A COMPARATIVE STUDY ON THE DEFLECTION CHARACTERISTICS OF PRESTRESSED GEOPOLYMER CONCRETE AND PORTLAND CONCRETE

BY

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A PROJECT SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF

BACHELOR OF ENGINEERING (B.ENG).

IN

THE DEPARTMENT OF CIVIL ENGINEERING,

(STRUCTURAL ENGINEERING PROGRAMME)

FACULTY OF ENGINEERING,

UNIVERSITY OF BENIN

BENIN CITY, NIGERIA

APRIL,2024

CERTIFICATION

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DEDICATION

I humbly dedicate this project to God Almighty who by his sure grace and profound mercyhas granted me good health, wisdom, knowledge and understanding all through my stay at the University of Benin.

My deepest gratitude goes to Mr. and Mrs. Yusuf, my parents, for their support during my education.

ACKNOWLEDGEMENT

First and foremost, my sincere gratitude goes to God Almighty for his immense grace, favor and protection upon my life from the beginning of my degree in the University of Benin. I would also like to express my deepest gratitude to my project supervisor Engr. (Engr.Prof. J. O. Okovido) for his guidance, support and expertise during the course of my research. I would like to appreciate the head of Structural Engineering Department Engr. Ngozi Ihemikpehen and her entire staff for the unwavering support and guidance which have been instrumental in shaping this project as well as the project coordinator, Engr. Ehi Oria Usifo, for his hard effort. His valuable insights, constructive feedback, and patience have been instrumental in enhancing the project quality. I extend my heartfelt appreciationto the faculty members of the University of Benin, Department of Civil Engineering, for their dedication to imparting knowledge and fostering an enriching learning environment. Their teachings and mentorship have significantly contributed to my growth as a civil engineering student.

I am indebted to my family and friends for their unwavering support, understanding, and encouragement throughout this demanding undertaking. Their constant motivation, love, and belief in my abilities have been a source of strength and inspiration.

Lastly, I would like to acknowledge the support and encouragement of my fellowclassmates and colleagues. Their camaraderie, intellectual discussions, and shared experiences have created a conducive environment for learning and personal growth.

ABSTRACT

This project is conducted to carry out a comparative study of the deflection characteristicsof Prestressed geopolymer concrete and Prestressed Portland cement concrete. The objectives are to conduct tests on the materials utilized, to carry out flexural tests and other supporting tests and to analyze the results obtained from all the tests performed.

The aim of the research is to compare the deflection characteristics of Portland Cement beams and Metakaolin based Geopolymer concrete beams.

The tests performed on the materials utilized were the sieve analysis test on aggregates, specific gravity test on the kaolin, metakaolin, cement and aggregates, and the tensile test on cables, tendons and wires. The other supporting tests done were the compressive strength test of Portland Cement concrete and geopolymer concrete, and workability test on concrete. The preliminary test proved that the calcined metakaolin samples were reactive when exposed to alkaline activators and metakaolin based geopolymer concrete exceeded the strength of ordinary Portland cement concrete in short time.

The compressive strength of the 8 molarity metakaolin based geopolymer concrete was gotten as 38.267 N/mm^2 after 1 day; after 5 days, it was gotten as 51.510 N/mm^2; after 7 days, it was gotten as 52.651 N/mm^2, and after 28 days, it was gotten as 57.950 N/mm^2. The compressive strength of the 10 molarity metakaolin based geopolymer concrete was gotten as 29.262 N/mm^2 after 1 day, and after 7 days, it was gotten as 38.730 N/mm^2. The average moment capacity of the geopolymer concrete beams prepared from 8 molarity of NaOH was gotten 482.36 Nm. The moment capacity range of the geopolymer concrete beams prepared from 10 molarity of NaOH was gotten as 338.0 – 349.5 N/mm^2.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is an indispensable material in the realm of construction, playing a pivotal role in shaping the modern built environment. Its importance stems from a combination of unique properties that make it a versatile, durable, and reliable building material.

The deflection characteristics of prestressed concrete play a pivotal role in determining the structural reliability, serviceability, and long-term performance of constructed elements. Precise control over deflections is essential for meeting stringent design criteria, ensuring that structures remain within acceptable limits under various loading conditions. In applications like bridges, where stringent performance standards are crucial, managing deflections is paramount to uphold safety and provide a comfortable experience for users.By strategically applying prestressing forces, engineers can tailor the deflection characteristics, minimizing sagging or excessive deformation. This level of control not only enhances the structural integrity but also contributes to the overall durability and aesthetic appeal of prestressed concrete structures.

Furthermore, the significance of deflection characteristics extends beyond immediate structural considerations. It directly impacts the functionality and aesthetics of buildings and bridges, influencing factors such as occupant comfort and visual appearance. A thorough understanding of deflection behavior enables engineers to optimize design parameters, striking a balance between strength and serviceability. Adherence to deflection limits outlined in design codes ensures that prestressed concrete structures not only meet safety standards but also provide enduring functionality, contributing to the longevity and reliability of infrastructure projects. Overall, the meticulous consideration of deflection characteristics is integral to achieving the desired performance and ensuring the sustained success of prestressed concrete structures in diverse applications. (Edward,2015)

Concrete structures can be subjected to various forces during their lifespan. Which include comprehensive, tension, shear, flexural etc. Understanding these forces during the designand construction phases are essential for creating durable and safe concrete structures. Proper reinforcement, material selection, and adherence to building codes contribute to theresilience of concrete against various forces. (M.K Hurst,1998).

The fundamental innovation lies in its ability to proactively counteract the inherent weakness of traditional concrete in tension. By introducing pre compression through strategically applied stresses, prestressed concrete achieves a remarkable enhancement in both strength and durability.

The significance of prestressed concrete is evident across various engineering applications, most notably in bridges and buildings. Its use allows for the creation of longer span structures, reducing the need for excessive supporting elements and opening up new possibilities in architectural design. This not only contributes to cost effectiveness but also promotes sustainability by utilizing materials more efficiently.

Moreover, prestressed concrete plays a pivotal role in addressing challenges posed by dynamic loads, such as those experienced in bridges. Its superior ability to withstand both static and dynamic forces enhances the safety and longevity of structures, making it an indispensable choice for critical infrastructure projects. As the construction industry increasingly emphasizes sustainability and efficiency, the importance of prestressed concrete in delivering resilient, resource efficient, and aesthetically pleasing structures continues to grow.

1.2 STATEMENT OF THE PROBLEM

Geopolymer concrete is one of the materials that has significantly reduced the environmental impact associated with traditional concrete. By utilizing metakaolin, a byproduct of industrial processes, instead of Portland cement, it diminishes reliance on a material known for its substantial carbon footprint. This shift aligns with global efforts to embrace sustainable construction practices, contributing to the industry's commitment to reduce its environmental footprint.

Geopolymer concrete is also referred to as "green concrete" due to its environmentally friendly composition and its role in promoting sustainable construction practices. Several key factors contribute to its designation as a green building material.

The application of prestressed concrete addresses several challenges and issues encountered in traditional reinforced concrete construction. Some key problems that prestressed concrete aims to solve include:

1. Flexural Strength Enhancement: Prestressed concrete is particularly effective in enhancing the flexural strength of structural elements. By introducing prestressing forces, the concrete is placed in compression, counteracting tensile forces and significantly increasing its ability to resist bending and cracking.

2. Reducing Deflections: Deflections in concrete structures can impact serviceability and user satisfaction. Prestressed concrete helps control and minimize deflections, ensuring that structures meet specified criteria for performance and user comfort.
3. Span Length Limitations: Traditional reinforced concrete has limitations in terms of span lengths for certain structural elements. Prestressed concrete allows for longer spans, reducing the need for additional supports and facilitating the design of more open and aesthetically pleasing spaces.
4. Cracking Control: Prestressed concrete mitigates the risk of cracking, especially in high stress areas. The compressive forces induced by prestressing counteract tensile stresses, reducing the likelihood of cracks forming and enhancing the durability of the structure.
5. Load Carrying Capacity: The method of prestressing significantly improves the load carrying capacity of structural elements. This is particularly beneficial in applications where high loads or heavy live loads need to be supported without compromising structural integrity.

1.3 AIM AND OBJECTIVE OF THE STUDY

The aim of this study is to carry out a comparative study of the deflection characteristics of Prestressed Metakaolin based Geopolymer concrete and Portland cement concrete beams.

The specific objectives of this study are:

1. To obtain relevant materials like metakaolin, Portland cement, aggregates, potable water
2. To carry out test on raw materials to be used such as metakaolin, cement, fine and coarse aggregates so as to determine the material characteristics.
3. To carry out other tests which are compressive strength of concrete, tensile test on tendons like cables, wires or bars made of high yield steel.
4. Casting prestressed concrete to determine initial and final setting time, examining the

curing requirements during and after casting and carrying out flexural test on them.

5. Analysis and evaluation of results gotten from the tests carried out at Civil Engineering laboratory, University of Benin.

1.4 SCOPE OF STUDY

Kaolin was calcinated in the Civil Engineering laboratory workshop in University of Benin to get metakaolin which involved heating kaolin to a high temperature of 800°C .and afterwards a Preliminary test was conducted on the metakaolin to ensure it is reactive and to determine its feasibility for the research.

Pilot tests were initially carried out to aid other tests like compressive strength of concrete test, tensile test and also to obtain the initial setting time, the final setting time, sieve analysis, specific gravity tests, hydrometer test, gauge calibration, and deflection test.

Using the local materials accessible for the experiment, it’s important to adhere to relevant standards and specifications including ASTM C1778 and ASTM C618 to ensure safety, durability and quality

With emphasis to the objectives and aim of the research, Portland cement obtained from Benin is also made readily available to compare with Metakaolin based Geopolymer concrete.

1.5 JUSTIFICATION OF STUDY

Prestressed geopolymer concrete and traditional Portland concrete represents two significant developments in the field of construction materials, each with distinct characteristics and implications for the construction industry. In this exploration, some importance of comparing these two materials are:

Performance Evaluation:

Comparing the performance of prestressed geopolymer concrete and Portland concrete is a critical aspect of assessing their suitability for various construction applications. Traditional

Portland concrete has been a staple in the construction industry for decades, known for its versatility and widespread use. However, as the industry strives for more sustainable and high-performance alternatives, geopolymer concrete has emerged as a promising contender. With the use of special binder systems based on the activation of industrial byproducts like fly ash or metakaolin, prestressed geopolymer concrete presents a novel approach. A three-dimensional network of aluminosilicate bonds is created during the geopolymerization process, which may have benefits for strength and durability. Compaction strength, tensile strength, and other mechanical property comparison studies are essential to comprehending the performance of geopolymer concrete vis à vis conventional concrete.

Sustainability Assessment:

Sustainability is a paramount consideration in modern construction practices, driven by the need to reduce environmental impact. Portland cement production is a major contributor to carbon emissions, making alternatives like geopolymer concrete appealing. Geopolymer concrete utilizes industrial by products, reducing the reliance on traditional cement clinker production. When comparing the environmental impact of Portland concrete and prestressed geopolymer concrete, it is necessary to evaluate elements like resource utilization, energy consumption, and embodied carbon. The construction industry's overall sustainability goals are aided by the decrease in carbon emissions related to the production of geopolymer concrete. Comprehending and calculating these advantages of sustainability is essential to making wise choices in ecologically responsible building endeavors.

Material Properties:

Exploring the material properties of prestressed geopolymer concrete and Portland concrete is fundamental to engineering robust and reliable structures. Prestressed geopolymer concrete may exhibit unique characteristics such as reduced shrinkage, enhanced resistance to chemical attacks, and improved long term durability. These properties are a result of the geo polymerization process, where aluminosilicate bonds contribute to a strong and cohesive matrix. Comparative studies on material properties go beyond traditional mechanical testing. They involve analyzing how each material behaves under specific environmental conditions, addressing challenges related to exposure to aggressive substances, freeze thaw cycles, and other external factors. Understanding these properties helps engineers design structures that meet performance requirements while considering the specific advantages and limitations of each material.

Cost Considerations:

Cost is a pivotal factor in construction projects, and comparing the economic feasibility of prestressed geopolymer concrete and Portland concrete is essential. While geopolymer concrete may have benefits in terms of reduced raw material costs and potential long term savings due to improved performance, it's crucial to evaluate the overall cost throughout the project life cycle. It is necessary to take into account variables like the initial cost of construction, ongoing maintenance costs, and possible savings from an extended service life. The utilization of comparative cost analyses offers a thorough comprehension of the financial consequences linked to the implementation of prestressed geopolymer concrete in construction endeavors.

Structural Behavior:

Understanding the structural behavior of both materials is fundamental to ensuring the safety and reliability of constructed elements. Comparative studies involve evaluating how prestressed geopolymer concrete and Portland concrete respond to different loading conditions, including static and dynamic loads. Structural behavior assessments consider factors like deflection, cracking behavior, and load carrying capacity. Prestressed geopolymer concrete, with its unique composition, may exhibit different structural responses compared to Portland concrete. These studies guide engineers in optimizing designs and ensuring that structures meet safety standards and performance expectations.

Adoption in Construction Practices

The successful integration of any new material into construction practices depends on its compatibility with existing methodologies, codes, and industry norms. Comparative studies help identify any challenges or modifications required for the adoption of prestressed geopolymer concrete in construction projects. The general significance of the study is the advancement of construction technology by evaluating the performance of a materials like prestressed geopolymer concrete. Understanding how this material behave under various conditions provides insights for refining construction practices and designing more resilient structures. Considering some economic benefits of the study, Geopolymer concrete often utilizes industrial by products like metakaolin, which may be more cost effective compared to the primary raw materials used in traditional Portland cement production. This can result in cost savings, especially if these by products are locally available. Geopolymer concrete is also known for its lower carbon footprint compared to Portland concrete. The production of Portland cement involves significant CO2 emissions, while geopolymer concrete uses industrial by products that would otherwise be considered waste performance evaluation due to good strength characteristics of metakaolin is also an importance of the research.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

Even though a San Francisco engineer patented prestressed concrete in 1886, it took fifty years for it to become a widely used building material. During the Second World War, prestressed concrete was the preferred building material in Europe due to a scarcity of steel and developments in high strength concrete and steel technology. However, the Walnut Lane Memorial Bridge in Philadelphia, Pennsylvania—the first prestressed concrete structure in North America—was not finished until 1951. (The Association for Portland Cement, 2024).

The high tensile strength of steel and the excellent compressive strength of concrete are combined in conventional reinforced concrete to create a structural material that is strong in both compression and tension. Prestressed concrete works on the basis of the idea that tensile stresses placed on a concrete member during service will be balanced by compressive stresses created by high strength steel tendons in the member prior to loads being applied.

Prestressing enables the construction of walls, floors, roofs, bridges, and other structures with longer unsupported spans by removing several design restrictions that conventional concrete imposes on span and load. Because of this, engineers and architects are able to create concrete structures that are shallower and lighter without compromising strength.

When a row of books is moved, the prestressing principle is put into practice. The books could be moved rather than carried and stacked vertically by exerting pressure on the books at the end of the row to keep them in a horizontal position. The row can be lifted and carried horizontally all at once when enough pressure is applied to cause compressive stresses to be created throughout the row.

Fig 2.1. Prestressed member

Pre tensioning or post tensioning the steel reinforcement causes compressive stresses in prestressed concrete. The steel is stretched prior to the concrete being poured in pre tensioning. Strains of high strength steel are stretched to between 70 and 80 percent of their ultimate strength and positioned between two abutments. After pouring concrete into moulds encircling the tendons, it is left to cure. The stretching forces are released when the concrete reaches the desired strength. Tensile stresses are converted into a yield stress as the steel reverts to its initial length concrete's compressive stress. Pretensioned concrete is commonly used to create wall panels, railway ties, piles, poles and roof slabs.

Post tensioning involves stretching the steel following the hardening of the concrete. Unstretched steel is surrounded by concrete, but not in contact with it. Thin walled steel forms are frequently used to form ducts in concrete units. The steel tendons are inserted, stretched against the ends of the unit, and anchored off externally to put the concrete into compression once it has hardened to the necessary strength. For cast in place concrete, bridges, big girders, floor slabs, shells, roofs, and pavements, post tensioned concrete is utilized.

2.1 REVIEWS ON METAKAOLIN BASED GEOPOLYMER CONCRETE

Because of the growing concerns about the environmental effects of the cement industries and the need to create a concrete friendly environment in the construction industry, metakaolin based geopolymer concrete has drawn a lot of attention as a viable substitute for conventional Portland cement based concrete and as a source of new cementless materials. The availability of metakaolin, a calcined form of kaolin clay, has made it a competitive alternative because of its pozzolanic qualities. It enhances the mechanical qualities, durability, and workability of concrete. Researchers have tested several mechanical, chemical, and physical factors. Compared to ordinary Portland cement, this review focusses on the use of metakaolin in geopolymer concrete, which is created when metakaolin reacts with alkaline activators. (Rasaad, Alaa M., 2013).

