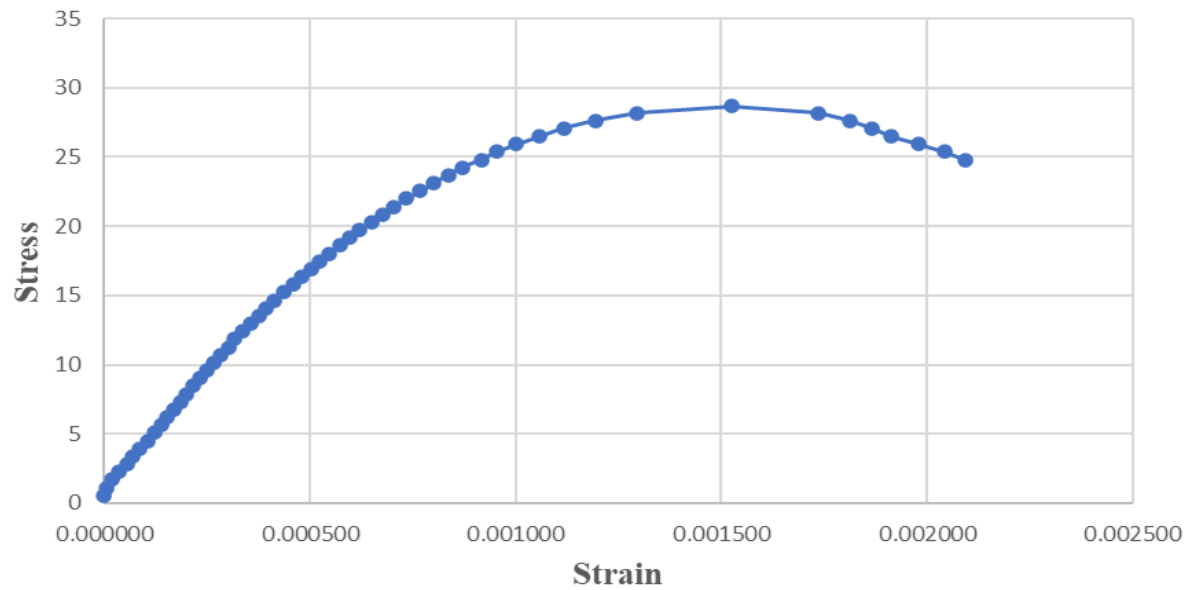


Appendix A-6. 2 Modulus Elasticity 0% Cylinder 2

0% fly ash, cylinder 2					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	1	10000	0.0005	0.000002	0.569675751
20	8	20000	0.004	0.000013	1.139351501
30	17	30000	0.0085	0.000028	1.709027252
40	25	40000	0.0125	0.000041	2.278703003
50	34	50000	0.017	0.000056	2.848378754
60	42	60000	0.021	0.000069	3.418054504
70	50	70000	0.025	0.000082	3.987730255
80	58	80000	0.029	0.000095	4.557406006
90	67	90000	0.0335	0.000110	5.127081756
100	78	100000	0.039	0.000128	5.696757507
110	86	110000	0.043	0.000141	6.266433258
120	94	120000	0.047	0.000154	6.836109009
130	102	130000	0.051	0.000167	7.405784759
140	111	140000	0.0555	0.000182	7.97546051
150	121	150000	0.0605	0.000198	8.545136261
160	130	160000	0.065	0.000213	9.114812011
170	139	170000	0.0695	0.000228	9.684487762
180	149	180000	0.0745	0.000244	10.25416351
190	159	190000	0.0795	0.000261	10.82383926

200	169	200000	0.0845	0.000277	11.39351501
210	179	210000	0.0895	0.000293	11.96319076
220	190	220000	0.095	0.000311	12.53286652
230	199	230000	0.0995	0.000326	13.10254227
240	210	240000	0.105	0.000344	13.67221802
250	220	250000	0.11	0.000361	14.24189377
260	231	260000	0.1155	0.000379	14.81156952
270	242	270000	0.121	0.000397	15.38124527
280	252	280000	0.126	0.000413	15.95092102
290	263	290000	0.1315	0.000431	16.52059677
300	273	300000	0.1365	0.000447	17.09027252
310	286	310000	0.143	0.000469	17.65994827
320	298	320000	0.149	0.000488	18.22962402
330	311	330000	0.1555	0.000510	18.79929977
340	322	340000	0.161	0.000528	19.36897552
350	337	350000	0.1685	0.000552	19.93865127
360	351	360000	0.1755	0.000575	20.50832703
370	366	370000	0.183	0.000600	21.07800278
380	380	380000	0.19	0.000623	21.64767853
390	396	390000	0.198	0.000649	22.21735428
400	413	400000	0.2065	0.000677	22.78703003
410	427	410000	0.2135	0.000700	23.35670578
420	446	420000	0.223	0.000731	23.92638153
430	463	430000	0.2315	0.000759	24.49605728
440	487	440000	0.2435	0.000798	25.06573303
450	521	450000	0.2605	0.000854	25.63540878
460	580	460000	0.29	0.000951	26.20508453

463.3	623	463300	0.3115	0.001021	26.39307753
460	648	460000	0.324	0.001062	26.20508453
450	708	450000	0.354	0.001160	25.63540878
440	787	440000	0.3935	0.001290	25.06573303
430	852	430000	0.426	0.001396	24.49605728
420	908	420000	0.454	0.001488	23.92638153
410	956	410000	0.478	0.001567	23.35670578
400	1001	400000	0.5005	0.001640	22.78703003

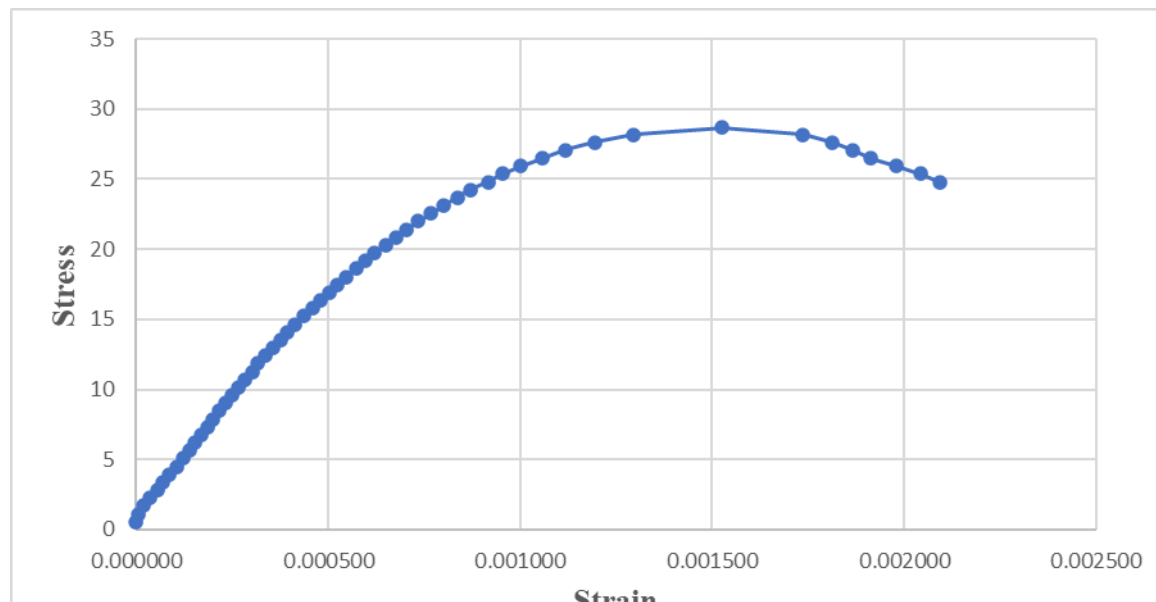


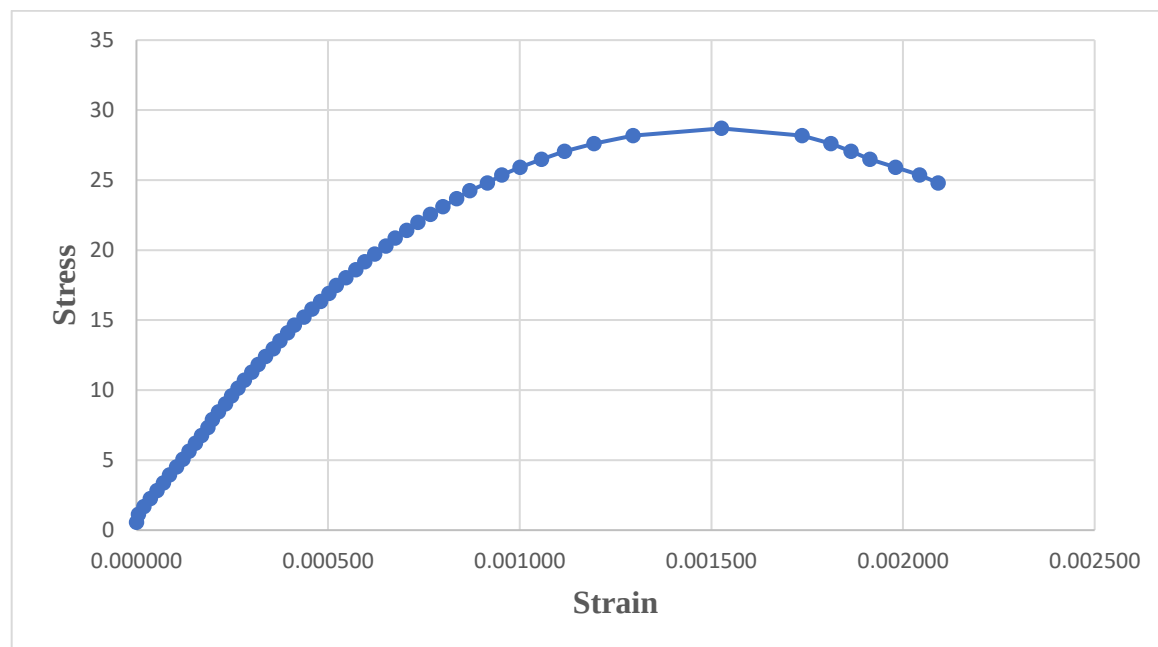
Appendix A-6. 3 Modulus Elasticity 0% Cylinder 3

0% fly ash, cylinder 3					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0.000000	0.563627478
20	3	20000	0.0015	0.000005	1.127254955
30	12	30000	0.006	0.000020	1.690882433
40	22	40000	0.011	0.000036	2.254509911
50	33	50000	0.0165	0.000054	2.818137388
60	43	60000	0.0215	0.000070	3.381764866
70	53	70000	0.0265	0.000087	3.945392344
80	64	80000	0.032	0.000105	4.509019821
90	74	90000	0.037	0.000121	5.072647299
100	84	100000	0.042	0.000137	5.636274777
110	94	110000	0.047	0.000154	6.199902255
120	104	120000	0.052	0.000170	6.763529732
130	114	130000	0.057	0.000186	7.32715721
140	121	140000	0.0605	0.000198	7.890784688
150	131	150000	0.0655	0.000214	8.454412165

160	142	160000	0.071	0.000232	9.018039643
170	152	170000	0.076	0.000249	9.581667121
180	162	180000	0.081	0.000265	10.1452946
190	172	190000	0.086	0.000281	10.70892208
200	184	200000	0.092	0.000301	11.27254955
210	194	210000	0.097	0.000317	11.83617703
220	206	220000	0.103	0.000337	12.39980451
230	218	230000	0.109	0.000357	12.96343199
240	229	240000	0.1145	0.000375	13.52705946
250	241	250000	0.1205	0.000394	14.09068694
260	252	260000	0.126	0.000412	14.65431442
270	267	270000	0.1335	0.000437	15.2179419
280	280	280000	0.14	0.000458	15.78156938
290	294	290000	0.147	0.000481	16.34519685
300	307	300000	0.1535	0.000502	16.90882433
310	319	310000	0.1595	0.000522	17.47245181
320	334	320000	0.167	0.000546	18.03607929
330	350	330000	0.175	0.000572	18.59970676
340	364	340000	0.182	0.000595	19.16333424
350	380	350000	0.19	0.000622	19.72696172
360	398	360000	0.199	0.000651	20.2905892
370	413	370000	0.2065	0.000675	20.85421667
380	431	380000	0.2155	0.000705	21.41784415
390	449	390000	0.2245	0.000734	21.98147163
400	469	400000	0.2345	0.000767	22.54509911
410	489	410000	0.2445	0.000800	23.10872659
420	511	420000	0.2555	0.000836	23.67235406

430	532	430000	0.266	0.000870	24.23598154
440	560	440000	0.28	0.000916	24.79960902
450	583	450000	0.2915	0.000954	25.3632365
460	612	460000	0.306	0.001001	25.92686397
470	646	470000	0.323	0.001057	26.49049145
480	683	480000	0.3415	0.001117	27.05411893
490	730	490000	0.365	0.001194	27.61774641
500	792	500000	0.396	0.001295	28.18137388
509.1	933	509100	0.4665	0.001526	28.69427489
500	1062	500000	0.531	0.001737	28.18137388
490	1108	490000	0.554	0.001812	27.61774641
480	1140	480000	0.57	0.001865	27.05411893
470	1170	470000	0.585	0.001914	26.49049145
460	1211	460000	0.6055	0.001981	25.92686397
450	1249	450000	0.6245	0.002043	25.3632365
440	1279	440000	0.6395	0.002092	24.79960902



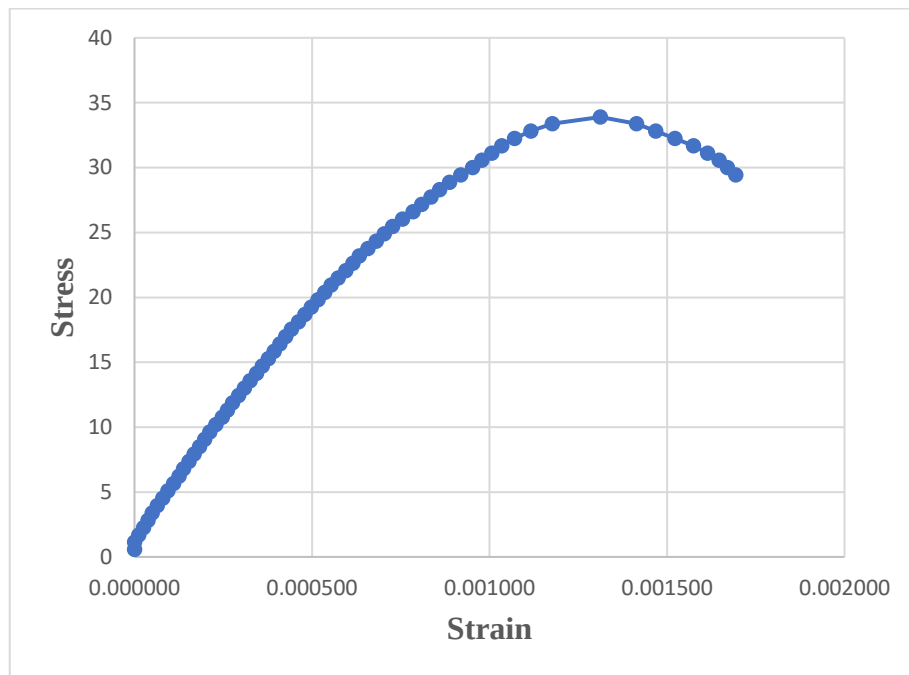


Appendix A-6. 4 Modulus Elasticity 20% Cylinder 1

20% fly ash, cylinder 1					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,565884242
20	0	20000	0	0,000000	1,131768484
30	7	30000	0,0035	0,000012	1,697652726
40	15	40000	0,0075	0,000025	2,263536968
50	23	50000	0,0115	0,000038	2,829421211
60	30	60000	0,015	0,000049	3,395305453
70	39	70000	0,0195	0,000064	3,961189695
80	48	80000	0,024	0,000079	4,527073937
90	57	90000	0,0285	0,000094	5,092958179
100	67	100000	0,0335	0,000110	5,658842421
110	76	110000	0,038	0,000125	6,224726663
120	84	120000	0,042	0,000138	6,790610905
130	93	130000	0,0465	0,000153	7,356495147
140	102	140000	0,051	0,000168	7,922379389
150	111	150000	0,0555	0,000182	8,488263632
160	120	160000	0,06	0,000197	9,054147874
170	129	170000	0,0645	0,000212	9,620032116
180	139	180000	0,0695	0,000228	10,18591636
190	150	190000	0,075	0,000247	10,7518006

200	159	200000	0,0795	0,000261	11,31768484
210	168	210000	0,084	0,000276	11,88356908
220	178	220000	0,089	0,000293	12,44945333
230	188	230000	0,094	0,000309	13,01533757
240	198	240000	0,099	0,000325	13,58122181
250	209	250000	0,1045	0,000344	14,14710605
260	219	260000	0,1095	0,000360	14,71299029
270	229	270000	0,1145	0,000376	15,27887454
280	239	280000	0,1195	0,000393	15,84475878
290	249	290000	0,1245	0,000409	16,41064302
300	259	300000	0,1295	0,000426	16,97652726
310	269	310000	0,1345	0,000442	17,54241151
320	281	320000	0,1405	0,000462	18,10829575
330	292	330000	0,146	0,000480	18,67417999
340	303	340000	0,1515	0,000498	19,24006423
350	314	350000	0,157	0,000516	19,80594847
360	326	360000	0,163	0,000536	20,37183272
370	337	370000	0,1685	0,000554	20,93771696
380	349	380000	0,1745	0,000574	21,5036012
390	362	390000	0,181	0,000595	22,06948544
400	374	400000	0,187	0,000615	22,63536968
410	385	410000	0,1925	0,000633	23,20125393
420	400	420000	0,2	0,000657	23,76713817
430	414	430000	0,207	0,000680	24,33302241

440	428	440000	0,214	0,000703	24,89890665
450	442	450000	0,221	0,000726	25,46479089
460	459	460000	0,2295	0,000754	26,03067514
470	477	470000	0,2385	0,000784	26,59655938
480	492	480000	0,246	0,000809	27,16244362
490	508	490000	0,254	0,000835	27,72832786
500	523	500000	0,2615	0,000860	28,29421211
510	540	510000	0,27	0,000888	28,86009635
520	559	520000	0,2795	0,000919	29,42598059
530	579	530000	0,2895	0,000952	29,99186483
540	595	540000	0,2975	0,000978	30,1064805
550	612	550000	0,306	0,001006	30,66400791
560	629	560000	0,3145	0,001034	31,22153533
570	651	570000	0,3255	0,001070	31,77906274
580	679	580000	0,3395	0,001116	32,33659016
590	716	590000	0,358	0,001177	32,89411758
599	798	599000	0,399	0,001312	33,39584661
590	860	590000	0,43	0,001414	33,38717028
580	893	580000	0,4465	0,001468	32,82128604
570	926	570000	0,463	0,001522	32,2554018
560	958	560000	0,479	0,001575	31,68951756
550	982	550000	0,491	0,001614	31,12363332
540	1002	540000	0,501	0,001647	30,55774907
530	1016	530000	0,508	0,001670	29,99186483
520	1030	520000	0,515	0,001693	29,42598059



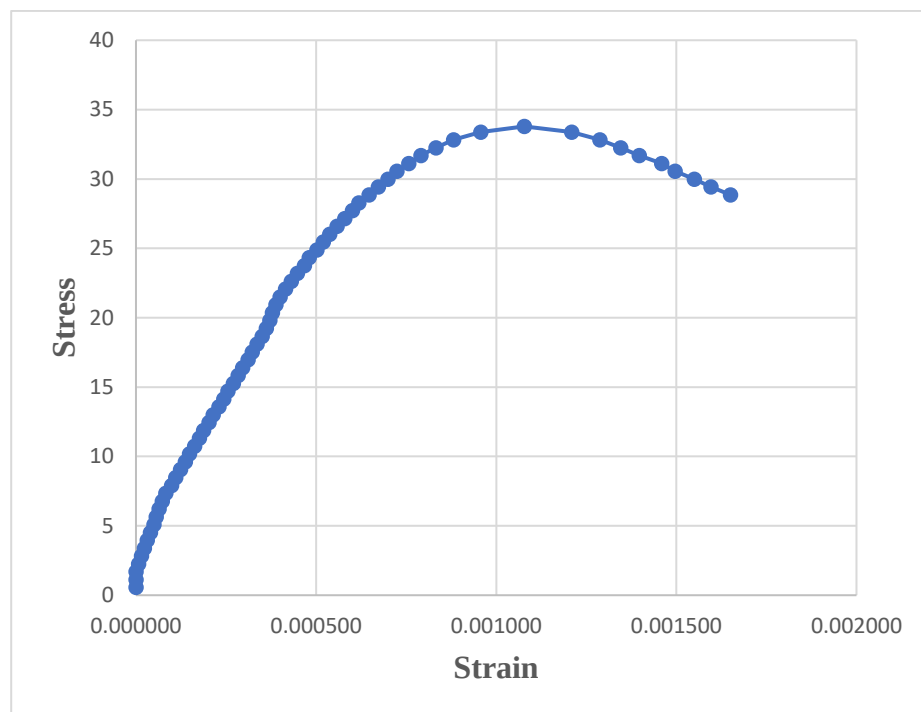
Appendix A-6. 5 Modulus Elasticity 20% Cylinder 2