2.2 PAST RELATED RESEARCHES ON FLEXURAL BEHAVIOUR

2.2.1 Muhammad and Tahir – 2019

(a) Objective and Scope

Examining the impact of adding steel and polypropylene fibers on the flexural behaviour of prestressed concrete girders was the primary goal of this study. The load carrying capacity of structures can be further increased by using fibers, even though prestressed concrete is widely used in the construction industry to achieve this goal. The purpose of this paper is to report on experimental work done to support the use of fibers in prestressed concrete members by the construction industry in order to enhance their mechanical properties. This study focused on small scale fiber reinforced I shaped prestressed concrete girders because previous research on fiber reinforced prestressed beams was limited. A control girder, a hybrid girder, two girders with different percentages of steel fibers, and two girders with different percentages of polypropylene fibers were among the six small scale prestressed concrete girders that were cast. In order to test these girders, center point loading was applied until failure. It was determined that a small volume fraction of fibers could be added to FRC girders to enhance not only their ductility but also their tensile and flexural strengths. By amplifying significant strains in steel and concrete, it also positively changed the failure pattern. Concrete reinforced with steel fibers exhibited greater energy absorption and deflection at ultimate loads when compared to other specimens.

(b) Tests results and conclusions

To ascertain the compressive strength at given ages, nine concrete cylinders (three for each curing age, i.e., 3, 7, and 28 days) were cast for each type of concrete mix in accordance with ASTM C39 10. Each cylinder measured 150 mm in diameter and 300 mm in height. Three cylinders with varying ages and their average compressive strength values.

Following center point loading on plain and fiber reinforced concrete girders, the following conclusions have been made based on experimental results:

(1) The specimen HyFRC's split tensile strength increased by 123% and its flexural strength by 47% as a result of the use of steel fiber reinforced concrete. This result may enable the use of lighter, smaller sections that have more ductility.

(2) The ductility index of girders with steel fibers was 47% higher in this study than girders with polypropylene fibres, indicating that the use of steel fibres in concrete increased the ductility of girders.

(3) Because steel fibres can penetrate concrete more easily and have a higher tensile strength than fibrillated polypropylene fibres, the load carrying capacity of steel and polypropylene fibres is increased by 47% and 6%, respectively, in comparison to control girders.

(4) Girders' resistance to cracking is increased when steel and polypropylene fibres are added to the concrete mixture.

(5) Concrete girders without steel reinforcement exhibit ductile failure, while those

reinforced with steel fibres exhibit sudden brittle failure.

2.2.2 Anthony et al 2019

Anthony and colleagues investigated the ideal proportion of polypropylene fibre in concrete to improve its compressive and flexural strengths. They came to the conclusion that concrete's flexural strength. Added low percentage fractions (0.25%) of fibres increased by as much as 65%. When 0.75% and 1% of fibres were added to the concrete matrix, the strength of the concrete showed a slight increase of 0.5% and a subsequent decrease. The results of this study showed that for both compressive and flexural strengths, the ideal dosage of polypropylene fibre was between 0.25% and 0.5%.

2.2.3 Kang et al 2019

(a) Object and scope

Steel fiber reinforced concrete (SFRC) beams' shear flexure coupling behaviour was examined by Kang et al. They used nonlinear modelling techniques to validate the test results while taking the effects of the shear flexure coupling into account. They studied the shear deformation of prestressed concrete beams with different steel fibre percentages per volume cast. They came to the conclusion that by adding steel fibres, prestressing beam shear strength and shear cracking were significantly increased. Increased flexural ductility was discovered in SFRC beams by Kang et al. Twelve reinforced concrete and steel fiber reinforced concrete beams that were subjected to four point loading served as the basis for the authors' conclusions. They investigated how SFRC beams without shear reinforcement behaved.

(b) Result and conclusion

The test results demonstrated that as fibre volume increased, so did the nominal stress at shear cracking and the ultimate shear strength. The researchers also noticed that the failure mode shifted from shear to flexure when steel fibres were added.

2.2.4 Eugene – 1954

(a) Object and scope

The objective was to explore and implement a structural technique using pre applied stresses to improve concrete's performance.

The scope encompassed establishing fundamental principles of applying pre compression to concrete, emphasizing the potential to enhance its structural performance.

(b) Results

Freyssinet introduced the concept of applying compressive stresses to concrete before subjecting it to external loads, known as prestressing. This resulted in improved tensile strength and overall structural performance.

The experimental application of prestressing demonstrated a significant reduction in deflection and cracking, showcasing the potential for increased load carrying capacity.

2.3 TYPES OF CONCRETE

Cement, a chemical substance used in construction that hardens to bind other materials together, is the main ingredient required to make concrete.

This project work will focus on two types of cement which include:

1. Portland cement concrete
2. Geopolymer cement concrete

2.3.1 PORTLAND CONCRETE

To create a mass of concrete with a high compressive strength, aggregate particles typically sand and gravel are bound together by a substance called Portland cement. Depending on the kind of cement that is wanted, a mixture of clay and limestone or chalk is used. Because it is a necessary component of concrete, mortar, and stucco, Portland cement is the most widely used type of cement worldwide. It is a fine powder made from grinding more than 90%

Portland cement clinker with a small amount of calcium sulphate added to regulate the setting time. The hydraulic material known as Portland cement clinker is made up of calcium silicates, specifically $3CaO.SiO_2$ and $2CaO.SiO_2$, to a minimum of two thirds by mass. (Olubisi Ige, 2013).

Portland cement can also be described as cement that does not require a reaction with water to harden; instead, it can be created by pulverizing clinker that contains one or more calcium silicate forms, typically including calcium sulphate. Portland cement is one of the least expensive materials that has been widely used over the past century worldwide due to the low cost and widespread availability of limestone, shale, and other naturally occurring materials. (Brooks and Neville, 1987).

The principal raw materials used in the manufacture of ordinary Portland cement are:

1. Argillaceous or silicates of alumina in the form of clays and shales
2. Chalk, limestone, and marl—a combination of clay and calcium carbonate are examples of calcareous materials.

The components are combined in a ratio of roughly two parts calcareous materials to one part argillaceous materials, and either the mixture is combined wet or the ingredients are crushed and ground in ball mills.

After that, the wet slurry or dry powder is burned at 800°C in a rotary kiln. After being removed from the kiln and allowed to cool, the clinker is ground to the required fineness for the product class in ball mills, where gypsum is added.

2.3.2 METAKAOLIN BASED GEOPOLYMER CONCRETE

Concrete that uses metakaolin a highly reactive aluminosilicate material instead of Portland cement is known as metakaolin based geopolymer concrete. An excellent substitute for conventional Portland cement concrete, geopolymer concrete has several advantages over it, including increased strength, durability, and environmental benefits.

When kaolin clay is heated to high temperatures 850 degrees in this case reactive amorphous aluminosilicate material is formed, which is the product known as metakaolin. The chemical reaction known as geo polymerization occurs when metakaolin is combined with alkaline activators like potassium or sodium hydroxide. The geopolymer gel created by this reaction is a three-dimensional network that serves as a binder for the concrete matrix. Metakaolin based geopolymer concrete is gradually taking the place of cement in construction projects that seek environmentally friendly concrete. Various researchers have tested mechanical, physical, and chemical factors to compare the effectiveness of prestressed geopolymer concrete to regular Portland cement made concrete.

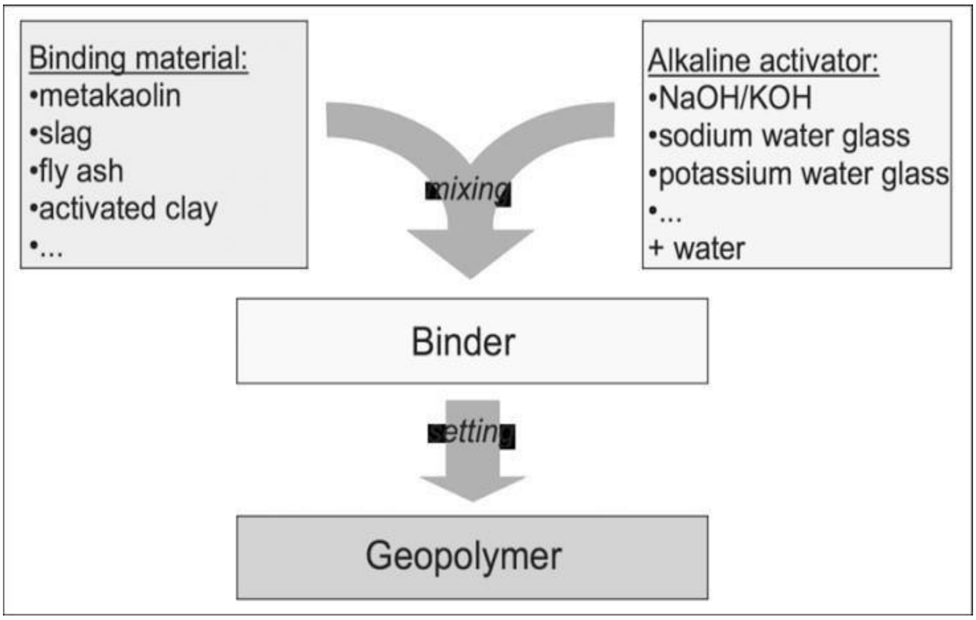


Fig 2.2: Illustration Of Geopolymer Concrete

2.4 COMPOSITION OF GEOPOLYMER CONCRETE

The binder system of geopolymer concrete is different from that of conventional Portland cement concrete. Geopolymer concrete uses a geopolymer binder in place of Portland cement; this binder is usually created by the alkaline activation of aluminosilicate materials.

1. Alkaline Activators: These are solutions that contain alkali metal silicates (like sodium silicate) and hydroxides (like sodium hydroxide). These activators work with the

aluminosilicate precursors to start the geo polymerization reaction.

2. Aluminosilicate Sources: An aluminosilicate source is needed for geopolymer concrete as the main precursor for the geo polymerization reaction. The source used in this study is metakaolin, which is kaolin clay that has been calcined.
3. In geopolymer concrete, coarse aggregates like crushed stone or gravel are also utilized. These bigger particles give the concrete bulk and increase its overall strength.
4. Like regular concrete, fine aggregate concrete also contains fine aggregates. The concrete's mechanical qualities and workability are enhanced by these aggregates. Sand is a common fine aggregate.

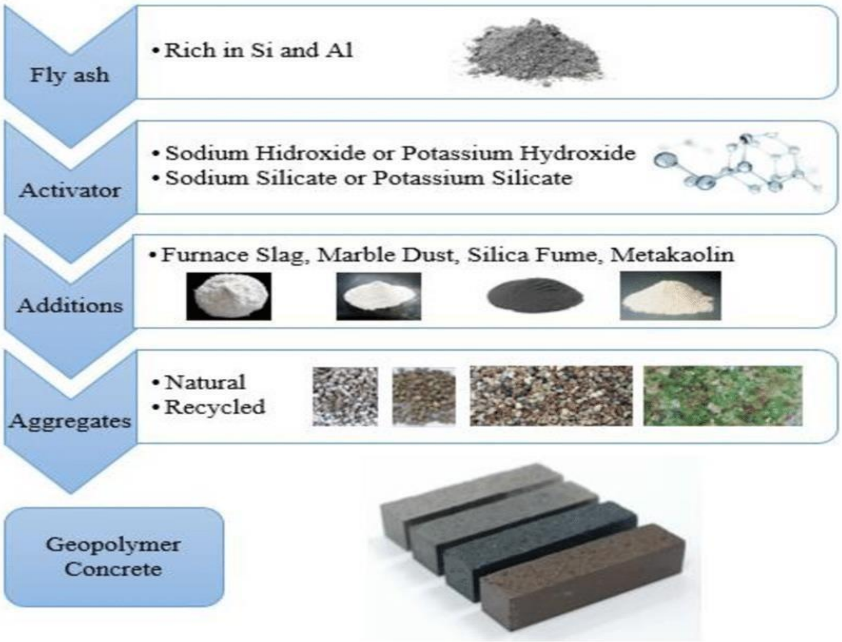


Fig 2.3: Geopolymer concrete composition

2.5 PRESTRESSED CONCRETE

Concrete that has been prestressed to achieve a desired degree of internal action counterbalancing external loading is known as prestressed concrete. The field of prestressed concrete analysis aims to reduce flexural strength by limiting the amount of tensile stress that is developed.

Under working conditions, there is cracking in the concrete sections. Because the section is subjected to an initial compressive load before being used, it differs from a conventional reinforced concrete section (Amer et al., 2017). Pretensioned and posttensioned are the two classifications for prestressed concrete members. Before the concrete is poured, steel tendons are stretched between the external buttresses to create prestressed concrete members that are pretensioned. The tendons are released from the buttresses once the concrete reaches the necessary strength, and the bond between the tendons and the concrete transfers the prestressing force to the member's concrete. When it comes to posttensioned prestressed concrete members, steel tendons are anchored at the ends of the member after the concrete has sufficiently strengthened and hardened. The tendons are then stretched in ducts within the concrete.

Long before prestressing concrete became a widely used construction technique, its basic principles were understood. The lack of use of high strength steel for the tendons and the gradual loss of the low initial steel stress due to concrete creep and shrinkage were the main reasons why early attempts to prestress concrete failed. (Park, R. (2003))

One of the major advantages is that for a given span and loading, a smaller prestressed concrete member is needed. (Hurst,1998)

2.5.1 MECHANICAL PROPERTIES OF PRESTRESSED CONCRETE

The mechanical properties of prestressed concrete are influenced by the application of internal forces through pre tensioning or post tensioning methods. Here are key mechanical aspects:

Compressive Strength: Prestressing induces compressive forces within the concrete, enhancing its compressive strength. This is crucial for supporting heavy loads and resisting compressive forces in structural members.

Tensile Strength: Prestressed concrete significantly improves tensile strength by countering tensile stresses, which are inherent in bending situations. The internal forces introduced through prestressing help resist cracking and improve the material's overall tensile performance.

Flexural Strength: When compared to non-prestressed concrete, prestressed concrete exhibits a significantly higher flexural or bending strength. This is because internal forces are redistributed, which leads to better resistance to bending moments and increased load carrying capacity.

Prestressed concrete reduces the number of cracks that form and how big they get, especially in areas where tensile stresses are applied. The internal compression promotes the structure's longevity and durability by assisting in the control of cracking.

Ductility and Deformation: Prestressed concrete exhibits greater ductility, allowing it to undergo larger deformations without failure. This characteristic is beneficial for structures subjected to dynamic loads or seismic events.

Modulus of Elasticity: Young's modulus, or the modulus of elasticity, is a material property that characterises a material's stiffness or rigidity. It measures the amount that a material elongates or deforms in response to an applied load. The ratio of stress to strain within the elastic range of deformation is known as the modulus of elasticity. Per usual, geopolymer concrete has a greater modulus of elasticity.

Shear strength: The ability of a material to withstand forces acting parallel to its surface is referred to as shear strength. Stated differently, shear strength is a property of materials that quantifies their ability to withstand deformation caused by lateral stress or forces that cause one layer of the material to move or slide in relation to a neighboring layer. The layers of a material move in parallel as a result of this kind of stress.

2.5.2 FACTORS OF CONCRETE USED IN PRESTRESSED CONCRETE

The main factors used are

1. Portland cement-based concrete.
2. A high early strength is required to enable quicker application of prestressed.
3. A larger elastic modulus is needed to reduce the shortening of the member.
4. A mix that reduces creep of the concrete to minimize losses of prestress.

2.5.3 ADVANTAGES OF PRESTRESSING CONCRETE

One of the major advantages of prestressed concrete over reinforced concrete is that for a given span and loading, a smaller prestressed member is required (Hurst,1998). This saving of the dead load of the structure is particularly important in long span structures such as bridges, where dead load is a large proportion of the total load. As well as saving concrete materials for members. There is also foundation costs reduction.

2.5.4 BASIC PRINCIPLE OF PRESTRESSING

The prestressing force (p) that satisfies the particular requirements, geometry, and loading of a given element can be found using stress strain relationships and mechanical principles. In certain cases, simplification is necessary, such as when a prestressed beam is assumed to be homogeneous and elastic. Let's now examine a rectangular leak with a simple support that is exposed to the indicated concentric prestress force P. The compressive stress is uniform and has an intensity on the beam cross section.

$$f = \frac{-p}{Ac}$$

Where A=bh is the cross sectional area of the beam section of width b and depth h . A minus sign is used for members in compression while a plus sign is used for members in tension throughout this study. Also, bending moments are drawn on the tensile side of themembers

If external transverse loads are applied to the beam, causing a moment M at mid span, the resulting stress there becomes

Where ft=stress at top fibersFb= stress at bottom fibers

C=1/2h for the rectangular section

Ig = gross moment of inertia of the section (bh3/12)

The equation above indicates that the presence of prestressing compressive force p/A is reducing the tensile Flexural stress mc/I to the extent intended in the design, either eliminating tension totally (even inducing compression) or permitting a level is tensile stress within allowable code limits. The compressive force AG the top fibers of the beam due to prestressing are compounded by application of loading stress.

Because of this, the concentric prestressing force reduces the beam's compressive stress capacity to withstand a significant external load. To get around this restriction, the prestressing tendon is positioned eccentrically below the neutral axis at mid span to cause tensile stresses at the top fibres as a result of prestressing.