20% fly ash, cylinder 2					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,565884242
20	0	20000	0	0,000000	1,131768484
30	0	30000	0	0,000000	1,697652726
40	4	40000	0,002	0,000007	2,263536968
50	9	50000	0,0045	0,000015	2,829421211
60	14	60000	0,007	0,000023	3,395305453
70	19	70000	0,0095	0,000031	3,961189695
80	24	80000	0,012	0,000039	4,527073937
90	30	90000	0,015	0,000049	5,032958179
100	34	100000	0,017	0,000056	5,658842421
110	39	110000	0,0195	0,000064	6,224726663
120	44	120000	0,022	0,000072	6,790610905
130	50	130000	0,025	0,000082	7,356495147
140	60	140000	0,03	0,000099	7,922379389
150	67	150000	0,0335	0,000110	8,488263632
160	75	160000	0,0375	0,000123	9,054147874
170	83	170000	0,0415	0,000137	9,620032116
180	90	180000	0,045	0,000148	10,18591636
190	99	190000	0,0495	0,000163	10,7518006

200	107	200000	0,0535	0,000176	11,31768484
210	114	210000	0,057	0,000188	11,88356908
220	123	220000	0,0615	0,000202	12,44945333
230	130	230000	0,065	0,000214	13,01533757
240	140	240000	0,07	0,000230	13,58122181
250	148	250000	0,074	0,000243	14,14710605
260	155	260000	0,0775	0,000255	14,71299029
270	164	270000	0,082	0,000270	15,27887454
280	172	280000	0,086	0,000283	15,84475878
290	180	290000	0,09	0,000296	16,41064302
300	189	300000	0,0945	0,000311	16,97652726
310	196	310000	0,098	0,000322	17,54241151
320	204	320000	0,102	0,000336	18,10829575
330	213	330000	0,1065	0,000350	18,67417999
340	220	340000	0,11	0,000362	19,24006423
350	226	350000	0,113	0,000372	19,80594847
360	230	360000	0,115	0,000378	20,37183272
370	236	370000	0,118	0,000388	20,93771696
380	243	380000	0,1215	0,000400	21,5036012
390	252	390000	0,126	0,000414	22,06948544
400	262	400000	0,131	0,000431	22,63536968
410	272	410000	0,136	0,000447	23,20125393
420	284	420000	0,142	0,000467	23,76713817
430	292	430000	0,146	0,000480	24,33302241
440	305	440000	0,1525	0,000502	24,89890665

450	316	450000	0,158	0,000520	25,46479089
460	327	460000	0,1635	0,000538	26,03067514
470	339	470000	0,1695	0,000558	26,59655938
480	352	480000	0,176	0,000579	27,16244362
490	365	490000	0,1825	0,000600	27,72832786
500	376	500000	0,188	0,000618	28,29421211
510	393	510000	0,1965	0,000646	28,86009635
520	409	520000	0,2045	0,000673	29,42598059
530	425	530000	0,2125	0,000699	29,67449283
540	440	540000	0,22	0,000724	30,23438892
550	460	550000	0,23	0,000757	30,79428502
560	481	560000	0,2405	0,000791	31,35418111
570	506	570000	0,253	0,000832	31,9140772
580	536	580000	0,268	0,000882	32,47397329
590	582	590000	0,291	0,000957	33,03386938
597,1	655	597100	0,3275	0,001077	33,43139561
590	735	590000	0,3675	0,001209	33,03386938
580	783	580000	0,3915	0,001288	32,47397329
570	818	570000	0,409	0,001345	31,9140772
560	849	560000	0,4245	0,001396	31,35418111
550	887	550000	0,4435	0,001459	30,79428502
540	910	540000	0,455	0,001497	30,23438892
530	942	530000	0,471	0,001549	29,67449283
520	970	520000	0,485	0,001595	29,11459674

510	1003	510000	0,5015	0,001650	28,55470065
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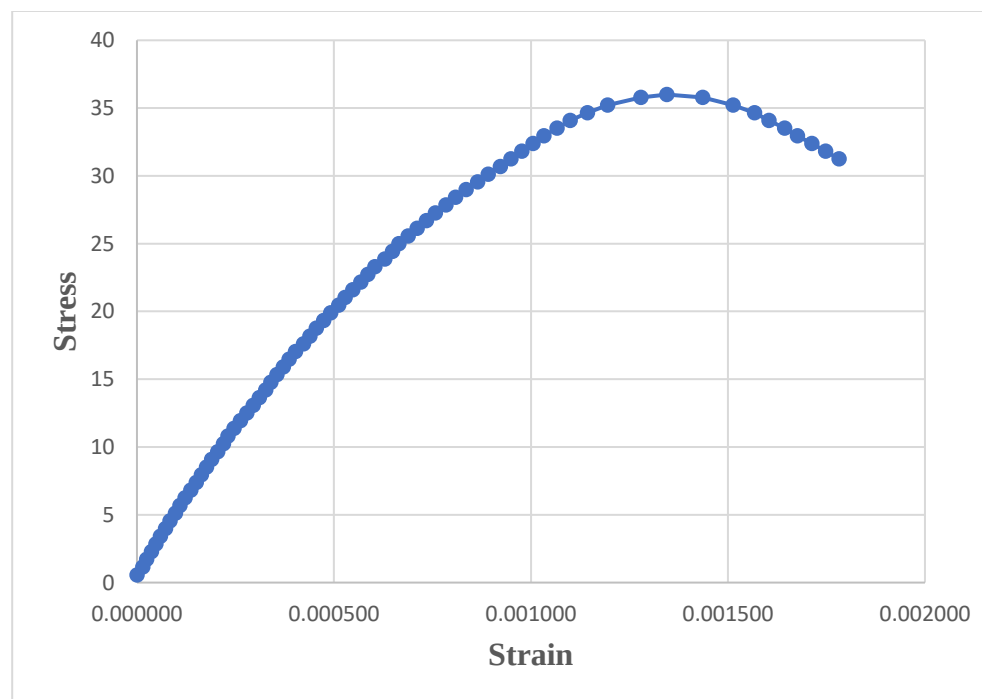
Appendix A-6. 6 Modulus Elasticity 20% Cylinder 3

20% fly ash, cylinder 3					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,565884242
20	9	20000	0,0045	0,000015	1,131768484
30	15	30000	0,0075	0,000025	1,697652726
40	22	40000	0,011	0,000036	2,263536968
50	29	50000	0,0145	0,000048	2,829421211
60	36	60000	0,018	0,000059	3,395305453
70	44	70000	0,022	0,000073	3,961189695
80	51	80000	0,0255	0,000084	4,527073937
90	59	90000	0,0295	0,000097	5,092958179
100	66	100000	0,033	0,000109	5,658842421
110	74	110000	0,037	0,000122	6,224726663
120	83	120000	0,0415	0,000137	6,790610905
130	91	130000	0,0455	0,000150	7,356495147
140	99	140000	0,0495	0,000163	7,922379389
150	107	150000	0,0535	0,000177	8,488263632
160	115	160000	0,0575	0,000190	9,054147874
170	124	170000	0,062	0,000205	9,620032116
180	133	180000	0,0665	0,000219	10,18591636
190	140	190000	0,07	0,000231	10,7518006

200	149	200000	0,0745	0,000246	11,31768484
210	159	210000	0,0795	0,000262	11,88356908
220	169	220000	0,0845	0,000279	12,44945333
230	179	230000	0,0895	0,000295	13,01533757
240	188	240000	0,094	0,000310	13,58122181
250	198	250000	0,099	0,000327	14,14710605
260	206	260000	0,103	0,000340	14,71299029
270	215	270000	0,1075	0,000355	15,27887454
280	225	280000	0,1125	0,000371	15,84475878
290	234	290000	0,117	0,000386	16,41064302
300	244	300000	0,122	0,000403	16,97652726
310	256	310000	0,128	0,000422	17,54241151
320	266	320000	0,133	0,000439	18,10829575
330	276	330000	0,138	0,000455	18,67417999
340	287	340000	0,1435	0,000474	19,24006423
350	298	350000	0,149	0,000492	19,80594847
360	310	360000	0,155	0,000512	20,37183272
370	320	370000	0,16	0,000528	20,93771696
380	332	380000	0,166	0,000548	21,5036012
390	344	390000	0,172	0,000568	22,06948544
400	355	400000	0,1775	0,000586	22,63536968
410	366	410000	0,183	0,000604	23,20125393
420	381	420000	0,1905	0,000629	23,76713817
430	393	430000	0,1965	0,000649	24,33302241
440	403	440000	0,2015	0,000665	24,89890665

450	417	450000	0,2085	0,000688	25,46479089
460	431	460000	0,2155	0,000711	26,03067514
470	445	470000	0,2225	0,000734	26,59655938
480	459	480000	0,2295	0,000757	27,16244362
490	475	490000	0,2375	0,000784	27,72832786
500	490	500000	0,245	0,000809	28,29421211
510	506	510000	0,253	0,000835	28,86009635
520	524	520000	0,262	0,000865	29,42598059
530	540	530000	0,27	0,000891	29,99186483
540	559	540000	0,2795	0,000922	30,55774907
550	575	550000	0,2875	0,000949	31,12363332
560	592	560000	0,296	0,000977	31,68951756
570	609	570000	0,3045	0,001005	32,38481151
580	626	580000	0,313	0,001033	32,95296609
590	646	590000	0,323	0,001066	33,52112068
600	666	600000	0,333	0,001099	34,08927527
610	693	610000	0,3465	0,001144	34,65742986
620	724	620000	0,362	0,001195	35,22558445
630	775	630000	0,3875	0,001279	35,79373903
633,6	815	633600	0,4075	0,001345	35,99827469
630	870	630000	0,435	0,001436	35,79373903
620	917	620000	0,4585	0,001513	35,22558445
610	950	610000	0,475	0,001568	34,65742986
600	972	600000	0,486	0,001604	34,08927527
590	996	590000	0,498	0,001644	33,52112068

580	1016	580000	0,508	0,001677	32,95296609
570	1038	570000	0,519	0,001713	32,38481151
560	1059	560000	0,5295	0,001748	31,81665692
550	1080	550000	0,54	0,001782	31,24850233