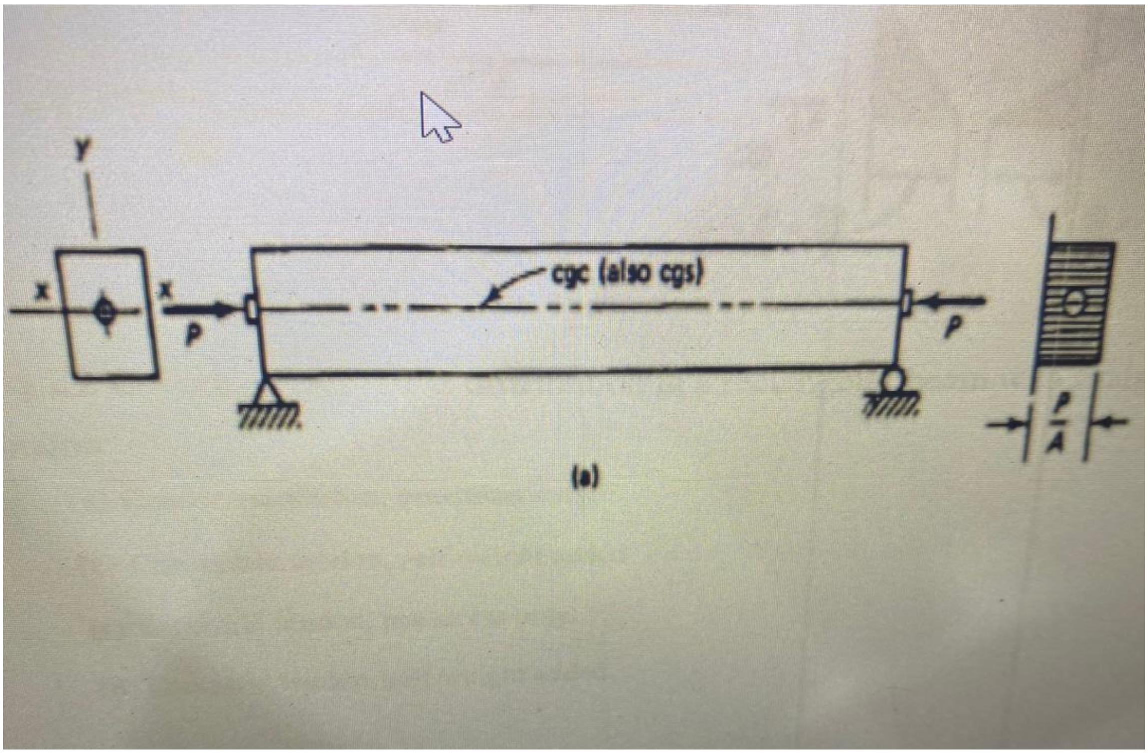


Fig 2.4: Stress distribution in rectangular beam

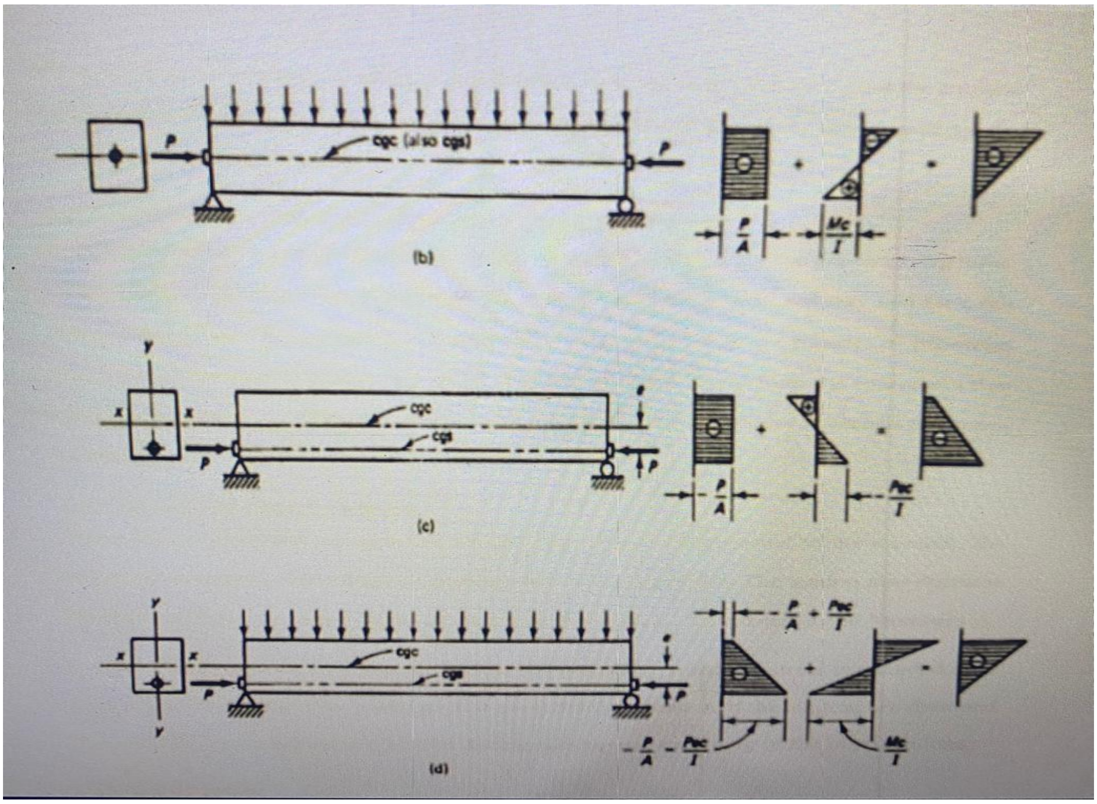


Fig 2.5: Concrete fiber stress distribution in a rectangular beam with straight tendon

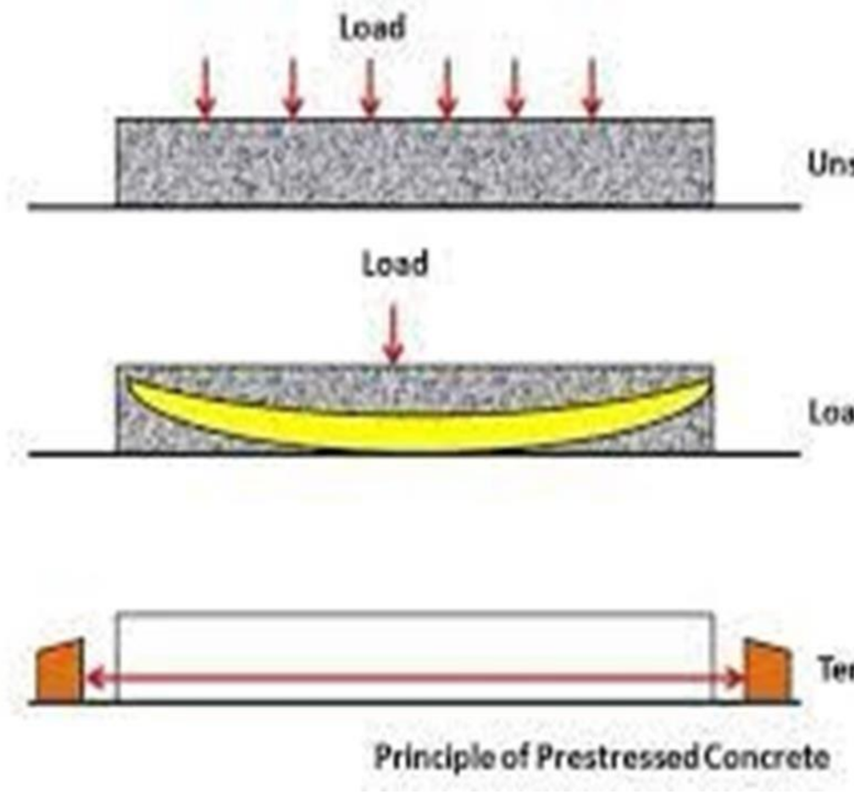


Fig 2.6: Principle of prestressed concrete

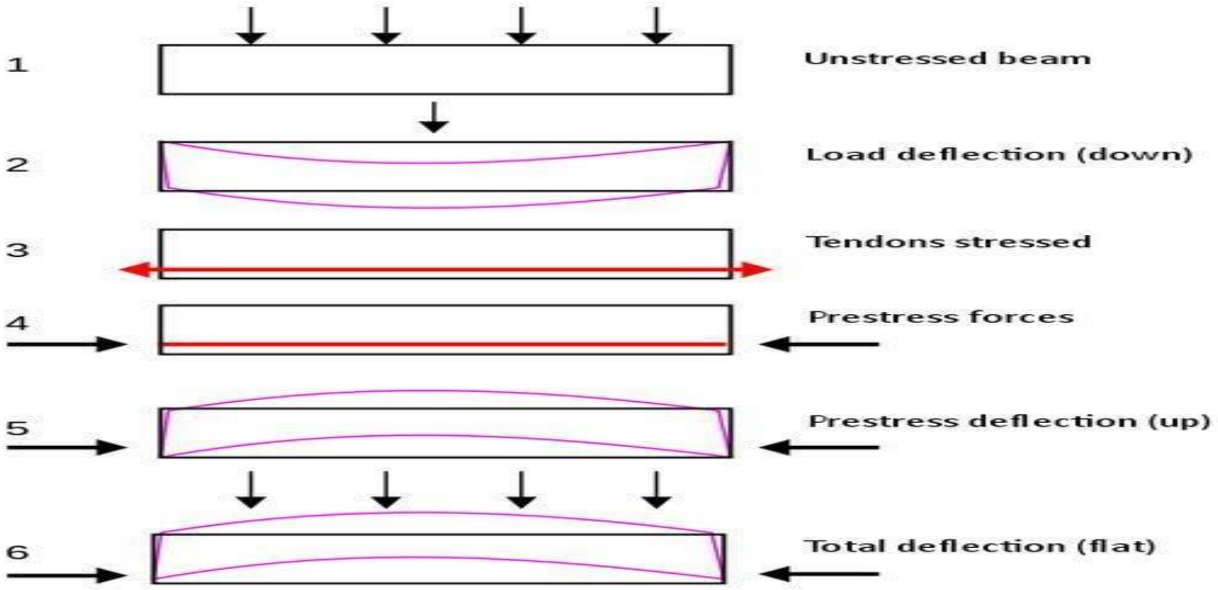


Fig 2.7: prestressed concrete diagram

Prestressing works by compressing the beam before it is loaded in a way that creates stresses in the section that act in opposition to those that arise from loading. Prestressing compresses the bottom of the beam, completely neutralizing any tension that may arise when it is loaded. Additionally, a key factor in the concrete's ability to resist shear is its compression. If a prestressed beam is visualized as a row of blocks that are compressed together, it is simple to understand that when a load is applied, the blocks will remain together as long as they are compressed tightly.

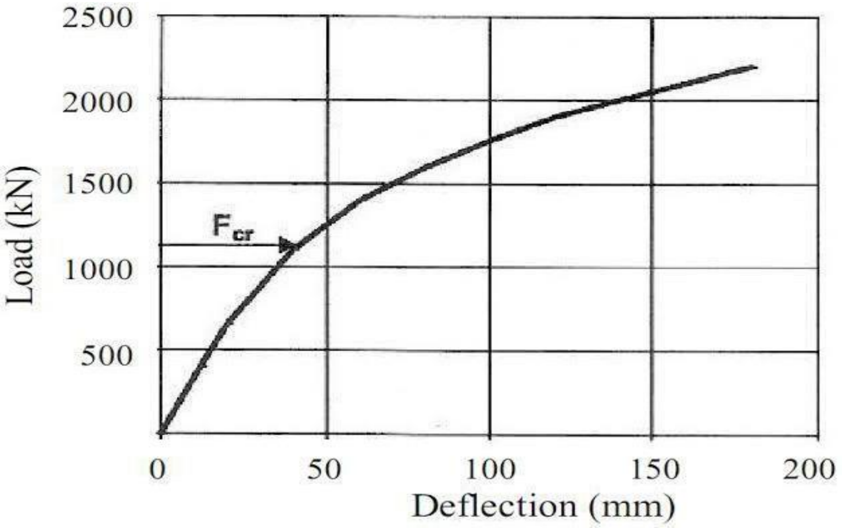
The requirement for steel reinforcement to withstand shear stresses will typically be eliminated in this situation, helped by the device that sweeps cables upward at the end of the beam.

2.5.5 DEFLECTION CHARACTERISTICS IN PRESTRESS CONCRETE

Deflection in prestressed concrete is a critical aspect that significantly influences the structural performance and serviceability of engineered structures. Prestressed concrete, an innovative construction material, departs from traditional methodologies by introducing compressive stresses to counteract tensile forces. Understanding the deflection characteristics involves delving into several key factors and their intricate interplay.

Fundamentally, prestressed concrete's unique approach mitigates the effects of external loads by preemptively introducing compressive stresses. This proactive measure enhances the material's overall strength, setting the stage for examining how deflection manifests in various scenarios. One crucial factor influencing deflection is the level of prestressing. Higher levels of prestressing actively work to minimize deflection, providing a counterforce against applied loads. Additionally, time dependent effects such as creep and shrinkage contribute to deflection over the lifespan of the structure. Creep refers to the gradual deformation under sustained loads, while shrinkage involves volume reduction, both necessitating consideration in structural analysis.

The geometry and support conditions of a structure play a pivotal role in determining deflection. Longer spans and flexible supports generally result in higher deflections, emphasizing the importance of understanding how these elements interact within the context of prestressed concrete. Different types of loads, whether live loads or environmental factors, also contribute to deflection. This requires a comprehensive understanding of how these loads interact with prestressed concrete to accurately predict and manage deflection behavior. Analytical methods are crucial tools for predicting and understanding deflection in prestressed concrete. Moment curvature analysis provides insights into the distribution of moments and curvatures along the length of a member. Finite Element Analysis (FEA) offers a detailed numerical examination of deflection under various conditions, providing a comprehensive understanding of complex structural interactions. Analytical models, derived from empirical data and observed behavior, further contribute to predicting deflection by considering factors such as material properties and support conditions. The implications of deflection in prestressed concrete extend to the design and construction phases. Serviceability limits, defined by codes and standards, directly address deflection to ensure user comfort and prevent structural damage. Designers face the challenge of balancing structural strength with serviceability requirements, leveraging the optimization potential inherent in prestressed concrete. Real world case studies, such as the South Viaduct of the Golden Gate Bridge and the Burj Khalifa, exemplify effective deflection control through careful design and prestressing. These structures showcase the adaptability of prestressed concrete in accommodating dynamic loads while maintaining structural integrity. Ongoing research into innovative materials like high performance concrete and fiber reinforced polymers holds promise for optimizing deflection characteristics. Integrating sustainability into design practices involves considering long term deflection characteristics, enhancing the



lifecycle performance of prestressed concrete structures.

Fig 2.8: Load defection curve of pressed concrete girder

2.5.6 LOSSES IN PRESTRESS CONCRETE

The prestressing force is the most crucial factor in applications involving prestressed concrete. Early on, it was noted that the pre stressing force decreases with time rather than remaining constant. Even when the tendons are being pre stressed and the pre stress is being transferred. There is a force drop from the gauge's recorded value to the concrete member; this force reduction is referred to as losses.

2.6 CREEP OF CONCRETE

This is the gradual increase in deformation under continuous load. The study of creep is crucial in prestressed concrete to determine the loss in prestress because the concrete's creep causes the tendon's prestress to gradually decrease. Creep occurs due to twocauses:

1. Rearrangement of hydrated cement paste

2. Expulsion of water from voids under loads

The creep strain depends on several factors. It increased with increase in the following variables

1.Cemnt content

2.Water to cement ratio

3. Air entrapment

4.Ambient temperature

2.7 PRESTRESSING TENDONS

High strength steels with a minimum of 270,000 psi can be used to achieve effective prestressing because of the high creep and shrinkage loss in concrete. Such extreme stress steels have sufficient residual stress levels to maintain the necessary prestressing force and can offset these losses in the surrounding concrete (Caprani, 2007). The different forms the steel may take are Wires, Strands, Tendon or Bars.

2.8 APPLICATIONS OF PRESTRESSED CONCRETE

1. FOUNDATION

Prestressed Concrete Piles: Buildings and marine structures have been constructed using prestressed concrete piles on a large scale. Prestressed concrete piles have gained a lot of popularity in the building of marine structures because of their exceptional handling strength and high level of durability in harsh environments, such as seawater. The prestressed concrete piles have many advantages in comparison with conventional piles, a few of them are:

1. High load carrying capacity.
2. Crack free under handling and driving.
3. Ability to take up lift (tension).
4. Can bear hard driving and can penetrate hard strata.
5. Durability in an adverse environment.

6. High column strength.

Given the aforementioned benefits, prestressed concrete piles are a great option for deep foundations under heavy loads on brittle soil. Currently, sheet piles, fender piles, and soldier piles are all made of prestressed concrete. It has been found to be resilient in a variety of settings, including the sub arctic and the desert, and is also utilized for carrying vertical loads with varying soil strengths.