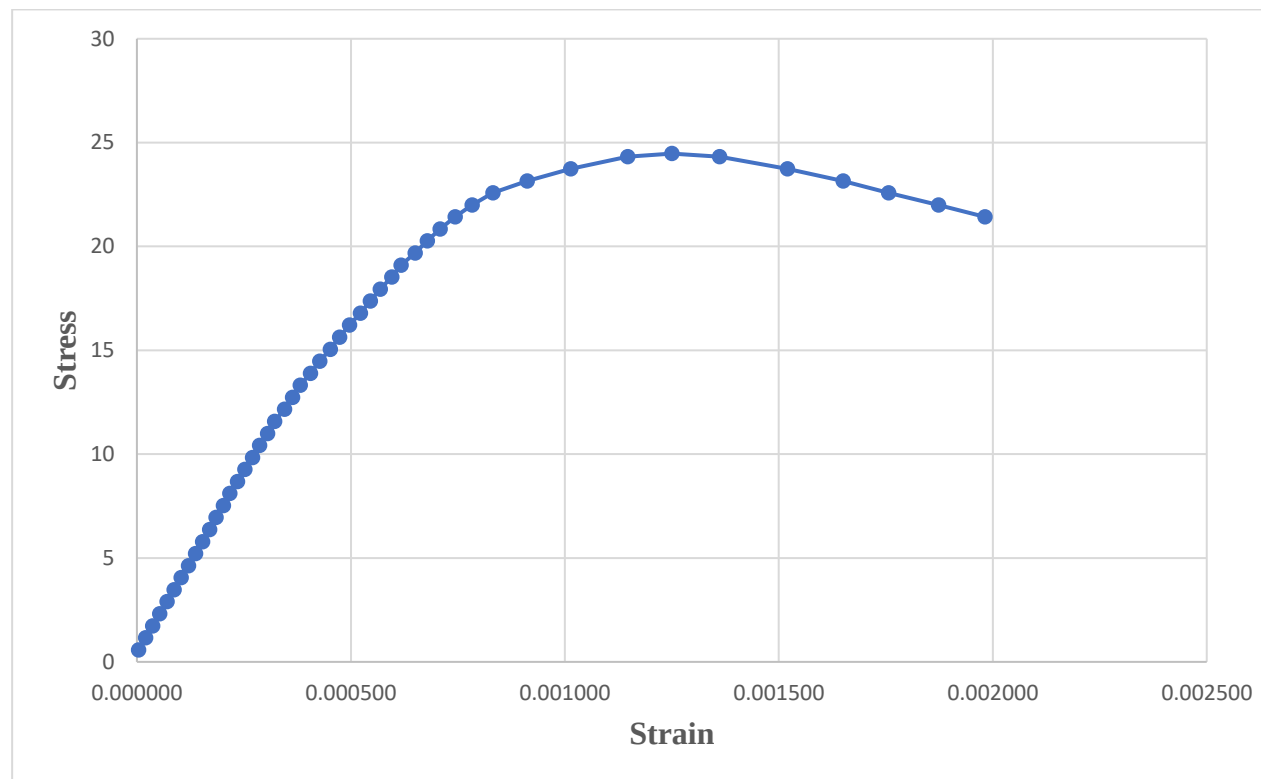


Appendix A-6. 7 Modulus Elasticity 25% Cylinder 1

25% fly ash, cylinder 1					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	2	10000	0,001	0,000003	0,578932348
20	12	20000	0,006	0,000020	1,157864696
30	22	30000	0,011	0,000037	1,736797044
40	32	40000	0,016	0,000053	2,315729392
50	42	50000	0,021	0,000070	2,89466174
60	52	60000	0,026	0,000087	3,473594088
70	62	70000	0,031	0,000103	4,052526436
80	72	80000	0,036	0,000120	4,631458784
90	82	90000	0,041	0,000137	5,210391132
100	92	100000	0,046	0,000153	5,78932348
110	102	110000	0,051	0,000170	6,368255828
120	111	120000	0,0555	0,000185	6,947188176
130	121	130000	0,0605	0,000202	7,526120524
140	130	140000	0,065	0,000217	8,105052872
150	141	150000	0,0705	0,000235	8,68398522
160	151	160000	0,0755	0,000252	9,262917568
170	162	170000	0,081	0,000270	9,841849916
180	172	180000	0,086	0,000287	10,42078226

190	183	190000	0,0915	0,000305	10,99971461
200	193	200000	0,0965	0,000322	11,57864696
210	207	210000	0,1035	0,000345	12,15757931
220	218	220000	0,109	0,000363	12,73651166
230	229	230000	0,1145	0,000382	13,315444
240	243	240000	0,1215	0,000405	13,89437635
250	256	250000	0,128	0,000427	14,4733087
260	271	260000	0,1355	0,000452	15,05224105
270	284	270000	0,142	0,000473	15,6311734
280	298	280000	0,149	0,000497	16,21010574
290	313	290000	0,1565	0,000522	16,78903809
300	327	300000	0,1635	0,000545	17,36797044
310	341	310000	0,1705	0,000568	17,94690279
320	357	320000	0,1785	0,000595	18,52583514
330	370	330000	0,185	0,000617	19,10476748
340	390	340000	0,195	0,000650	19,68369983
350	407	350000	0,2035	0,000678	20,26263218
360	425	360000	0,2125	0,000708	20,84156453
370	446	370000	0,223	0,000743	21,42049688
380	470	380000	0,235	0,000783	21,99942922
390	499	390000	0,2495	0,000832	22,57836157
400	547	400000	0,2735	0,000912	23,15729392
410	608	410000	0,304	0,001013	23,73622627
420	688	420000	0,344	0,001147	24,31515862

422.7	750	422700	0,375	0,001250	24,47147035
420	817	420000	0,4085	0,001362	24,31515862
410	912	410000	0,456	0,001520	23,73622627
400	990	400000	0,495	0,001650	23,15729392
390	1054	390000	0,527	0,001757	22,57836157
380	1124	380000	0,562	0,001873	21,99942922
370	1189	370000	0,5945	0,001982	21,42049688

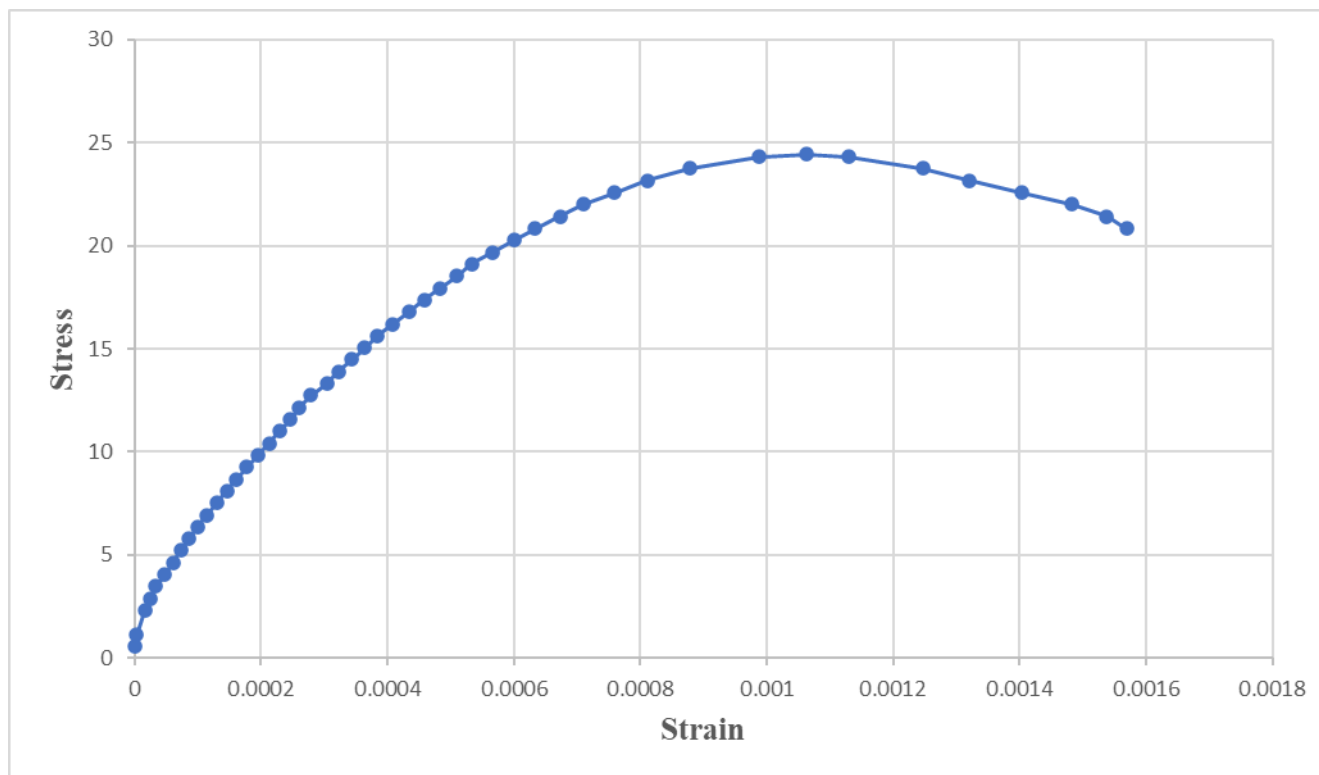


Appendix A-6. 8 Modulus Elasticity 25% Cylinder 2

25% fly ash, cylinder 2					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,565884242
20	0	20000	0	0,000000	1,131768484
30	5	30000	0,0025	0,000008	1,697652726
40	10	40000	0,005	0,000017	2,263536968
50	15	50000	0,0075	0,000025	2,829421211
60	20	60000	0,01	0,000033	3,395305453
70	29	70000	0,0145	0,000048	3,961189695
80	37	80000	0,0185	0,000062	4,527073937
90	44	90000	0,022	0,000073	5,092958179
100	52	100000	0,026	0,000086	5,658842421
110	60	110000	0,03	0,000100	6,224726663
120	69	120000	0,0345	0,000115	6,790610905
130	78	130000	0,039	0,000130	7,356495147
140	88	140000	0,044	0,000146	7,922379389
150	97	150000	0,0485	0,000161	8,488263632
160	107	160000	0,0535	0,000178	9,054147874
170	118	170000	0,059	0,000196	9,620032116
180	128	180000	0,064	0,000213	10,18591636
190	138	190000	0,069	0,000229	10,7518006

200	148	200000	0,074	0,000246	11,31768484
210	157	210000	0,0785	0,000261	11,88356908
220	168	220000	0,084	0,000279	12,44945333
230	183	230000	0,0915	0,000304	13,01533757
240	194	240000	0,097	0,000322	13,58122181
250	207	250000	0,1035	0,000344	14,14710605
260	219	260000	0,1095	0,000364	14,71299029
270	231	270000	0,1155	0,000384	15,27887454
280	246	280000	0,123	0,000409	15,84475878
290	261	290000	0,1305	0,000434	16,78903809
300	276	300000	0,138	0,000459	17,36797044
310	291	310000	0,1455	0,000484	17,94690279
320	307	320000	0,1535	0,000510	18,52583514
330	321	330000	0,1605	0,000534	19,10476748
340	341	340000	0,1705	0,000567	19,68369983
350	361	350000	0,1805	0,000600	20,26263218
360	381	360000	0,1905	0,000633	20,84156453
370	405	370000	0,2025	0,000673	21,42049688
380	427	380000	0,2135	0,000710	21,99942922
390	457	390000	0,2285	0,000760	22,57836157
400	488	400000	0,244	0,000811	23,15729392
410	528	410000	0,264	0,000878	23,73622627
420	594	420000	0,297	0,000987	24,31515862
422	640	422000	0,32	0,001064	24,43094509
420	680	420000	0,34	0,001130	24,31515862

410	750	410000	0,375	0,001247	23,73622627
400	794	400000	0,397	0,001320	23,15729392
390	845	390000	0,4225	0,001405	22,57836157
380	892	380000	0,446	0,001483	21,99942922
370	925	370000	0,4625	0,001538	21,42049688
360	944	360000	0,472	0,001569	20,84156453

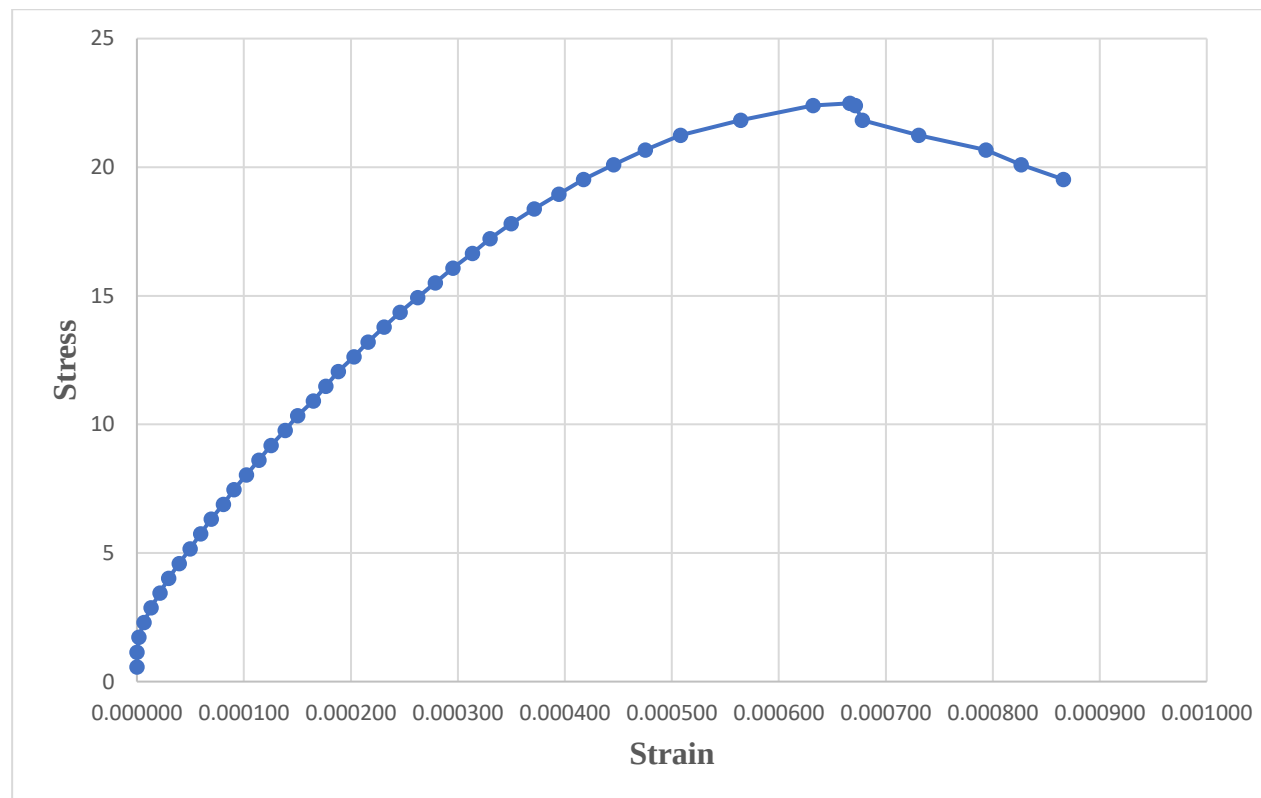


Appendix A-6. 9 Modulus Elasticity 25% Cylinder 3

25% fly ash, cylinder 3					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,574276075
20	0	20000	0	0,000000	1,148552149
30	1	30000	0,0005	0,000002	1,722828224
40	4	40000	0,002	0,000007	2,297104298
50	8	50000	0,004	0,000013	2,871380373
60	13	60000	0,0065	0,000021	3,445656447
70	18	70000	0,009	0,000030	4,019932522
80	24	80000	0,012	0,000040	4,594208597
90	30	90000	0,015	0,000049	5,168484671
100	36	100000	0,018	0,000059	5,742760746
110	42	110000	0,021	0,000069	6,31703682
120	49	120000	0,0245	0,000081	6,891312895
130	55	130000	0,0275	0,000091	7,465588969
140	62	140000	0,031	0,000102	8,039865044
150	69	150000	0,0345	0,000114	8,614141119
160	76	160000	0,038	0,000125	9,188417193
170	84	170000	0,042	0,000139	9,762693268
180	91	180000	0,0455	0,000150	10,33696934
190	100	190000	0,05	0,000165	10,91124542

200	107	200000	0,0535	0,000177	11,48552149
210	114	210000	0,057	0,000188	12,05979757
220	123	220000	0,0615	0,000203	12,63407364
230	131	230000	0,0655	0,000216	13,20834972
240	140	240000	0,07	0,000231	13,78262579
250	149	250000	0,0745	0,000246	14,35690186
260	159	260000	0,0795	0,000262	14,93117794
270	169	270000	0,0845	0,000279	15,50545401
280	179	280000	0,0895	0,000295	16,07973009
290	190	290000	0,095	0,000313	16,65400616
300	200	300000	0,1	0,000330	17,22828224
310	212	310000	0,106	0,000350	17,80255831
320	225	320000	0,1125	0,000371	18,37683439
330	239	330000	0,1195	0,000394	18,95111046
340	253	340000	0,1265	0,000417	19,52538654
350	270	350000	0,135	0,000445	20,09966261
360	288	360000	0,144	0,000475	20,67393868
370	308	370000	0,154	0,000508	21,24821476
380	342	380000	0,171	0,000564	21,82249083
390	383	390000	0,1915	0,000632	22,39676691
391,5	404	391500	0,202	0,000666	22,48290832
390	407	390000	0,2035	0,000671	22,39676691
380	411	380000	0,2055	0,000678	21,82249083
370	443	370000	0,2215	0,000731	21,24821476
360	481	360000	0,2405	0,000793	20,67393868

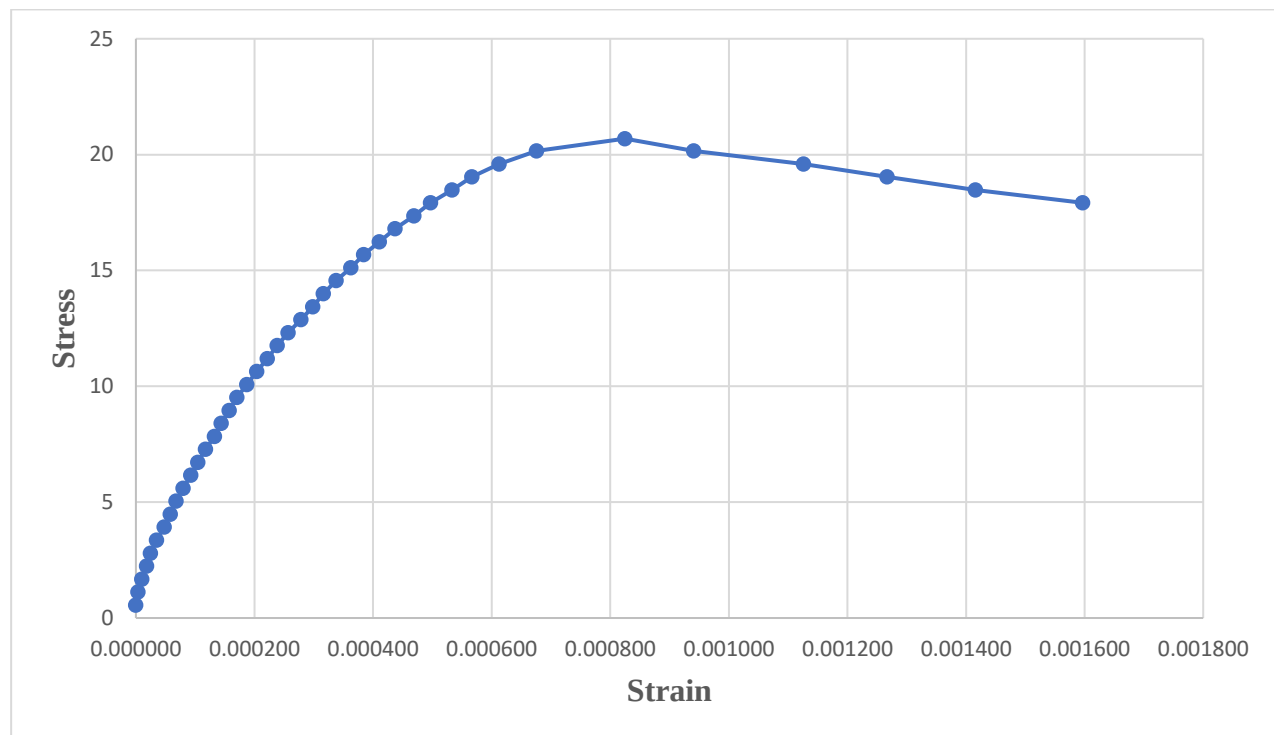
350	501	350000	0,2505	0,000826	20,09966261
340	525	340000	0,2625	0,000866	19,52538654



Appendix A-6. 10 Modulus Elasticity 30% Cylinder 1

30% fly ash, cylinder 1					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,559896091
20	2	20000	0,001	0,000003	1,119792182
30	6	30000	0,003	0,000010	1,679688274
40	11	40000	0,0055	0,000018	2,239584365
50	15	50000	0,0075	0,000025	2,799480456
60	21	60000	0,0105	0,000035	3,359376547
70	29	70000	0,0145	0,000048	3,919272638
80	35	80000	0,0175	0,000058	4,47916873
90	41	90000	0,0205	0,000068	5,039064821
100	48	100000	0,024	0,000079	5,598960912
110	56	110000	0,028	0,000093	6,158857003
120	63	120000	0,0315	0,000104	6,718753094
130	71	130000	0,0355	0,000118	7,278649186
140	80	140000	0,04	0,000132	7,838545277
150	87	150000	0,0435	0,000144	8,398441368
160	95	160000	0,0475	0,000157	8,958337459
170	103	170000	0,0515	0,000171	9,51823355
180	113	180000	0,0565	0,000187	10,07812964
190	123	190000	0,0615	0,000204	10,63802573
200	134	200000	0,067	0,000222	11,19792182