By using prestressed anchors, which are available at very great depths, it is not necessary to drive the pile all the way to the rock. Depending on the state of the soil, the pile can only be driven so far before prestressed cable is sent through it and into the rock. After that, the cable is grouted and stressed.

2. BRIDGES

The superstructures of bridges demonstrate the remarkable role that prestressed concrete plays in construction. It is widely utilised in both highway and rail bridges.

Many kinds of bridges can be built with great success using the prestressing technique.

a. Simply Supported Bridges: For medium and short spans, they are used. These beams' cross sections could be in the form of an I, a T, two Ts, or a box. It is possible to pre or post tension the girders. Neoprene or other kinds of bearings are typically used to support these beams at either end, which can be precast or cast in situ.

b. Cantilever Bridges: This approach is typically used for bridges with greater spans. Cantilevers will extend from each of the piers in this method. To join the cantilevers, a suspended span of the shorter length will be used. Cantilevers are typically lengthened by securing short precast segments. Every section is fastened to the balancing extension situated on the opposite end of the pier.

c. Cable Stayed Bridges: Extraordinarily long spans built with this construction technique. The deck or slab in this kind of construction is supported by several prestressed cables that are fixed to the anchor tower. This technique allows for the construction of spans up to 300 m. Other types of bridges like bridges with Bow String Truss, Stressed Ribbon Deck, and Arch Bridges are included.

3. **MARINE STRUCTURES**

Because of its strength, economy, and longevity, prestressed concrete is becoming more and more popular in the marine structure industry. We have already covered its application to foundations in the previous section.

The superstructures of marine projects are increasingly using prestressed concrete.

4. **WATER CARRYING STRUCTURE**

a. Aqueducts: Because of its watertightness and smooth surface, prestressed concrete is determined to be the best material to use in the construction of aqueducts. Because of its exceptional strength, prestressed concrete makes it possible to build long span aqueducts with large water carrying capacities.

b. Water Tanks: Prestressed concrete is also used in the construction of circular water tanks.

Compared to R.C.C., they can tolerate greater circumferential stress. Because of their great strength, prestressed concrete tanks have walls that are substantially thinner than R.C.C. Because of these benefits, prestressed concrete is becoming more and more popular when used to build reservoirs and overhead water tanks.

5. **INDUSTRIAL STRUCTURES**

The use of prestressed concrete in the building of industrial structures is growing in popularity. Prestressing is typically used on the tie members of trusses. Employing prestressed concrete has the following benefits:

longer spans of trusses can be constructed. The aesthetic look of the structure is enhanced.

6. **PRETENSIONED PRODUCTS**

Much progress has been made in the field of pretension, which is very advantageous. One of the many uses of pretension is the widespread production of prestressed electric transmission poles. The railway sleeper is a new and significant addition to the list. Around the world, numerous plants producing these sleepers are proliferating. Prefabricated homes also make extensive use of precast pretensioned members. There is great potential for growth and diversification with this application. (Burman, Govina, 2020).

2.9 PRE-TENSIONING IN CONCRETE DESIGN

Pre tensioning and post tensioning are the two processes that can impact a structure's prestressed concrete design. Two additional classifications for pre tensioning exist: linear pre tensioning and circular pre tensioning. Before pouring concrete, pre tensioning is achieved by stretching tendons wires or strands between two anchorages to a predetermined tension. Tendons are then cemented to the concrete along their entire length after the concrete is poured. Tendons are cut at the anchorages and released once the concrete has solidified. Tendons tend to shorten and revert to their original length, imparting a compressive stress to the concrete through bonding. Using hydraulic jacks usually results in stress on the tendons. Tendon ends are anchored to abutments spaced up to 200 meters apart, which maintains the tension in the tendons during the pouring and curing of concrete. The term prestressing bench or bed refers to the abutments and additional formwork used in this process. Although the fundamental idea behind all pre tensioning construction techniques is widely understood, the majority of them are patented. (Mishra Gopal, 2010).

2.10 ISSUES SOUROUNDING PRESTRESS

Here are some of the most common challenges associated with precast concrete structures:

i. Sealing the Joints

ii. Shipping the Product

iii. Offloading & Rigging Concerns

iv. Preparation of Subgrade

v. Lack of Flexibility

vi. Repairing Spalls or Cracks

2.10.1 SEALING THE JOINTS

Precast concrete joints may experience sealing issues. Joints may eventually drift apart, jeopardizing and weakening the structure. Inadequate application of joint sealants can lead to this issue. This typically happens when the joint sealant instructions are not correctly followed. Joint adhesion may be weakened and proper joint sealing may be impeded if the joints are not thoroughly cleaned and prepared before applying the joint sealant. Joint sealant issues are, nevertheless, typically highly avoidable. The application of precast joint sealants should be successful and joint sealant issues should not arise if the joint sealant instructions are followed and all necessary preparations are made before applying the joint sealant, such as making sure the joints are clean and clear of any dirt or debris and verifying that the joints are properly formed to fit together correctly by performing a dry fit or checking the alignment before applying the joint sealant.

2.10.2 SHIPPING THE PRODUCT

It can be difficult to ship precast concrete, so the manufacturer and the person in charge of the job site should work together to make the delivery happen. Because of its weight and the potential for large structures, precast concrete can be challenging to move. Transporting larger structures may require specialized trucking and a number of preparations. The more configurations that may be required to make transportation easier, the larger the structures' height, width, and weight. Permits are needed for structures wider than 8 feet 6 inches. Permits and escorts are needed for structures wider than 14 feet. Two escorts and a permit are needed for structures wider than sixteen feet. A weight permit is also required for precast concrete structures that weigh more than a specific amount. Route inspections are necessary for shipments taller than 13 feet, and it might be necessary to use bucket lifts in order to avoid powerlines. To make sure the path is safe for the structures to travel, it will be surveyed. Transporting precast concrete may seem logistically difficult, but by working with seasoned hauling companies that are knowledgeable about DOT regulations and have the appropriate trucks and trailers, the delivery process can go smoothly. Precast designers can typically split a structure into multiple sections to minimize the weight or size of any individual precast section in the event that the structure is too large, too tall, or too heavy to be transported in one piece. In the field, there are various techniques for establishing structural connections between precast sections. This lowers the lifting capacity required on site and enables the transportation of these big structures.

2.10.3 OFFLOADING AND RIGGING CONCERNS

Offloading and correctly rigging the structures presents another challenge when working with precast concrete. Typically, lifting and moving the structures requires the use of cranes or other large machinery. Knowing the capacity of the crane, rigging, and lifting devices carries some risk, just like any other crane related procedure. In order to ensure that the structure is secure before lifting, it is crucial to use the appropriate rigging.

When shoring an excavation improperly, it can result in disastrous failures and should, if needed, be inspected and engineered. It is wise to involve the crane company and inspect the job site prior to installation if there are overhead obstructions or if there are concerns about the shoring. To guarantee that very large structures are lifted correctly, qualified engineers should create lifting diagrams and rigging plans. A safer and more effective offloading and setting procedure will be made possible by knowing how to properly rig a precast structure, identifying the lifting capacities of the equipment and rigging devices, and knowing which equipment is most appropriate for each individual lift.

2.10.4 PREPARATION OF SUBGRADE

One of the most crucial steps in a successful installation of precast concrete is subgrade preparation. If done wrong, this can lead to issues. Weak subgrades can shift the structure and cause it to settle incorrectly, which can lead to cracks or sinking. For instance, if any of these structures have electrical cables passing through them as they move underground, those cables could break and cause serious issues. Making sure the subgrade is appropriately ready for the structure is the best way to guarantee that this won't happen. The ground needs to be properly excavated before doing this. Remove any unnecessary materials or debris. This will help prevent settlement or any shifting that could lead to the concrete cracking, as well as help create a level and firm subgrade. Additionally, the subgrade needs to be fully flat and compacted. It's critical to understand the acceptable backfill material when backfilling the subgrade. Compacted and evenly distributed backfill is required. The likelihood of problems occurring will be significantly reduced and the stability of the structure will be ensured by properly preparing the subgrade.

2.10.5 LACK OF FLEXIBILITY

Because precast concrete is rigid once it is constructed and delivered to the job site, it can present difficulties. Precast constructions are occasionally designed using as built drawings that depict the anticipated subsurface conditions. When a precast structure is designed to integrate with preexisting plumbing, it is possible that the plumbing will not be where it should be, which could make the precast structure ineffective.

Partial excavations can be done ahead of time to confirm utility locations before precast structure manufacturing in order to prevent this kind of situation. Thin wall knockouts, which are precast wall sections made especially to be thinner and enable the area needed to be broken through, can also be used to design structures.

CHAPTER THREE

3.0 METHODOLOGY

Geopolymer concrete (GPC) is a type of concrete that uses industrial waste materials such as fly ash and slag as binders, instead of ordinary Portland cement (OPC). GPC has many advantages over OPC, such as lower carbon emissions, higher strength, and better durability. The procedure for comparing the prestress of geopolymer concrete and ordinary Portland cement is covered in this chapter. Finding the differences between the prestress behaviour of geopolymer concrete and regular Portland concrete is the primary objective of the study. The University of Benin's Structural Laboratory, which houses the Civil Engineering Department, was the site of the experimental investigation.

3.1 MATERIALS

The concrete beams made in the laboratory were made using the following materials:

1. Cement (OPC)
2. Fine aggregate
3. Coarse aggregate
4. Metakoalin
5. Water
6. Cables
7. Sodium silicate
8. Sodium Hydroxide

3.1.1 CONCRETE

Cement, aggregate, and water are the three components that make up concrete, a composite building material. Usually, the aggregate consists of a fine aggregate like sand mixed with coarse gravel or crushed rocks like granite or limestone. The cement. The aggregate is typically bound by Portland cement made of limestone and additional cementitious materials like fly ash and slag cement. The desired properties are also attained by adding different chemical admixtures. The dry composite is then combined with water to allow for pouring, solidification, and hardening into rock-hard strength a process called hydration. Water and cement react to form a strong bond that eventually turns the mixture into a sturdy substance that resembles stone. Concrete's tensile strength is significantly lower than its compressive strength. The ratio of water to cementitious materials, design elements, and mixing all affect concrete's ultimate strength. Methods of placement and curing used. A stronger concrete is produced by using a lower water cement (cementitious) ratio than one with a higher ratio. The character is mostly determined by the quality of the paste that is created when cement and water are combined. For most structural work, the concrete is designed to give compressive strengths of 15 to 35 MPa. This process of arranging the ingredients in the mixture is known as "designing the mixture."

3.1.2 CEMENT

An essential component of construction, cement acts as a binder to keep the constituent parts of mortar and concrete together. Cement is made up mostly of calcium, silicon, aluminum, and iron. It goes through a rigorous manufacturing process to achieve its necessary qualities. The procedure entails raising the temperature of a combination of raw materials in a kiln, such as iron ore, limestone, and clay or shale. The final cement product is made by finely ground powdered clinker, which is a sintered material.

Portland cement, which bears the name of the English island of Portland, is the most common kind. It is available in different formulations (such as Type I and Type II) designed to meet particular building requirements. Cement undergoes hydration a chemical reaction that forms a gel-like substance when it is mixed with water. In order to bind aggregates together to create concrete, this hydrated cement paste functions as a glue. The importance of cement comes from its function as the main component of concrete, a material used in many construction projects. Concrete is a composite material with remarkable strength, durability, and versatility. It is made of cement, aggregates (like sand and gravel), and water. It is used in many different construction projects, such as roads, bridges, buildings, and dams. The environmental impact of cement production, characterized by high energy consumption and carbon dioxide emissions, has prompted ongoing research into sustainable alternatives. Blended cements, incorporating supplementary materials like flyash or slag, and the exploration of alternative binders are avenues to reduce the ecological footprint of cement. As a regulated material adhering to stringent quality standards, cement remains integral to the advancement of modern infrastructure and sustainable construction practices. Efforts to balance its structural indispensability with environmental stewardship continue to shape the future of cement in the construction industry.

3.1.3 FINE AGGREGATE

Coarse aggregate is gravel that has been crushed, cleaned, and sieved so that the particles range in size from 5 to 50 mm. Fine aggregate is natural sand that has been cleaned and sieved to remove particles larger than 5 mm. Delivery of the coarse and fine aggregate occurs separately. A prepared mixture of fine and coarse aggregate is more expensive than natural all-in aggregate because it needs to be sieved. Sand is used in the production of concrete and mortar, as well as in sandblasting and polishing. In foundries, sands with a small amount of clay are used to make moulds. Water is filtered through clear sands. Sand is shipped by weight and is sold in cubic yards (0.76 m3) and tonnes (0.91 metric tonnes). The weight of the grain varies from 1,538 to 1,842 kg/m3, based on its size and composition. The fine aggregate is passing through 4.75 mm sieve and had a specific gravity of 2.67.

3.1.4 COARSE AGGREGATE

Crushed stone used to make coarse aggregate is used to make concrete. The stone used for commerce is graded, crushed, and quarried. The most common types of crushed stone used are trap rock, limestone, and granite. Larger sizes may be utilized for massive concrete aggregate, but the sizes range from 0.25 to 2.5 in (0.64 to 6.35 cm). As coarse aggregate, angular-shaped machine-churned granite is used.

3.1.5 METAKAOLIN

One pozzolanic substance that is frequently used in the creation of geopolymer concrete is metakaolin. It comes from thermally activating kaolin clay, a naturally occurring mineral clay that is primarily made of kaolinite. Heating kaolin clay to high temperatures is the first step in turning it into metakaolin. Metakaolin is created when the kaolin clay undergoes physical and chemical changes as a result of the calcination process. The elimination of water that is chemically bonded and the conversion of the crystalline kaolin structure into an amorphous or partially amorphous structure are the two main modifications.

Metakaolin is often chosen for geopolymer concrete formulations when other precursors like fly ash or slag are not readily available or when specific performance characteristics are desired. Its use contributes to the versatility of geopolymer technology in offering sustainable alternatives to conventional concrete production.

3.1.6 WATER

Generally speaking, water that is safe to drink is acceptable for use in concrete. Vegetables, acids, oils, alkalis, and other organic contaminants should not be present in water. Weaker concrete is also produced by soft water. There are primarily two uses for water in concrete mix. Initially, it reacts chemically with the cement to create cement paste, where the inert. Until the cement paste hardens, the aggregate is kept suspended. Furthermore, it serves as a lubricant in the cement and fine aggregate mixture.

3.2 MATERIAL TEST

1. Sieve Analysis
2. Specific Gravity
3. Tensile Test
4. Workability (Slump test)

3.2.1 SLUMP TEST

To make sure the mixture has received the proper amount of water, the slump test is carried out. The slump cone and the base are lubricated as part of the BS 1881; Part 102 procedures. The suggested mix ratio was used to mix the concrete in the concrete mixer. Three layers of mixed concrete were poured into the cone, and each layer was tamped 25 times with a tamping rod. After that, the cone is completely filled; no more tamping is necessary; instead, the excess concrete is removed by rolling the tamping rod over the surface. Subsequently, the slump cone is positioned adjacent to the concrete, and the tamping rod is positioned above the cone, covering the concrete. The slump value is determined by measuring the difference in height between the slump cone and the concrete. After being cleaned and oil-lubricated, the slump test cone was set up on a level, impermeable base and filled in three layers with new concrete. To guarantee proper compaction, the tamping rod was used 25 times on each layer. The top of the cone was not level with the third layer when it was completed. After that, the cone was cautiously raised vertically, leaving a mound of concrete that gradually sagged or slumped. The removed cone was then set on the base next to the concrete pile, with the cone's tamping rod extending above the pile's top. The slump of the newly laid concrete was then determined by measuring and recording the settlement to the nearest 5mm.

Fig 3.1: Slump Test

3.2.1.1 APPARATUS

The apparatus used include:

a. Slump cone: Shaped like the frustrum of a cone, with a height of 300 millimeters, a bottom diameter of 200 millimeters, and a top diameter of 100 millimeters.

b. Base plate

c. Measuring tape

d. Tamping rod

3.2.1.2 PROCEDURES

1. The interior surface of the slump cone was dried, cleaned, and clear of any cement residue that had set.
2. Interior surface was lubricated with oil/grease to stop the slump cone from sticking and for easy removal
3. The slump cone was securely positioned, placed on a square metalbase
4. plate. Stabilize the cone by placing its metal arms on the base plate.

5. Three layers of freshly mixed concrete were placed within the slump cone, each about a quarter of the cone's height.
6. The strokes were uniformly distributed throughout the cross-section by tamping the concrete 25 times with a tamping rod after each layer.
7. After the third layer has been compacted evenly, the cone was filled with new concrete until it was full, to let the extra concrete spill over.
8. Surplus concrete was removed by using a trowel
9. While the cone was still being held in place, the base plate and the bottom of the cone was cleaned, to remove any remaining concrete.
10. The slump cone was raised vertically from the newly laid concrete and set it gently nextto the concrete.
11. For measuring and recording purposes, the tamping rod was placed atop the cone andalign it with the concrete mound's height.
12. A measuring tape was used to determine the slump, which is the difference betweenthe cone's height and the height of the concrete specimen.