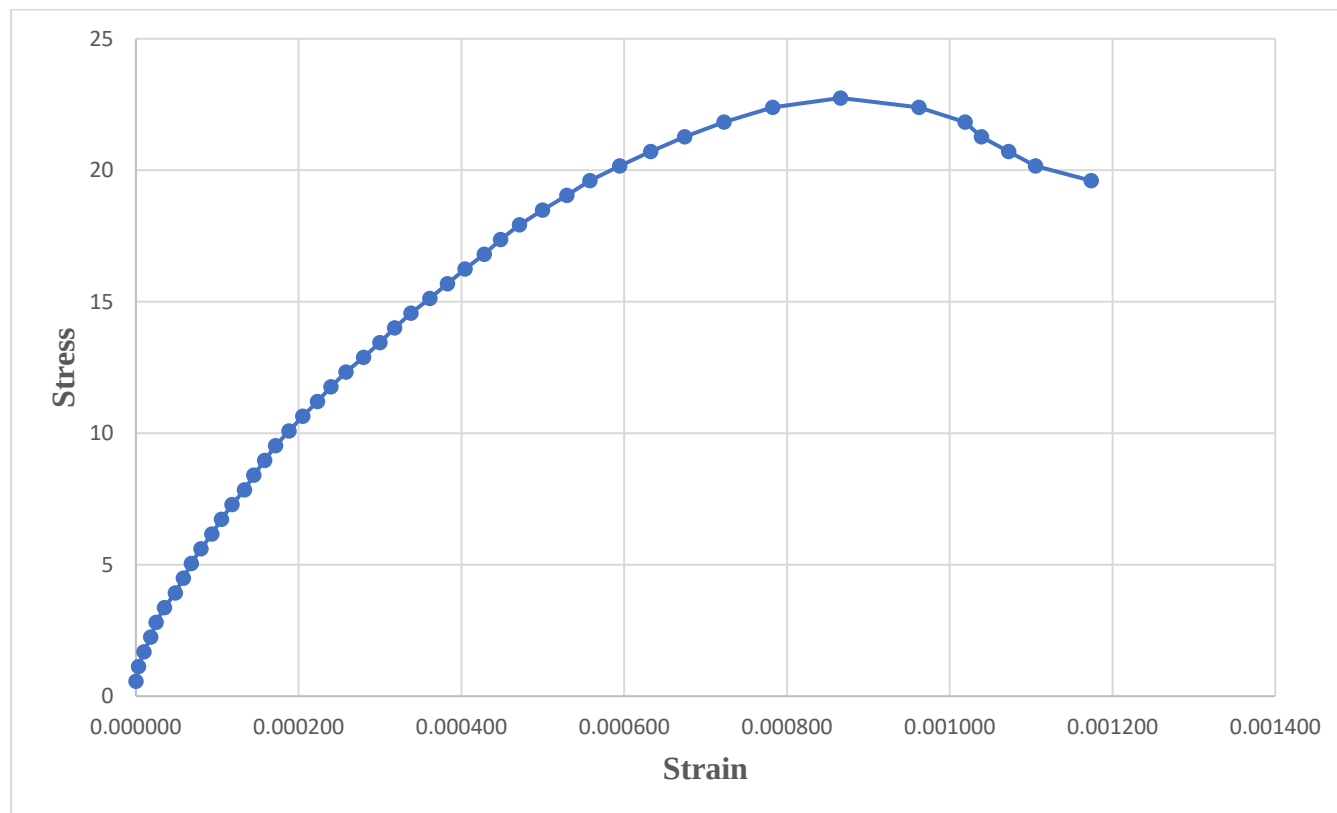
210	144	210000	0,072	0,000238	11,75781792
220	155	220000	0,0775	0,000257	12,31771401
230	168	230000	0,084	0,000278	12,8776101
240	180	240000	0,09	0,000298	13,43750619
250	191	250000	0,0955	0,000316	13,99740228
260	204	260000	0,102	0,000338	14,55729837
270	219	270000	0,1095	0,000363	15,11719446
280	232	280000	0,116	0,000384	15,67709055
290	248	290000	0,124	0,000411	16,23698664
300	264	300000	0,132	0,000437	16,79688274
310	283	310000	0,1415	0,000469	17,35677883
320	300	320000	0,15	0,000497	17,91667492
330	322	330000	0,161	0,000533	18,47657101
340	342	340000	0,171	0,000566	19,0364671
350	370	350000	0,185	0,000613	19,59636319
360	408	360000	0,204	0,000676	20,15625928
369.5	498	369500	0,249	0,000825	20,68816057
360	568	360000	0,284	0,000941	20,15625928
350	680	350000	0,34	0,001126	19,59636319
340	765	340000	0,3825	0,001267	19,0364671
330	855	330000	0,4275	0,001416	18,47657101
320	964	320000	0,482	0,001597	17,91667492



Appendix A-6. 11 Modulus Elasticity 30% Cylinder 2

30% fly ash, cylinder 2					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,559896091
20	2	20000	0,001	0,000003	1,119792182
30	6	30000	0,003	0,000010	1,679688274
40	11	40000	0,0055	0,000018	2,239584365
50	15	50000	0,0075	0,000025	2,799480456
60	21	60000	0,0105	0,000035	3,359376547
70	29	70000	0,0145	0,000048	3,919272638
80	35	80000	0,0175	0,000058	4,47916873
90	41	90000	0,0205	0,000068	5,039064821
100	48	100000	0,024	0,000080	5,598960912
110	56	110000	0,028	0,000093	6,158857003
120	63	120000	0,0315	0,000105	6,718753094
130	71	130000	0,0355	0,000118	7,278649186
140	80	140000	0,04	0,000133	7,838545277
150	87	150000	0,0435	0,000145	8,398441368
160	95	160000	0,0475	0,000158	8,958337459
170	103	170000	0,0515	0,000171	9,51823355
180	113	180000	0,0565	0,000188	10,07812964
190	123	190000	0,0615	0,000205	10,63802573
200	134	200000	0,067	0,000223	11,19792182

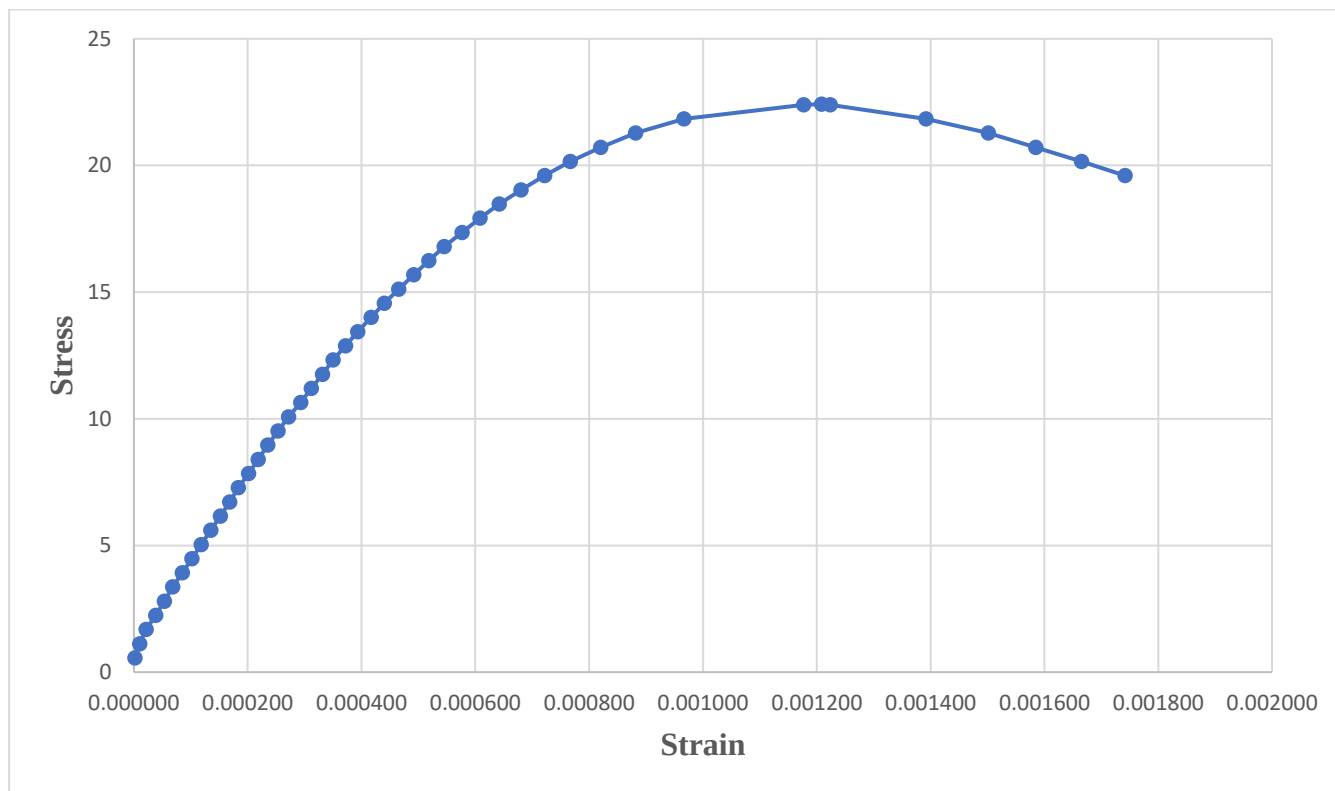
210	144	210000	0,072	0,000240	11,75781792
220	155	220000	0,0775	0,000258	12,31771401
230	168	230000	0,084	0,000280	12,8776101
240	180	240000	0,09	0,000300	13,43750619
250	191	250000	0,0955	0,000318	13,99740228
260	203	260000	0,1015	0,000338	14,55729837
270	217	270000	0,1085	0,000361	15,11719446
280	230	280000	0,115	0,000383	15,67709055
290	243	290000	0,1215	0,000405	16,23698664
300	257	300000	0,1285	0,000428	16,79688274
310	269	310000	0,1345	0,000448	17,35677883
320	283	320000	0,1415	0,000471	17,91667492
330	300	330000	0,15	0,000500	18,47657101
340	318	340000	0,159	0,000529	19,0364671
350	335	350000	0,1675	0,000558	19,59636319
360	357	360000	0,1785	0,000594	20,15625928
370	380	370000	0,19	0,000633	20,71615537
380	405	380000	0,2025	0,000674	21,27605147
390	434	390000	0,217	0,000723	21,83594756
400	470	400000	0,235	0,000783	22,39584365
406.3	520	406300	0,26	0,000866	22,74857819
400	578	400000	0,289	0,000962	22,39584365
390	612	390000	0,306	0,001019	21,83594756
380	624	380000	0,312	0,001039	21,27605147
370	644	370000	0,322	0,001072	20,71615537
360	664	360000	0,332	0,001106	20,15625928
350	705	350000	0,3525	0,001174	19,59636319



Appendix A-6. 12 Modulus Elasticity 30% Cylinder 3

30% fly ash, cylinder 3					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_o$)(mm)	Tension(P/A)(Mpa)(stress)
10	1	10000	0,0005	0,000002	0,559896091
20	6	20000	0,003	0,000010	1,119792182
30	13	30000	0,0065	0,000022	1,679688274
40	23	40000	0,0115	0,000038	2,239584365
50	32	50000	0,016	0,000053	2,799480456
60	41	60000	0,0205	0,000068	3,359376547
70	51	70000	0,0255	0,000085	3,919272638
80	61	80000	0,0305	0,000102	4,47916873
90	71	90000	0,0355	0,000118	5,039064821
100	81	100000	0,0405	0,000135	5,598960912
110	91	110000	0,0455	0,000152	6,158857003
120	101	120000	0,0505	0,000168	6,718753094
130	110	130000	0,055	0,000183	7,278649186
140	121	140000	0,0605	0,000202	7,838545277
150	131	150000	0,0655	0000218	8,398441368
160	141	160000	0,0705	0,000235	8,958337459
170	152	170000	0,076	0,000253	9,51823355
180	163	180000	0,0815	0,000272	10,07812964
190	176	190000	0,088	0,000293	10,63802573
200	187	200000	0,0935	0,000312	11,19792182
210	199	210000	0,0995	0,000332	11,75781792

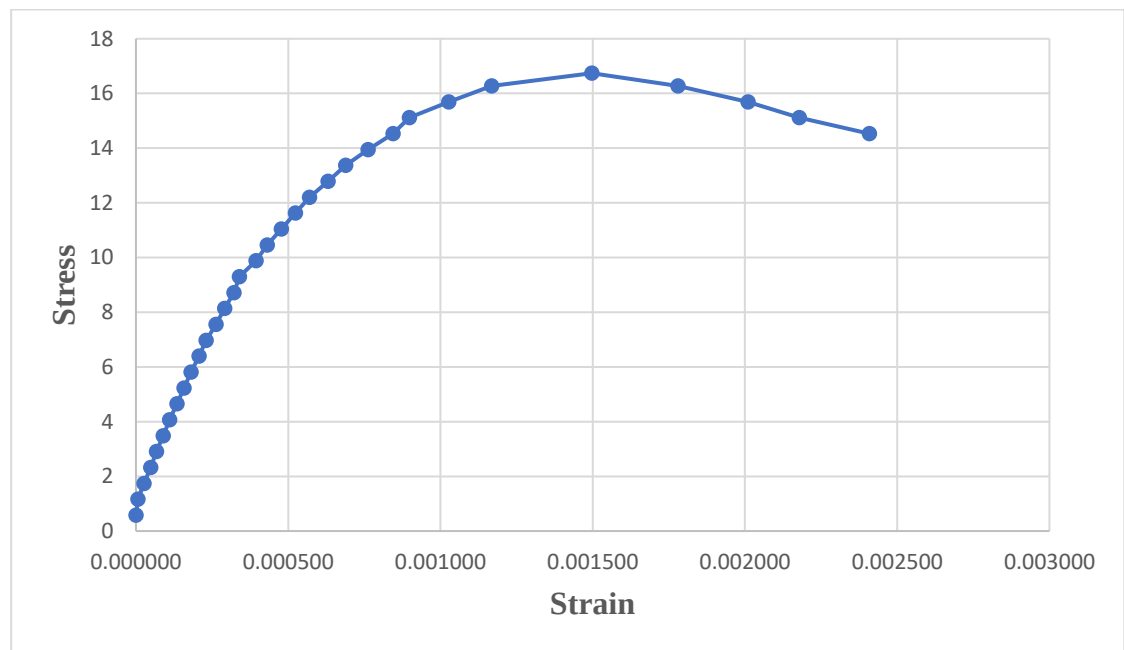
220	210	220000	0,105	0,000350	12,31771401
230	223	230000	0,1115	0,000372	12,8776101
240	236	240000	0,118	0,000393	13,43750619
250	250	250000	0,125	0,000417	13,99740228
260	264	260000	0,132	0,000440	14,55729837
270	279	270000	0,1395	0,000465	15,11719446
280	295	280000	0,1475	0,000492	15,67709055
290	311	290000	0,1555	0,000518	16,23698664
300	327	300000	0,1635	0,000545	16,79688274
310	346	310000	0,173	0,000577	17,35677883
320	365	320000	0,1825	0,000608	17,91667492
330	385	330000	0,1925	0,000642	18,47657101
340	408	340000	0,204	0,000680	19,0364671
350	433	350000	0,2165	0,000722	19,59636319
360	460	360000	0,23	0,000767	20,15625928
370	492	370000	0,246	0,000820	20,71615537
380	529	380000	0,2645	0,000882	21,27605147
390	580	390000	0,29	0,000967	21,83594756
400	706	400000	0,353	0,001177	22,39584365
400.4	725	400400	0,3625	0,001208	22,41823949
400	734	400000	0,367	0,001223	22,39584365
390	835	390000	0,4175	0,001392	21,83594756
380	901	380000	0,4505	0,001502	21,27605147
370	951	370000	0,4755	0,001585	20,71615537
360	999	360000	0,4995	0,001665	20,15625928
350	1045	350000	0,5225	0,001742	19,59636319



Appendix A-6. 13 Modulus Elasticity 35% Cylinder 1

35% fly ash, cylinder 1					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	0	10000	0	0,000000	0,58128175
20	4	20000	0,002	0,000007	1,1625635
30	16	30000	0,008	0,000026	1,743845249
40	29	40000	0,0145	0,000048	2,325126999
50	41	50000	0,0205	0,000068	2,906408749
60	54	60000	0,027	0,000089	3,487690499
70	67	70000	0,0335	0,000111	4,068972249
80	81	80000	0,0405	0,000134	4,650253998
90	95	90000	0,0475	0,000157	5,231535748
100	109	100000	0,0545	0,000181	5,812817498
110	125	110000	0,0625	0,000207	6,394099248
120	139	120000	0,0695	0,000230	6,975380997
130	159	130000	0,0795	0,000263	7,556662747
140	176	140000	0,088	0,000291	8,137944497
150	194	150000	0,097	0,000321	8,719226247
160	205	160000	0,1025	0,000340	9,300507997
170	238	170000	0,119	0,000394	9,881789746
180	260	180000	0,13	0,000431	104630715
190	288	190000	0,144	0,000477	11,04435325

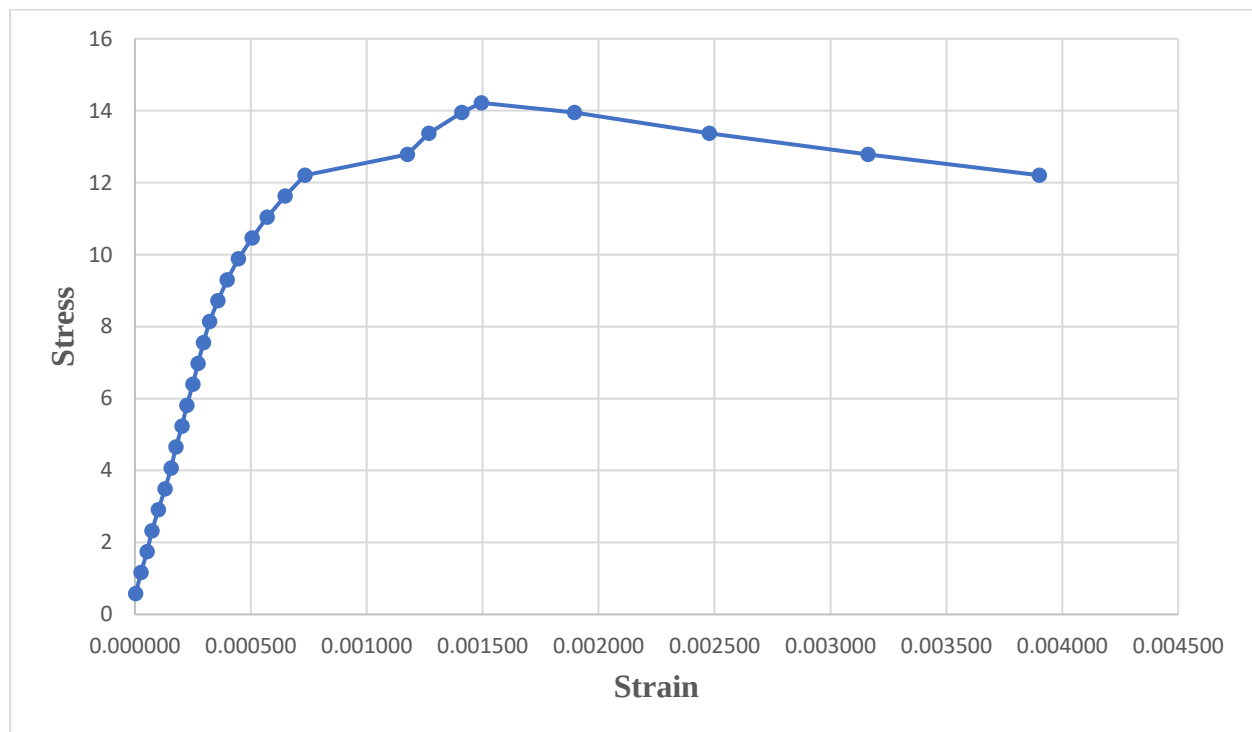
200	316	200000	0,158	0,000523	11,625635
210	344	210000	0,172	0,000570	12,20691675
220	381	220000	0,1905	0,000631	12,7881985
230	416	230000	0,208	0,000689	13,36948025
240	460	240000	0,23	0,000762	13,95076199
250	510	250000	0,255	0,000845	14,53204374
260	542	260000	0,271	0,000898	15,11332549
270	620	270000	0,31	0,001027	15,69460724
280	705	280000	0,3525	0,001168	16,27588899
288	904	288000	0,452	0,001497	16,74091439
280	1075	280000	0,5375	0,001780	16,27588899
270	1214	270000	0,607	0,002011	15,69460724
260	1315	260000	0,6575	0,002178	15,11332549
250	1454	250000	0,727	0,002408	14,53204374