3.2.2 SIEVE ANALYSIS

Using a series of test sieves, a material is separated into numerous particle size classifications of progressively smaller sizes in this test. The mass of the particle retained on each of the various sieves is related to the material's initial mass. The ratios of each sieve that passes through are given in both numerical and graphical form. The test was designed to determine the particle size distribution of the coarse aggregate (granite) in compliance with (BS EN 993-1-1997).

3.2.2.1 APPARATUS

The apparatus used include:

i) A set of British Standard sieve

ii) Weighing balance

iii) Cleaning brush

iv) Scoop

v) Pan

3.2.2.2 PROCEDURE

1. If any particles get lodged in the holes of the sieves, clean them with a cleaning brush.
2. The weight of each sieve and receiving pan were recorded.
3. Record the specimen's weight after weighing it.
4. Put the sieves in sequence such that the bigger openings go to the top and the smaller openings go to the bottom.
5. Store the specimen with the weight recorded on the upper sieve, and subsequently place the entire sieve stack into the sieve shaker (remember to save the receiving pan andlid).
6. Take note of the time and let the shaker run for 10 to 15 minutes.
7. After removing the sieve stack from the shaker, weigh each sieve and receiving pan independently.

3.2.3 SPECIFIC GRAVITY

The ratio of a substance's density to that of a reference substance at a given temperature is known as specific gravity. It is also the ratio of a substance's mass to that of a reference substance. The volume of voids in aggregates can be calculated using specific gravity, which helps with the right proportioning of concrete mixtures.

3.2.3.1 APPARATUS

1. Weighing Balance
2. Wire Basket

3. Container
4. Wire Hanger
5. Brush
6. Oven

3.2.3.2 PROCEDURE

1. Wash the aggregates thoroughly to remove any dust or impurities.
2. Oven dry the aggregate until a constant weight is achieved.
3. Weigh the dry aggregates in air using the balance.
4. Immerse the aggregates in water using the wire basket, ensuring complete submersion.
5. Fill the pycnometer with water at a known temperature.
6. Record the initial volume of water in the pycnometer.
7. Place the submerged aggregates in the pycnometer, ensuring the water level rises.
8. Record the final volume of water, considering the displaced water by the aggregates.

Calculate the specific gravity (*G*) using the formula:

$$\mathbf{W_{bw}\ (\textit{for specific temperature, } T_x) = \frac{\rho w(Tx)}{\rho w(Ti)} \text{ x } ((W_{bw}\ \text{at } T_i) - W_b) + W_b}$$

Where:

$\rho_w(T_x)$ = density of water identified by temperature

$\rho_w(T_i)$= density of water identified by temperature

W_{bw} = weight of pycnometer and water in grams

W_b = weight of pycnometer in grams

T_i = observed/recorded temperature of the water in Celsius

T_x = any other desired temperature in Celsius

3.2.4 TENSILE STRENGTH TEST

Tensile strength test which is also called tension testing (Czichos and Horst, 2006), is a fundamental material science and engineering test in which a specified specimen is subjected to a controlled tension until failure. the tensile strength test is carried out using the universal testing machine. the test was performed according to the ASTM E8/E8M 13 standard.

3.2.4.1 PROCEDURE

a. The cables were cut in length of 300mm
b. They were then placed in the universal testing machine
c. They were slowly extended until the cut
d. The force at which the cut is recorded
e. The test was carried out on the cables, wires, and strands and their results were recorded.

3.2.4.2 MOULD PREPARATION

Different moulds were use in the course of carrying out this project.

i) Cube mould (100mm X 100mm)
ii) Prestressing I section mould: the dimension are as follows:

a) depth of flange = 15mm

b) length of top flange = 45mm

c) web thickness= 25mm

d) depth of web = 45mm

e) depth of bottom flange = 30mm

f) length of top flange = 45mm

g) span = 900mm

iii) untensionsed beam moulds (100mm X 100mm X 500mm)

prestress cables of 3mm diameter was used and the cable cover were 10mm on all sides.

3.2.5 INITIAL SETTING TIME

The moment cement paste begins to harden is known as the initial setting time of concrete. In theory, the first setting time for concrete is the interval of time between adding water to the cement and the point at which the needle in a 1 mm square section of the Vicat mould fails to pierce the cement paste, which is positioned between 5 and 7 mm from the mold's bottom.

3.2.5.1 APPARATUS

1. Vicats apparatus
2. Balance
3. Measuring cylinder
4. Stop watch
5. Glass plate
6. Enamel tray
7. Trowel

3.2.5.2 PROCEDURE

1. Place the test block confined in the mould and resting on the non-porous plate, underthe rod bearing the needle
2. lower the needle gently until it comes in contact with the surface test block and quick release, allowing it to penetrate into the test block
3. repeat this procedure

3.2.6 FINAL SETTING TIME

When cement paste has sufficiently dried to the point where a 1 mm needle leaves an impression on the paste in the mould but a 5 mm needle leaves no trace, this is known as the final setting time.

3.2.6.1 APPARATUS

1. Vicats apparatus
2. Balance
3. Measuring cylinder
4. Stop watch
5. Glass plate
6. Enamel tray
7. Trowel

3.2.6.2 PROCEDURE

1. Replace the needle of the Vicats apparatus by the needle with an annular attachment
2. the cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression there on, while theattachment fails to do so.
3. Record this time.

3.2.7 COMPRESSIVE STRENGTH

The capacity of concrete to withstand loads or forces that would cause it to contract in size or dimension is known as its compressive strength. Numerous variables, including the water-to-cement ratio, the strength of the cement, the caliber of the raw materials used to make concrete, and quality control procedures used in the process, affect the compressive strength of concrete. The control cube samples' compressive strength was ascertained using BS 1881: Part 116 (1983). At 7, 14, and 28 days after the concrete's age, three (3) 100 mm x 100 mm x 100 mm cube samples for the control mix were tested. During testing, the smooth end face of every sample was positioned at the center of the concentric circle, directly above the compressor, to guarantee consistent loading throughout the region.

The Multifunctional Computerized Control Console Machine (MCC8) was used to conduct the test. The compressive strength was taken as a ratio of the ultimate load to cross-sectional area of each sample. The average of the triplicate sample was the final outcome.

Fig 3.2**:** Multifunctional Computerized Control Console Machine (MCC8)

3.3 PREPARATION OF ALKALINE ACTIVATOR SOLUTION

The alkaline compounds employed for the activation of the metakaolin are sodium hydroxide and sodium silicate. The sodium hydroxide was prepared for different molarities. The sodium hydroxide and sodium silicate where mixed in a proportion as shown in the mix design.

3.4 CONCRETE MIX DESIGN

The concrete mix design was done according to BS 5328, Part 2

Table 3.1: 8M Geopolymer Concrete Design Mix

Stage		Item	Values		Results
1.		characteristic strength	50N/mm^2	use lesser	0.63
		defective	5%		
		k	1.64		
		standard deviation	8N/mm^2		
		target mean strength	63.12		
		metakaolin class	43.5		
		free AAS/MK content	0.63		
			0.7		
		AAS/MK	0.234		
2		slump or vee-bee time	10-30		255
		max. aggregate content	10mm		
		free AAS content	220kg/mm^3		
3		metakaolin content	349kg/mm^3		349
		min. metakaolin content	450		
4		SS: NaOH	2		
		Sodium Hydroxide	73.35g		
		Sodium Silicate	146.7g		
5		Sodium Hydroxide	40g/mol		
		10M NaOH	320g/L		
		Water	229.17cm^3		
		40g of NaOH	31g solid	9g water	
		In 60g of NaOH	56.83	16.5	85
		Ratio of Solids in NaOH	0.231		
		Ratio of Solids in SS	0.4410		
		Mass of water in NaOH	56.3682		
		Mass of water in SS	81.9867		
		Total water content	138.3548		155.86
		Water/Geopolymer ratio	0.321		
6		absolute volume of MK	0.15m^3		0.63
		absolute volume of NaOH	0.054m^3		
		absolute volume of SS	0.11m^3		
		TAC volume	0.67m^3		
7		grading of aggregate	70%		
		proportion of aggregate	28		
		fine aggregate content	490g		
		coarse aggregate content	1266g		

Table 3.2: 8M Geopolymer Concrete Design Mix Ratio

Material	**Metakaolin**	**AAS**	**Fine Aggregate**	**Coarse aggregate**
Quantities per $1m^3$	349	220	490	1266
Ratio	1	0.63	1.1	2.9

Table 3.3: 10M Geopolymer Concrete Design Mix Ratio

Stage	**Item**	**Values**		**Results**
1.	characteristic strength	50N/mm^2	use lesser	0.63
	defective	5%		
	k	1.64		
	standard deviation	8N/mm^2		
	target mean strength	63.12		
	metakaolin class	43.5		
	free AAS/MK content	0.63		
		0.7		
	AAS/MK	0.245		
2	slump or veebee time	30-60		255
	max. aggregate content	20mm		
	free AAS content	255kg/mm^3		
3	metakaolin content	405kg/mm^3		405
	min. metakaolin content	450		
4	SS:NaOH	2		
	Sodium Hydroxide	85g		
	Sodium Silicate	170g		

5	Sodium Hydroxide	40g/mol		85
	10M NaOH	400g/L		
	Water	212.5cm^3		
	40g of NaOH	31g solid	9g water	
	In 60g of NaOH	65.875	19.125	
	Ratio of Solids in NaOH	0.284		155.86
	Ratio of Solids in SS	0.441		
	Mass of water in NaOH	60.8257		
	Mass of water in SS	95.03		
	Total water content	155.8557		
	Water/Geopolymer ratio	0.309		
6	absolute volume of MK	0.17m^3		0.63
	absolute volume of NaOH	0.06m^3		
	absolute volume of SS	0.13m^3		
	TAC volume	0.63m^3		
7	grading of aggregate	60%		
	proportion of aggregate	28		
	fine aggregate content	457g		
	coarse aggregate content	1180g		

Table 3.4: 10M Geopolymer Concrete Design Mix Ratio

Material	Metakaolin	AAS	Fine Aggregate	Coarse aggregate
Quantities per 1m^3	405	255	457	1180
Ratio	1	0.63	1.1	3.9

3.5 Concrete Mixing

The mixing of concrete (OPC and GPC) was done inside a concrete mixing machine, the dry materials starting from coarse aggregates for the control cube samples (gravel) were first weighed followed by sand and cement and placed in the mixer and mixed together with the aid of a shovel. After this, the required sodium hydroxide and sodium silicate was then weighed and poured into the mixer and the mixer used to thoroughly mix all the materials until a uniform mix was obtained in accordance to BS 1881 – Part – 125.

Fig 3.3: Concrete mixer

3.6 Casting of concrete cubes

After the proper mixing of the concrete (OPC and GPC) using the mechanical concrete mixing machine and the slump test completed, the still workable concrete was then poured into a cube mold. To accomplish this for the best form of concrete specimen, the molds were placed on a flat horizontal surface after securing them properly on all edges. Using a trowel, the concrete was then poured into each mold taking care to avoid segregation of the mortar and aggregate. Once the mold was filled up, it was then transferred to a vibrating table for proper compaction. This was done in accordance with BS 1881 – Part – 110.

Figure 3.4: Casting of concrete beam and cubes

3.7 Compaction

By applying vibration for the shortest amount of time required to fully compact the concrete beams without over vibrating, compaction was done to make sure that all trapped air in the concrete mass was entirely removed. If present, excessive segregation and laitance/loss of entrained air can be caused by over-vibration. The workability of the concrete and the vibrator's efficiency determine how long the vibration must last. As soon as the concrete surface took on a somewhat glazed appearance and became relatively smooth, the vibration stopped. The top layer was compacted, then the excess concrete outside the mould was wiped off and smoothed over with a trowel and plasterer's float. Clause 6 of BS 1881-108: 1983).

3.8 Curing

Water curing was utilized because it is the best method of curing that satisfies all needed concrete curing requirements, according to BS 1881 – Part – 111. The curing of the OPC samples was carried out in the Curing Tank of the UNIBEN Civil Engineering

Laboratory using Potable water that covered all the samples with at a minimum height of about 120mm above each beam. The beam samples were left in this state at room temperature until the required curing age was completed.

The geopolymer concrete beams did not need water for curing, rather it underwent air curing (a curing mode that simply leaves the sample exposed to ambient temperature, as opposed to water in the case of cement concrete).

3.9 Pretensioning Procedure

The essential devices used in the pre-tensioning and the processes carried out are given in the descriptions as follows;

i. Prestressing frame/ End Abutments

ii. Shuttering/Mold

iii. Jacking system

iv. Anchoring devices

3.9.1 Shuttering and Mould

The pre-stressing frame is made up of steel plates having factory fitted holes to receive the steel tendons, which are connected together by means of a high strength steel rod. The steel plates at the end positions serve as the end abutments and they are kept at sufficient distances apart which allows for several members to be cast in a single line at one time.

The pre-tensioning system known as the Stress Bench involves inserting a concrete mould into the frame, then stretching and anchoring tendons through the holes in the frame to the frame's booms.

Figure 3.5: Prestressing frame

The tendons are put under tension using the hydraulic jacks. Commonly used tools are hydraulic jacks. These jacks rely on pump-generated oil pressure to function. Pascal's law serves as the design basis for jacks. A separate load cell or the pressure reading from a gauge attached to the oil inflow are used to determine the load applied by a jack.

Figure 3.6: Hydraulic jacks

3.9.2 SHUTTERING AND MOULD

The mold prepared and employed in this setup is a wooden irregular I-Section beam formwork of dimensions: top flange – 45mm x 15mm, web – 25mm x 45mm, and bottom flange – 45mm x 30mm; into which holes are drilled to receive and pass the tendon through them. The molds are placed on straight lines in between the high strength steel rods employed as the shuttering. These shuttering are tightened and fastened together to the pre-stressing steel frames by means of high strength bolts.

3.9.3 ANCHORING DEVICES

Bolts and nuts were used to secure the tendons in place just behind the pre-stressing frame in anchoring devices, which are frequently constructed using the wedge and friction principle. Tendons in pretensioned members must be kept taut throughout the concrete's casting and setting processes. Simple, low-cost quick-release bolts were typically used in this situation. Before the concrete is cast, two end abutments, or end steel plates, are pulled together by 3.0 mm diameter high-strength steel tendons in the pre-tensioning system setup. Below is a schematic diagram showing the placement of the applied pre-stress force:

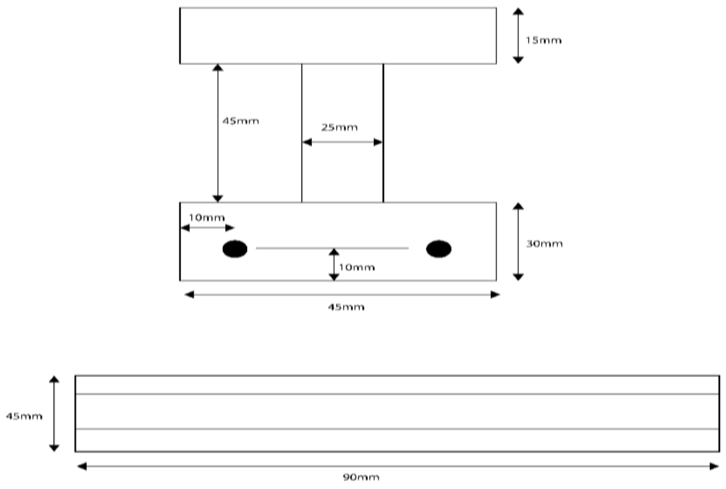


Figure 3.7: Tendon section

The tendons are severed from the abutments once the concrete reaches the required strength for pre-stressing. Because of their bond, the tendons' pre-stress is transferred from them to the concrete. Elastic shortening occurs in the member during the transfer of pre-stress. The member is prone to bending and deflecting because the tendons are positioned eccentrically (chamber).

3.10 MIX DESIGN

Table 3.5 Mix Design For 8 Molarity and 10 Molarity Design Mix

QUANTITIES PER 1M3	METAKAOLIN (KG)	AAS (KG)	FINE AGGREGATE (KG)	COARSE AGGREGATE(KG)		
				10mm	20mm	40mm
8M	349	220	490		1266	
	1	0.63	1.4		3.6	
10M	349	220	493		1271	
	1	0.63	1.4		3.6	

AAS=SH+SS

SH Sodium hydroxide=73.3

SS Sodium silicate=146.7

ASS= 73.3+146.7=220

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter, we shall present the comprehensive results of our investigation into the deflection behaviour of prestressed geopolymer concrete as against prestressed ordinary Portland cement concrete. Thorough testing and analysis were conducted in our research to shed light on the complex interplay between these variables and their influence on concrete strength in the Nigerian construction context.

4.1 LABORATORY TEST RESULTS

4.1.1 SEIVE ANALYSIS TEST

The sieve analysis was conducted using standard sieve sizes that met the requirements of the BS 1377 2 1990 specification for test sieves. Sieve analysis was graphically represented using grading curves. The fine and coarse aggregates fell between the limitations specified in BS 882: 1992, as indicated by the grading curves below. Grading is an important factor in determining the fine aggregate content and, in turn, the amount of coarse aggregate required when building a concrete mix. The workability of concrete is affected by grading.