Appendix A-6. 14 Modulus Elasticity 35% Cylinder 2

35% fly ash, cylinder 2					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_0$)(mm)	Tension(P/A)(Mpa)(stress)
10	2	10000	0,001	0,000003	0,5812817
20	16	20000	0,008	0,000027	1,1625635
30	31	30000	0,0155	0,000052	1,7438452
40	44	40000	0,022	0,000074	2,3251270
50	60	50000	0,03	0,000101	2,9064087
60	77	60000	0,0385	0,000129	3,4876905
70	93	70000	0,0465	0,000156	4,0689722
80	105	80000	0,0525	0,000176	4,6502540
90	121	90000	0,0605	0,000203	5,2315357
100	133	100000	0,0665	0,000223	5,8128175
110	149	110000	0,0745	0,000250	6,3940992
120	162	120000	0,081	0,000272	6,9753810
130	176	130000	0,088	0,000295	7,5566627
140	192	140000	0,096	0,000322	8,1379445
150	213	150000	0,1065	0,000358	8,7192262
160	237	160000	0,1185	0,000398	9,3005080
170	266	170000	0,133	0,000446	9,8817897
180	301	180000	0,1505	0,000505	10,4630715

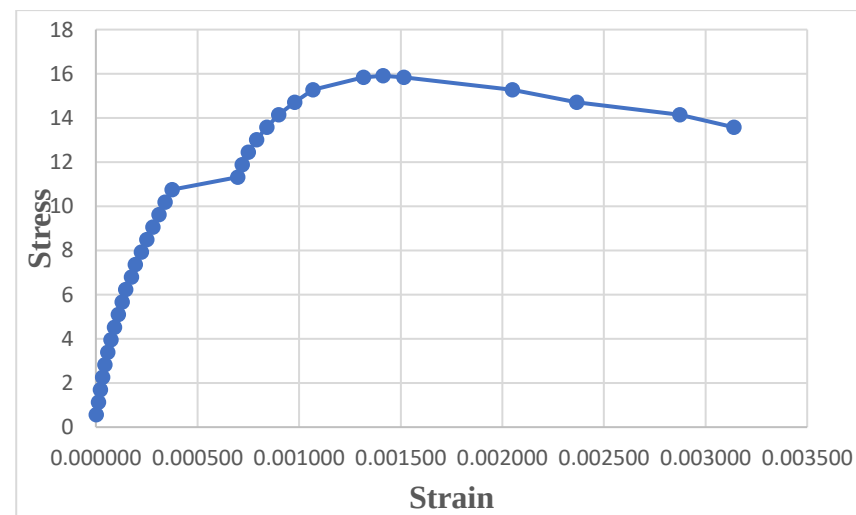
190	340	190000	0,17	0,000571	11,0443532
200	386	200000	0,193	0,000648	11,6256350
210	437	210000	0,2185	0,000733	12,2069167
220	700	220000	0,35	0,001175	12,7881985
230	755	230000	0,3775	0,001267	13,3694802
240	840	240000	0,42	0,001410	13,9507620
244,6	890	244600	0,445	0,001494	14,2181516
240	1130	240000	0,565	0,001897	13,9507620
230	1476	230000	0,738	0,002477	13,3694802
220	1884	220000	0,942	0,003162	12,7881985
210	2324	210000	1,162	0,003901	12,2069167



Appendix A-6. 15 Modulus Elasticity 35% Cylinder 3

35% fly ash, cylinder 3					
Load (kN)	Dial record	Load (N)	Actual $\Delta L(1/2\Delta L)(mm)$	Strain($\Delta L/L_o$)(mm)	Tension(P/A)(Mpa)(stress)
10	1	10000	0.0005	0.000002	0,5812817
20	7	20000	0.0035	0.000012	1,1625635
30	13	30000	0.0065	0.000022	1,7438452
40	19	40000	0.0095	0.000032	2,3251270
50	26	50000	0.013	0.000044	2,9064087
60	34	60000	0.017	0.000057	3,4876905
70	44	70000	0.022	0.000074	4,0689722
80	54	80000	0.027	0.000091	4,6502540
90	65	90000	0.0325	0.000110	5,2315357
100	76	100000	0.038	0.000128	5,8128175
110	87	110000	0.0435	0.000147	6,3940992
120	103	120000	0.0515	0.000174	6,9753810
130	115	130000	0.0575	0.000194	7,5566627
140	132	140000	0.066	0.000223	8,1379445
150	148	150000	0.074	0.000250	8,7192262
160	166	160000	0.083	0.000280	9,3005080
170	184	170000	0.092	0.000310	9,8817897
180	201	180000	0.1005	0.000339	10,4630715
190	222	190000	0.111	0.000375	11,0443532
200	413	200000	0.2065	0.000697	11,6256350
210	426	210000	0.213	0.000719	12,2069167

220	444	220000	0.222	0.000749	12,7881985
230	468	230000	0.234	0.000790	13,3694802
240	498	240000	0.249	0.000840	13,9507620
250	533	250000	0.2665	0.000899	14,5320437
260	579	260000	0.2895	0.000977	15,1133255
270	633	270000	0.3165	0.001068	15,6946072
280	780	280000	0.39	0.001316	16,2758890
281.1	837	281100	0.4185	0.001412	16,3398300
280	898	280000	0.449	0.001515	16,2758890
270	1214	270000	0.607	0.002049	15,6946072
260	1402	260000	0.701	0.002366	15,1133255
250	1702	250000	0.851	0.002872	14,5320437
240	1860	240000	0.93	0.003139	13,9507620



Appendix 7. Compressive Strength Machine



Appendix A-7. 1 Sample at the Compressive Strength Machine



Appendix A-7. 2 The Samples after Compressive Strength Test



Appendix 8. Modulus of Elasticity Machine



Appendix A-8. 1 After Modulus of Elasticity Test (1)



Appendix A-8. 2. After Modulus of Elasticity Test (2)



Appendix A-8. 3 Before Modulus of Elasticity Test



Appendix A-8. 4 A Sample at the Modulus of Elasticity Machine



Appendix 9. After Tensile Strength Test 2



Appendix A-9. 1 Tensile Strength Machine



Appendix 10. Equipment and Materials

Appendix A-10. 1 Bucket



Appendix A-10. 2 Cylinder Mold



Appendix A-10. 3 Filter Equipment



Appendix A-10. 4 OHAUS digital scale



Appendix A-10. 5 Oven



Appendix A-10. 6 Paintbrush**Appendix A-10. 7 Putty Knife****Appendix A-10. 8 Scoop****Appendix A-10. 9 Trowel**

Appendix A-10. 10 Vernier Caliper**Appendix A-10. 11 Chemical Addition****Appendix A-10. 12 Class C of Fly Ash****Appendix A-10. 13 Coarse Aggregate (Gravel)**

Appendix A-10. 14 Fine Aggregate (Sand)**Appendix A-10. 15 Ordinary Portland Cement****Appendix A-10. 16 Sulfur Powder**

Appendix A-10. 17 Water**Appendix A-10. 18 wheelbarrow**



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Laboratorium Jurusan Teknik Sipil

CONCRETE CYLINDER COMPRESSIVE TEST DATA

(SK SNI M-14-1989-F)

Nama: FAROQ ALI ALI HUSSEIN QAZWAN

Nim : 20511453

Keperluan: Tugas Akhir

No	Date of Curing	Date of test	Concrete's Age	FA Ratio %	Dimension (mm)		Area (mm ²)	Weight (Kg)	Max. load (kN)	Compressive Strength (MPa)	Code/ Information
					Diameter	Height					
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>
1	4/6/2024	18/6/2024	14 days	0%	149,7	303,9	17600,84	12,53	454,19	25,81	Trial Mix f'c 20 Mpa
2	4/6/2024	18/6/2024	14 days		149,2	307	17483,47	12,85	488,34	27,93	
3	4/6/2024	18/6/2024	14 days		150,2	303	17718,61	12,60	466,26	26,31	
								Average	26,68		



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CONCRETE CYLINDER COMPRESSIVE TEST DATA
(SK SNI M-14-1989-F)

No	Date of Curing	Date of test	Concrete's Age	FA Ratio %	Dimension (mm)		Area (mm2)	Weight (Kg)	Max. load (kN)	Compressive Strength (MPa)	Code/ Information
					Diameter	Height					
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>
1	4/6/2024	18/6/2024	14 days	20%	150,5	303,5	17789,46	13,00	480,21	26,99	Trial Mix f'c 20 Mpa
2	4/6/2024	18/6/2024	14 days		150,3	305,9	17742,22	12,95	495,56	27,93	
3	4/6/2024	18/6/2024	14 days		150	305	17671,46	12,91	517,78	29,30	
									Average	28,08	

CONCRETE CYLINDER COMPRESSIVE TEST DATA

(SK SNI M-14-1989-F)

No	Date of Curing	Date of test	Concrete's Age	FA Ratio %	Dimension (mm)		Area (mm2)	Weight (Kg)	Max. load (kN)	Compressive Strength (MPa)	Code/ Information
					Diameter	Height					
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>
1	4/6/2024	18/6/2024	14 days	25%	150,2	298,1	17718,61	12,48	409	23,08	Trial Mix f'c 20 Mpa
2	4/6/2024	18/6/2024	14 days		149,7	302,3	17593,79	12,64	416	23,64	
3	4/6/2024	18/6/2024	14 days		149,2	297,9	17483,47	12,29	410	23,45	
									Average	23,39	

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CONCRETE CYLINDER COMPRESSIVE TEST DATA
(SK SNI M-14-1989-F)

No	Date of Curing	Date of test	Concrete's Age	FA Ratio %	Dimension (mm)		Area (mm ²)	Weight (Kg)	Max. load (kN)	Compressive Strength (MPa)	Code/ Information
					Diameter	Height					
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>
1	4/6/2024	18/6/2024	14 days	30%	150,3	303	17742,22	12,997	385	21,70	Trial Mix f'c 20 Mpa
2	4/6/2024	18/6/2024	14 days		150,8	301,9	17860,46	12,82	397	22,23	
3	4/6/2024	18/6/2024	14 days		151,2	305	17955,33	12,84	393	21,89	
									Average	21,94	



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(SK SNI M-14-1989-F)

No	Date of Curing	Date of test	Concrete's Age	FA Ratio %	Dimension (mm)		Area (mm2)	Weight (Kg)	Max. load (kN)	Compressive Strength (MPa)	Code/ Information
					Diameter	Height					
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>
1	6/6/2024	20/6/2024	14 days	35%	150,1	298,5	17695,03	12,18	301,39	17,03	Trial Mix f'c 20 Mpa
2	6/6/2024	20/6/2024	14 days		150	296,9	17671,46	12,27	272,23	15,41	
3	6/6/2024	20/6/2024	14 days		149,6	299,7	17577,34	12,36	239,49	13,62	
									Average	15,35	



Disetujui oleh,

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