The fine aggregate is distributed throughout a 2.260mm to 0.075mm sieve, according to Table 4.1 sieve analysis, and is categorized as medium fine sand.

Table 4.1: Sieve analysis of fine aggregate

RESULTS						
% sand		99.14	D60 (mm)	0.42	Cu = D60/D10	1.92
% fines		0.86	D30 (mm)	0.32	Cc	1.11
			D10 (mm)	0.22		

Table 4.2: Sieve analysis of fine aggregate

SIEVE ANALYSIS TEST AND PARTICLE SIZE DISTRIBUTION CURVE					
Total mass = 100g					
Sieve No.	**Sieve Sizes (mm)**	**Mass Retained (g)**	**Cumulative Retained**	**% Mass Retained**	**% Passing**
2.36	2.36	2.16	2.16	2.17	97.83
2	2	1.15	3.31	3.30	96.70
1.18	1.18	8.22	11.53	11.48	88.52
600	0.6	19.22	30.75	30.62	69.38
425	0.425	9.06	39.81	39.64	60.36
300	0.3	35.67	75.48	75.16	24.84
212	0.212	15.94	91.42	91.03	8.97
150	0.15	5.23	96.65	96.23	3.77
75	0.075	2.92	99.57	99.14	0.86
loss		0.43			

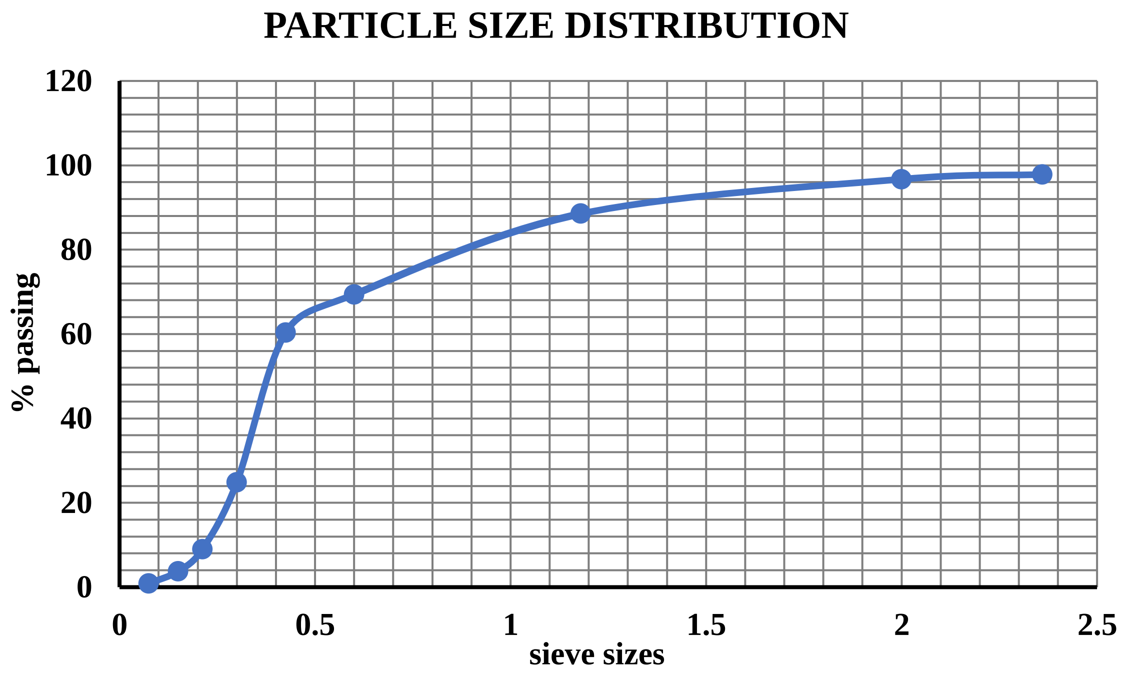


Figure 4.1 Grading curve for fine aggregate

4.1.2 SPECIFIC GRAVITY TEST

The specific gravity test was conducted to determine the relative density of materials such as aggregates and cement, compared to the density of water at a specified temperature. This property plays a critical role in concrete mix design, workability, and strength. For aggregates, the specific gravity indicates the material's porosity, influencing the durability and overall performance of the concrete. The test follows ASTM C127 for coarse aggregates and ASTM C128 for fine aggregates, or BS EN 1097 6 for both types of aggregates.

Table 4.3: Specific Gravity Test

SPECIFIC GRAVITY TEST RESULTS OF SAMPLES								
Sample no	bt (g)	bt+s (g)	bt+s+w (g)	b+k	b+w	material		S.G
2C	23.1	47.12	88.08		74.12	metakaolin		2.39
2A	21.88	46.28	90.68		76.46			2.40
Average								2.39
MB	17.77	70.10	100.78		68.69	sand		2.59
OA	19.77	60.10	95.17		70.13			2.64
Average								2.61
GC	18.09	47.72	85.08		67.42	ceramics		2.48
OC	21.10	50.71	91.08		73.62			2.44
Average								2.46
GLE	24.69	47.07	90.24		77	kaolin		2.45
EE	20.8	44.32	88.15		73.84			2.55
Average								2.50
							Sk(kerosene	
RAI	22.73	47.10	81.91	63.9	74.44	cement	0.80	3.03
OUI	20.40	48.13	84.88	64.5	75.6		0.80	3.02
Average								3.03
CYLINDER	262.0	576	936		742	granite		2.62

The meaning of the abbreviations in the table are shown below.

bt bottle

S bottle + sample

K – kerosene

S.G specify gravity.

Sk specify gravity of kerosene.

4.1.3 TENSILE TEST FOR CABLES

The tensile strength test on the strands, tendons and cables was carried out using the Universal Testing Machine. The test was performed according to the ASTM E8/E8M 13 standard. Each sample that was tested was of 300mm length. The results obtained from the test are presented below in Table 4.4.

Table 4.4: Tensile Test for Cables

Material	Diameter (mm)	Failure load (KN)
Strand	0.35	0.192
Tendon	1.05	0.922
Cable	2.42	4
	2.90	3
	2.95	7
	3.10	4

4.1.4 COMPRESSIVE STRENGTH TEST RESULTS

The test was conducted in accordance with BS 1881:part 116(1983). The compressive strength test was performed on metakaolin based geopolymer concrete for the testing period of 1,5,7, and 28 days respectively. Their respective strength and densities are represented in the table below. Compressive strength test results at curing age for the required mix where AA is the label for the required mix. The average results obtained from the test are presented in Table 4.5 below.

Table 4.5 The compressive strength for crushing values for 8 molarity of NaOH mix at different ages.

DAYS	**SPECIMIEN**	**DENSITY (Kg/m^3)**	**WEIGHT (Kg)**	**LOAD (KN)**	**AVERAGE STRENGTH (N/mm^2)**
1	A1	2500	2.5	382.67	38.267
5	A2	2510	2.50	515.10	51.510
7	A3	2506.67	2.51	469.00	46.900
28	A4	2446.67	2.45	579.50	57.950

Table 4.6 The compressive strength for crushing values for the required mix at different ages for 10 molarity of NaOH.

DAYS	**SPECIMIEN**	**DENSITY (Kg/m^3)**	**WEIGHT (Kg)**	**LOAD (KN)**	**AVERAGE STRENGTH (N/mm^2)**
3	A1	2500	2.5	292.62	29.262
14	A2	2510	2.50	364.23	36.423
28	A4	2446.67	2.45	429.02	42.902

Table 4.7 The compressive strength for crushing values for the required mix at different ages for 12 molarity of NaOH.

DAYS	SPECIMIEN	DENSITY (Kg/m^3)	WEIGHT (Kg)	LOAD (KN)	AVERAGE STRENGTH (N/mm^2)
1	A1	2565	2.565	419.18	41.918
3	A2	2657	2.657	381.52	38.152
28	A4	2577	2.577	344.98	34.498

Table 4.8 The compressive strength for crushing values of the various mix design of ordinary Portland cement.

GRADE	DAYS	AVERAGE WEIGHT (KG)	AVERAGE LOAD (KN)
C-30	7	2.52	115.88
	14	2.51	157.42
	28	2.46	233.10
C-40	7	2.36	167.26
	14	2.34	214.60
	28	2.39	349.25
C-50	7	2.46	194.00
	14	2.50	196.02
	28	2.44	326.12
C-60	7	2.37	264.15
	14	2.39	271.39
	28		

4.2 DEFLECTION TEST

Below are the test results from the deflection test conducted in the lab after conducting the flexural test on the prestressed beams.

Points taken while the test has been carried out

The point where the specimen starts to fail

The point when the beam collapse

what happened at collapse (if the tendons broke or deboned)

4.2.1 Deflection Test for 8 Molarity at 7 Days

The deflection test for the 8 Molarity specimen shows a gradual increase in deflection as the load increases. Initially, at low loads (0.5–1.5 kN), the deflection increases slowly. However, after reaching a load of 2.0 kN, a crack was observed. Beyond this point, the deflection continues to increase more significantly with higher loads, reaching a maximum deflection of 15.85 mm at 5.5 and 6.0 kN. The data indicates a steady rise in deflection with increasing load, suggesting the specimen becomes more flexible and eventually cracks under higher loads. The graph in Figure 4.2 visually demonstrates this relationship between load and deflection.

Table 4.9: Deflection Test for 8 Molarity at 7 Days

8 MOLARITY SPECIMIEN	
DEFLECTION (mm)	**LOAD (KN)**
0.5	6.98
1.0	10.38
1.5	10.40
2.0	10.40------**CRACK**
2.5	11.04
3.0	12.18
3.5	13.35
4.0	14.35
4.5	15.20
5.0	15.75
5.5	15.85
6.0	15.85

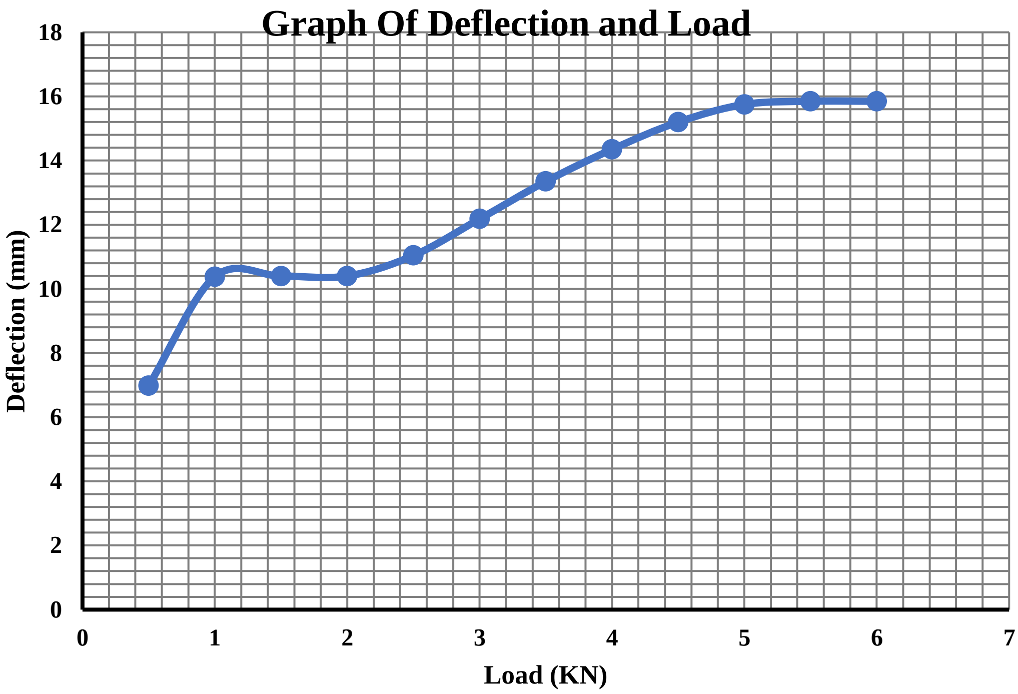


Figure 4.2 Graph of Deflection and Load for 8 Molarity at 7 Days

4.2.2 Deflection Test Results for 10 Molarity at 7 Days

The deflection test for the 10 Molarity specimen demonstrates a continuous increase in deflection as the load increases. Initially, at lower loads (0.5–1.5 kN), deflection rises steadily. A crack appears at 1.5 kN, but the deflection continues to increase gradually as the load increases further. Beyond the cracking point, the deflection increases at a faster rate, reaching a maximum of 27.48 mm at 11.5 kN. The specimen shows significant deflection under higher loads, indicating a progressive weakening as the load intensifies. This result suggests that the 10 Molarity specimen exhibits increased flexibility and deflection under applied loads compared to the 8 Molarity specimen. The graph of this data would likely show a steep, upward slope reflecting the relationship between load and deflection.

Table 4.10: Deflection Test for 10 Molarity at 7 Days

10 MOLARITY SPECIMIEN	
DEFLECTION (mm)	**LOAD (KN)**
0.5	5.85
1.0	9.98
1.5	11.54--------**CRACK**
2.0	11.85
2.5	12.97
3.0	12.97
3.5	13.75
4.0	14.98
4.5	16.34
5.0	17.5
5.5	18.32
6.0	19.55
6.5	20.54
7.0	21.72
7.5	22.30
8.0	23.16
8.5	23.83
9.0	24.32
9.5	25.20
10.0	25.96
10.5	26.45
11.0	26.99
11.5	27.48

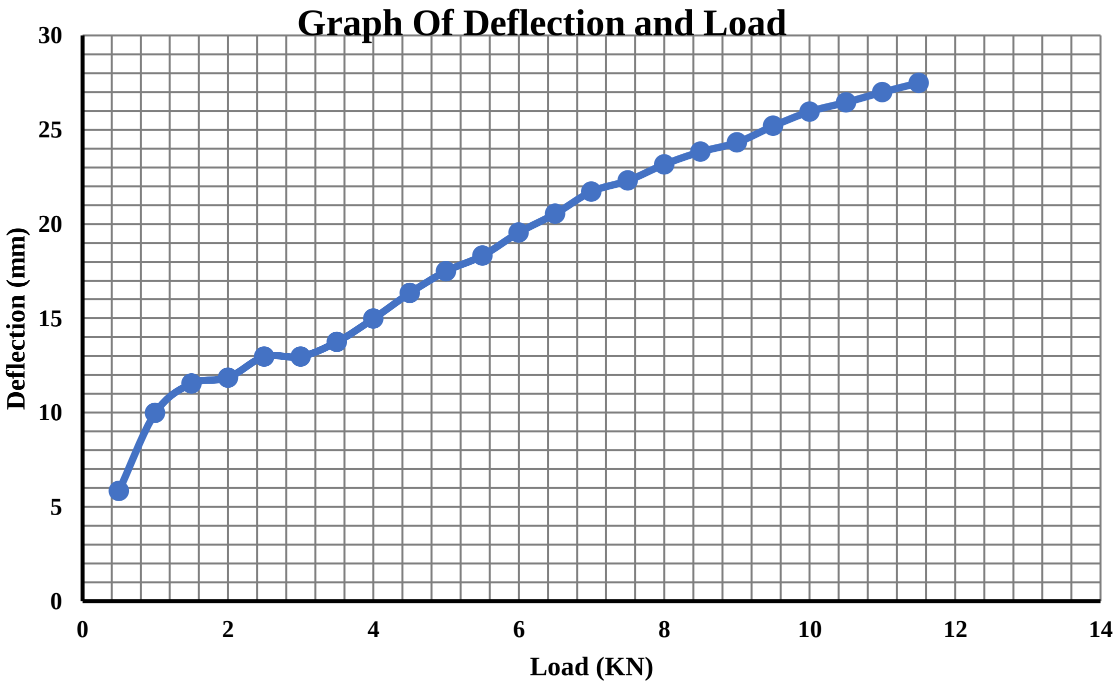


Figure 4.3 Graph of Deflection and Load for 10 Molarity at 7 Days

4.2.3 Deflection Test Results for 12 Molarity at 7 Days

The deflection test for the 12 Molarity specimen shows a moderate increase in deflection with load, but the deflection values remain relatively lower compared to the 8 and 10 Molarity specimens. Initially, at lower loads (0.5–1.5 kN), the deflection increases gradually, with a crack observed at 1.5 kN. After cracking, the deflection continues to rise, but at a slower rate, reaching a peak deflection of 16.37 mm at 4.5 kN and maintaining this value through higher loads (5.0–6.0 kN).

The test suggests that the 12 Molarity specimen experiences less significant deflection compared to the 8 and 10 Molarity specimens under the same loading conditions, indicating that higher molarity may result in a stiffer material with more resistance to deflection, although cracking begins at similar loads.

Table 4.11: Deflection Test for 12 Molarity at 7 Days

12 MOLARITY SPECIMIEN	
DEFLECTION (mm)	**LOAD (KN)**
0.5	9.36
1.0	9.64
1.5	11.59--------**CRACK**
2.0	12.35
2.5	13.58
3.0	13.58
3.5	14.45
4.0	15.55
4.5	16.37
5.0	16.37
5.5	16.37
6.0	16.37

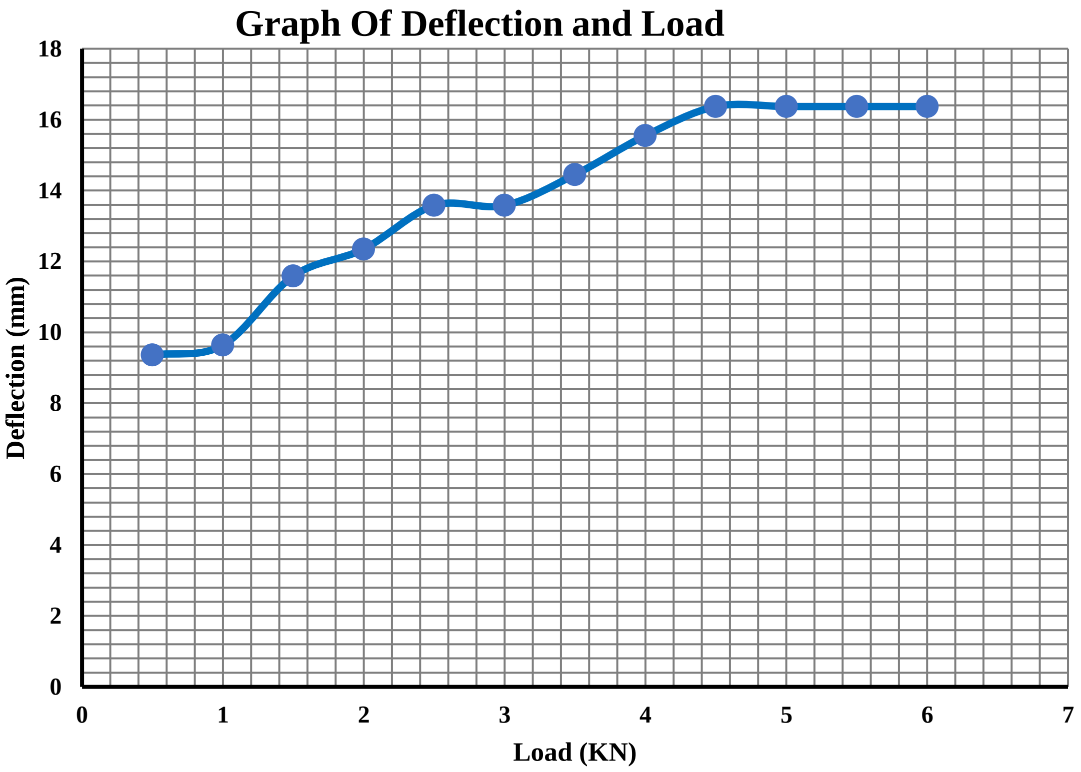


Figure 4.4 Graph of Deflection and Load for 12 Molarity at 7 Days

4.2.4 Deflection Test Results for Grade 30 Concrete at 7 Days

The deflection test for Grade 30 Concrete shows a steady increase in deflection as the load is applied. At lower loads (0.5–1.5 kN), the deflection increases gradually, with a crack observed at 1.5 kN. After cracking, the deflection continues to increase at a moderate rate, reaching a maximum of 11.45 mm at 5.5 and 6.0 kN. The behaviour of the Grade 30 concrete indicates that it becomes more flexible after cracking, with deflection continuing to increase significantly under higher loads. Overall, the deflection values for Grade 30 concrete are lower than those observed in the 8 and 10 Molarity specimens, suggesting that Grade 30 concrete exhibits greater stiffness and resistance to deflection before significant cracking occurs.

Table 4.12: Deflection Test for Grade 30 Concrete at 7 Days

GRADE 30 CONCRETE	
DEFLECTION (mm)	**LOAD (KN)**
0.5	4.49
1.0	5.17
1.5	6.33-----**CRACK**
2.0	6.49
2.5	7.19
3.0	7.82
3.5	8.71
4.0	9.45
4.5	10.28
5.0	11.02
5.5	11.45
6.0	11.45

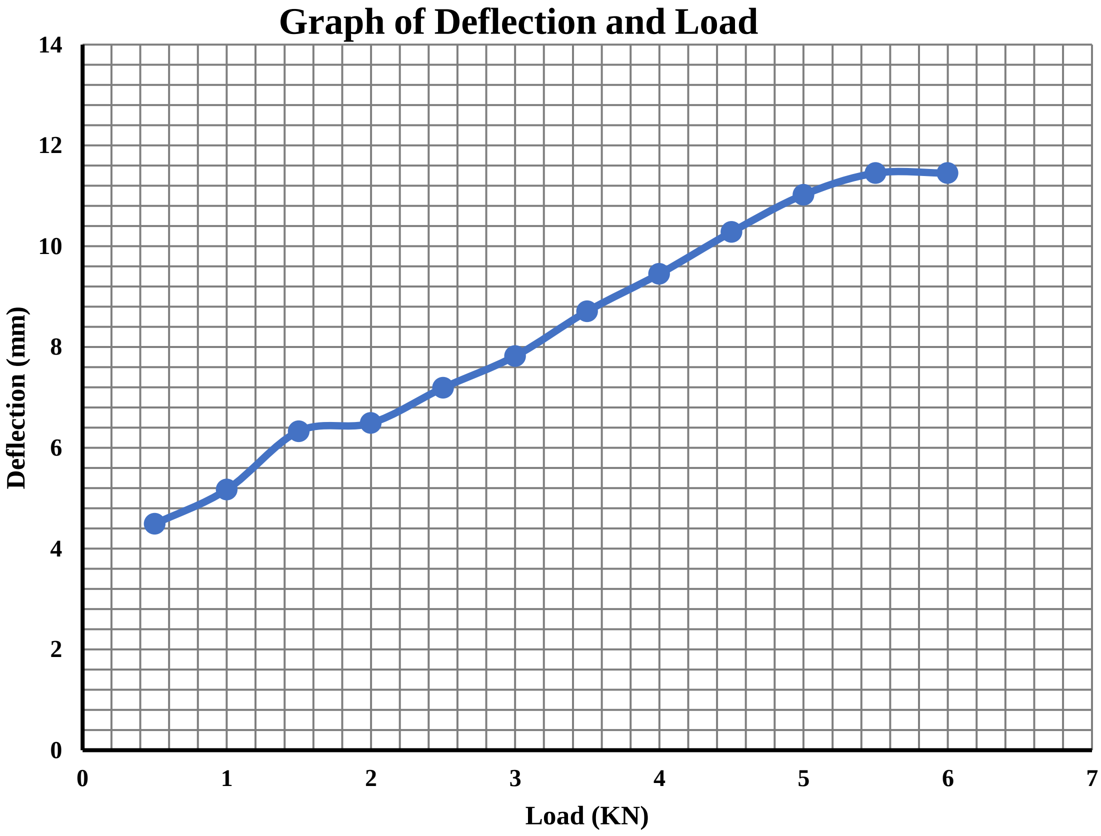


Figure 4.5 Graph of Deflection and Load for Grade 30 Concrete at 7 Days

4.2.5 Deflection Test Results for Grade 40 Concrete at 7 Days

The deflection test for Grade 40 Concrete shows a gradual increase in deflection with increasing load. At lower loads (0.5–1.5 kN), the deflection increases steadily, with a crack observed at 1.5 kN. After cracking, the deflection continues to rise more gradually, reaching a maximum deflection of 15.76 mm at 7.0 and 7.5 kN. This indicates that the Grade 40 concrete exhibits more deflection at higher loads compared to Grade 30 concrete, but still shows a relatively stiff behaviour in comparison to the 8 and 10 Molarity specimens.

The results suggest that Grade 40 concrete is more resistant to deflection and cracking under load than the lower molarity specimens, but it still experiences significant deflection as the load increases. The performance of Grade 40 concrete demonstrates better overall strength and stiffness when compared to the earlier molarity mixtures tested.

Table 4.13: Deflection Test for Grade 40 Concrete at 7 Days

GRADE 40 CONCRETE	
DEFLECTION (mm)	**LOAD (KN)**
0.5	7.29
1.0	8.38
1.5	8.99-----**CRACK**
2.0	9.00
2.5	9.95
3.0	10.90
3.5	11.51
4.0	11.89
4.5	12.65
5.0	13.03
5.5	13.79
6.0	14.85
6.5	15.59
7.0	15.76
7.5	15.76

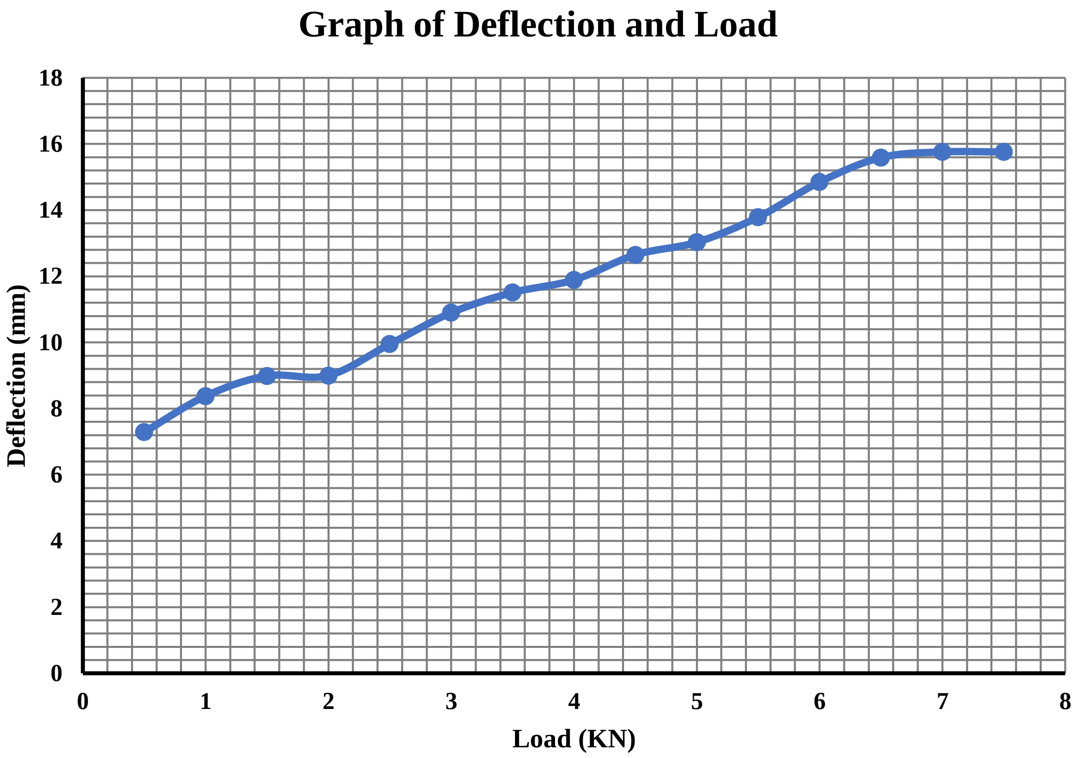


Figure 4.6 Graph of Deflection and Load for Grade 40 Concrete at 7 Days

4.2.6 Deflection Test Results for Grade 50 Concrete at 7 Days

The deflection test for Grade 50 Concrete shows a consistent increase in deflection as the load is applied. At lower loads (0.5–1.5 kN), the deflection grows steadily, with a crack appearing at 1.5 kN. After cracking, the deflection continues to rise more noticeably, reaching a maximum deflection of 20.04 mm at 8.5 kN.

This test indicates that Grade 50 concrete exhibits higher deflection values compared to Grade 30 and Grade 40 concrete under similar loading conditions. The material demonstrates significant flexibility after cracking, and the deflection increases steadily at higher loads. Despite its higher strength grade, the deflection behaviour shows that it still experiences considerable flexibility under higher loads. This suggests that while Grade 50 concrete provides enhanced strength, it also demonstrates a relatively higher level of deflection compared to other concrete grades tested.

Table 4.14: Deflection Test for Grade 50 Concrete at 7 Days

GRADE 50 CONCRETE	
DEFLECTION (mm)	**LOAD (KN)**
0.5	8.5
1.0	10.0
1.5	11.37-----CRACK
2.0	12.18
2.5	13.0
3.0	13.79
3.5	14.35
4.0	15.38
4.5	16.47
5.0	17.40
5.5	17.65
6.0	17.65
6.5	17.84
7.0	18.95
7.5	19.45
8.0	19.68
8.5	20.04

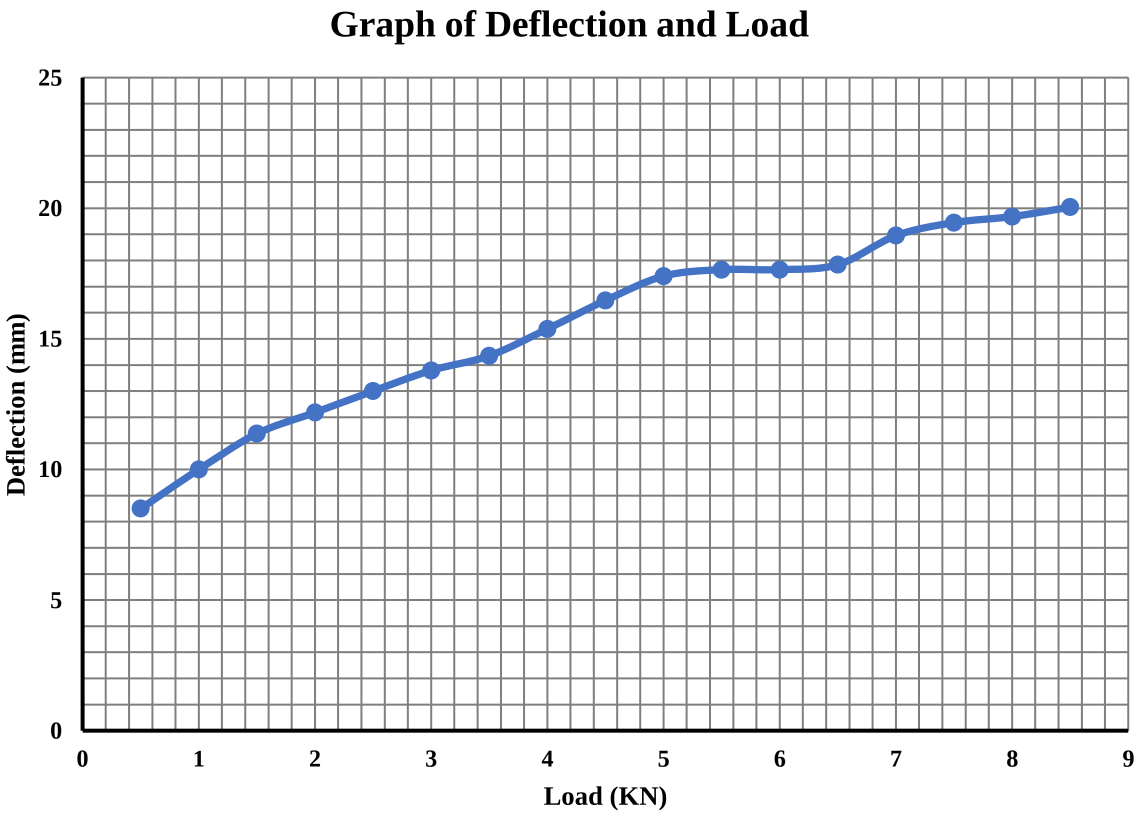


Figure 4.7 Graph of Deflection and Load for Grade 50 Concrete at 7 Days

4.2.7 Deflection Test Results for 8 Molarity at 28 Days

The deflection test for 8 Molarity specimens at 28 days shows a gradual increase in deflection with increasing load for both specimens (A and B) as shown in Table 4.15. For specimen A, the deflection ranges from 0.5 mm at 0.5 kN to 33.42 mm at 3.5 kN. Similarly, for specimen B, deflection increases from 0.5 mm at 0.5 kN to 33.24 mm at 3.5 kN. Both specimens exhibit similar behavior, with deflection rising consistently as the load increases.

This indicates that after 28 days, the deflection characteristics of the 8 Molarity specimens remain relatively consistent, suggesting stable performance in terms of flexibility and structural behavior under load. The results also indicate that both specimens experience a notable increase in deflection at higher loads, but without significant discrepancies between the two specimens. The overall deflection values are somewhat higher than the 7-day results, suggesting that the material continues to evolve in its performance as it cures further.

Table 4.15: Deflection Test for 8Molarity at 28 Days

8 MOLARITY (A)		8 MOLARITY (B)	
LOAD (KN)	**DEFLECTION (mm)**	**LOAD (KN)**	**DEFLECTION (mm)**
14.60	0.5	13.10	0.5
32.05	1.0	26.66	1.0
32.05	1.5	26.66	1.5
33.16	2.0	26.66	2.0
35.06	2.5	29.53	2.5
36.96	3.0	33.24	3.0
37.37	3.5	33.42	3.5

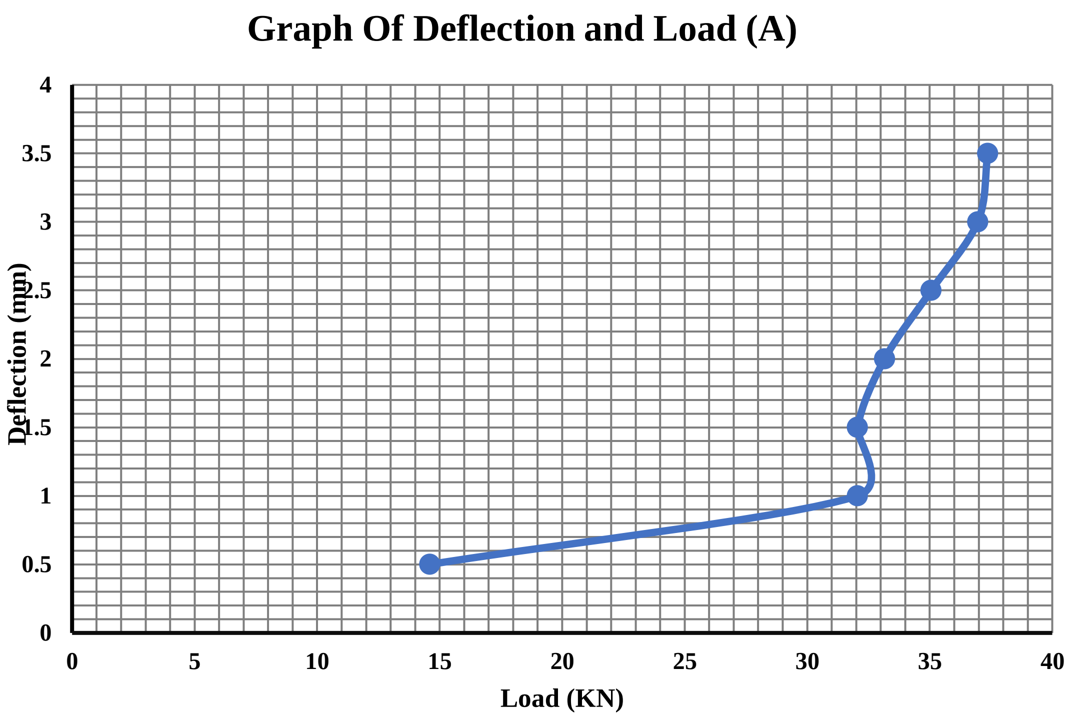


Figure 4.8 Deflection Test for 8 Molarity (A) at 28 Days

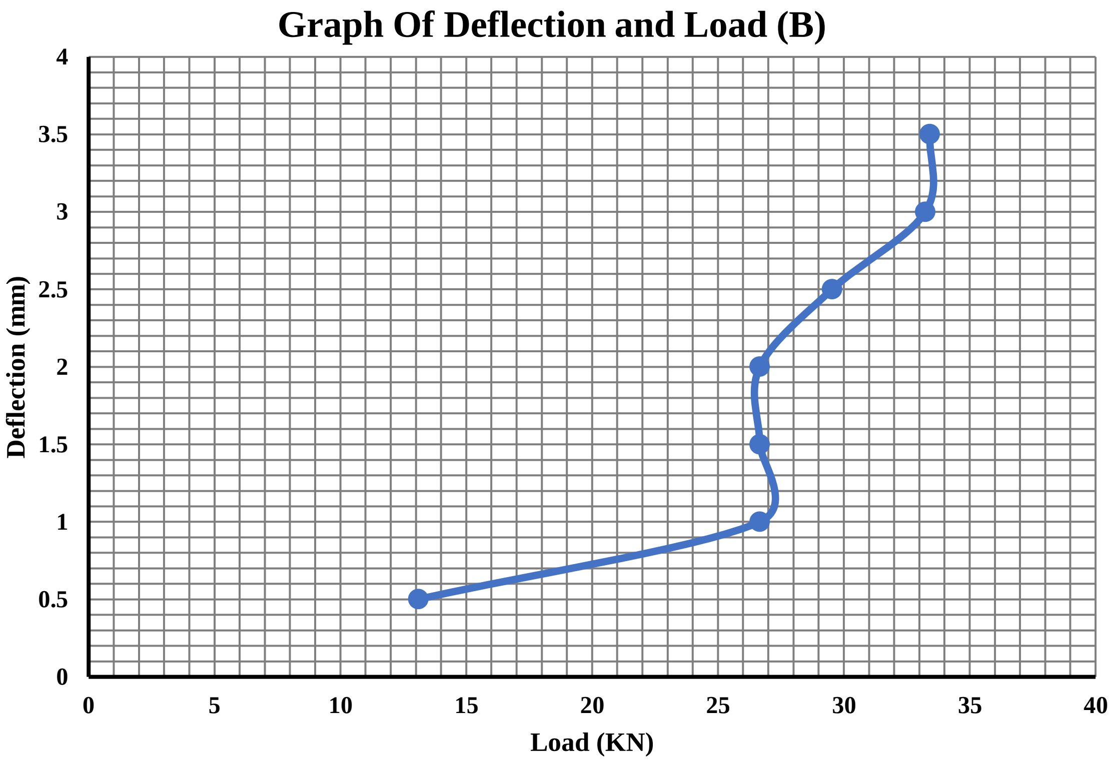


Figure 4.9 Deflection Test for 8 Molarity (B) at 28 Days

4.2.8 Deflection Test Results for 10 Molarity at 28 Days

The deflection test for 10 Molarity specimens at 28 days shows a clear increase in deflection as the load increases for both specimens (A and B) as shown in Table 4.16. For specimen A, deflection begins at 0.5 mm with a load of 0.5 kN and increases to 51.91 mm at 3.5 kN. For specimen B, deflection starts at 0.5 mm at 0.5 kN and reaches 51.91 mm at 3.5 kN as well. Both specimens show significant deflection as the load increases, with the deflection values rising rapidly after 2.0 kN. The results indicate that at higher loads, the deflection increases substantially, suggesting that the 10 Molarity specimens, like the 8 Molarity ones, exhibit increasing flexibility and less resistance to deformation as the load is applied. These deflection values at 28 days are higher compared to the 7-day results, which may indicate further development in the material's properties over time. However, the overall deflection trends between both specimens are comparable, suggesting similar behavior in response to loading.

Table 4.16: Deflection Test for 10 Molarity at 28 Days

10 MOLARITY (A)		**10 MOLARITY (B)**	
LOAD (KN)	**DEFLECTION (mm)**	**LOAD (KN)**	**DEFLECTION (mm)**
13.48	0.5	10.62	0.5
29.34	1.0	18.46	1.0
33.96	1.5	31.44	1.5
37.68	2.0	34.32	2.0
44.24	2.5	40.84	2.5
54.78	3.0	47.83	3.0
54.78	3.5	51.91	3.5

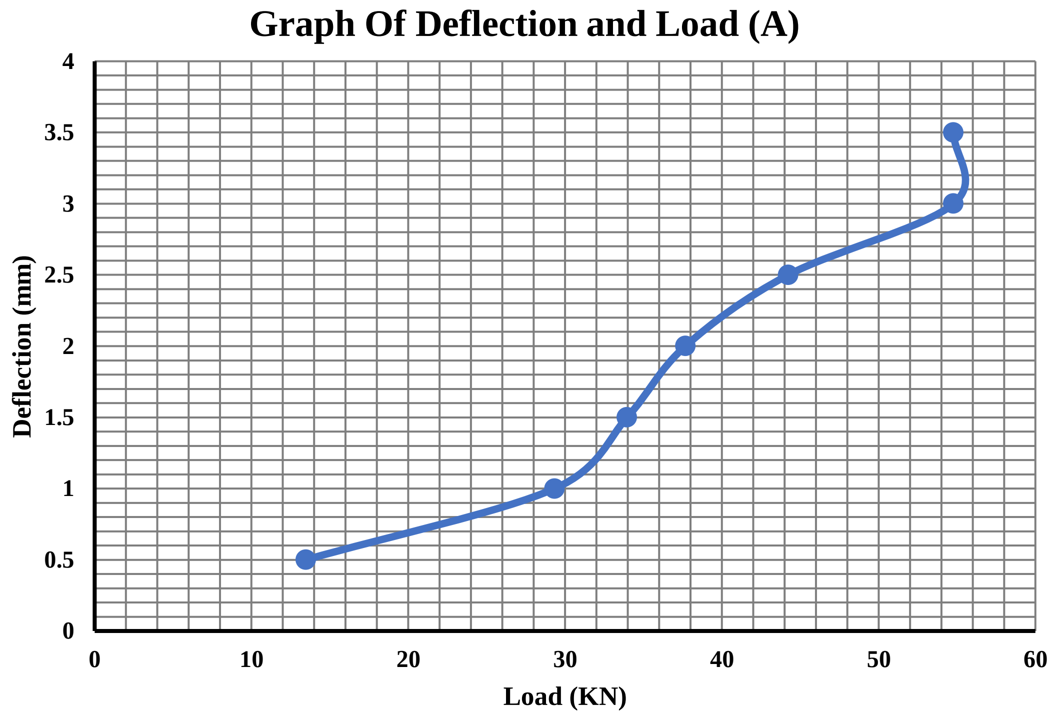


Figure 4.10 Deflection Test for 10 Molarity (A) at 28 Days

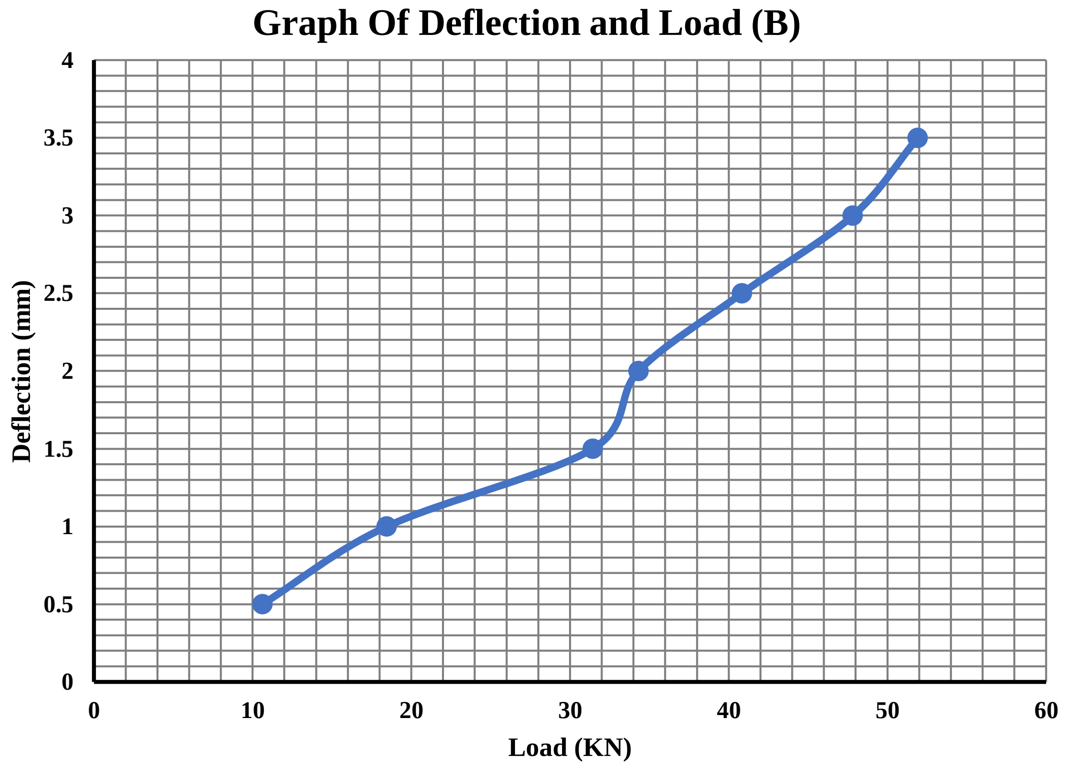


Figure 4.11 Deflection Test for 10 Molarity (B) at 28 Days

4.2.9 Deflection Test Results for 12 Molarity at 28 Days

The deflection test for the 12 Molarity specimen at 28 days shows a steady increase in deflection with increasing load. The deflection starts at 11.54 mm under 0.5 kN and rises gradually as the load increases, reaching 58.13 mm at 5.0 kN as observed in Table 4.17. The data indicates that the specimen experiences a relatively consistent and significant increase in deflection as the load progresses, reflecting the material's tendency to deform more under higher loads. Compared to the 7-day results, the deflection values at 28 days are noticeably higher, indicating that the specimen's flexibility increases over time as it continues to cure and strengthen. This trend suggests that the 12 Molarity specimen becomes more prone to deflection at higher loads after 28 days, which may indicate changes in the material's stiffness or an increase in its deformation capacity.

Table 4.17: Deflection Test for 12 Molarity at 28 Days

12 MOLARITY	
LOAD (KN)	**DEFLECTION (mm)**
11.54	0.5
16.96	1.0
24.21	1.5
28.24	2.0
32.35	2.5
35.94	3.0
45.92	3.5
50.92	4.0
54.84	4.5
58.13	5.0

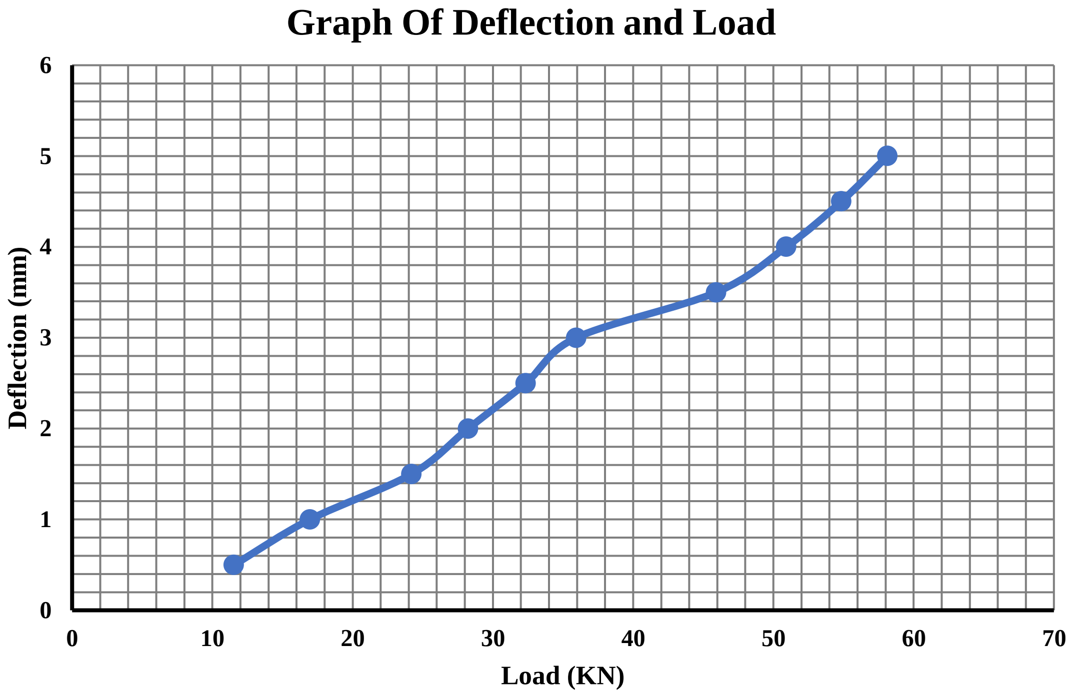


Figure 4.12 Deflection Test for 12 Molarity at 28 Days

4.2.10 Deflection Test Results for Ordinary Portland Cement Prestressed Beam at 28 Days

The deflection test results for prestressed ordinary Portland cement (OPC) beams of Grade 30, Grade 40, and Grade 50 at 28 days show a clear trend of increasing deflection as the load increases for all grades. Deflection starts at 0.5 mm under 13.46 kN and increases steadily with the load, reaching a maximum deflection of 64.56 mm at 3.5 kN also deflection begins at 0.5 mm with 14.32 kN and rises to 67.92 mm at 3.5 kN and finally deflection starts at 0.5 mm under 19.97 kN and shows the highest deflection values among the three grades, reaching a maximum of 73.51 mm at 3.5 kN for Grade 30, Grade 40 and Grade 50 respectively a shown in Table 4.18.

These results suggest that as the grade of concrete increases, both the load required to induce deflection and the magnitude of deflection itself increase. Grade 50 concrete, while stronger, exhibits higher deflections under similar loading conditions compared to

Grade 30 and Grade 40. This trend is expected due to the increased strength, but it also indicates that higher-grade concrete may allow for more deformation before failure, especially under higher loads.

Table 4.18: Prestressed Beam Deflection Test at 28 Days

GRADE 30		GRADE 40		GRADE 50	
LOAD (KN)	**DEFLECTION (mm)**	**LOAD (KN)**	**DEFLECTION (mm)**	**LOAD (KN)**	**DEFLECTION (mm)**
13.46	0.5	14.32	0.5	19.97	0.5
20.48	1.0	22.81	1.0	32.45	1.0
32.89	1.5	35.78	1.5	44.96	1.5
45.24	2.0	48.34	2.0	54.50	2.0
51.35	2.5	50.96	2.5	63.33	2.5
55.22	3.0	56.82	3.0	71.20	3.0
64.56	3.5	67.92	3.5	73.51	3.5

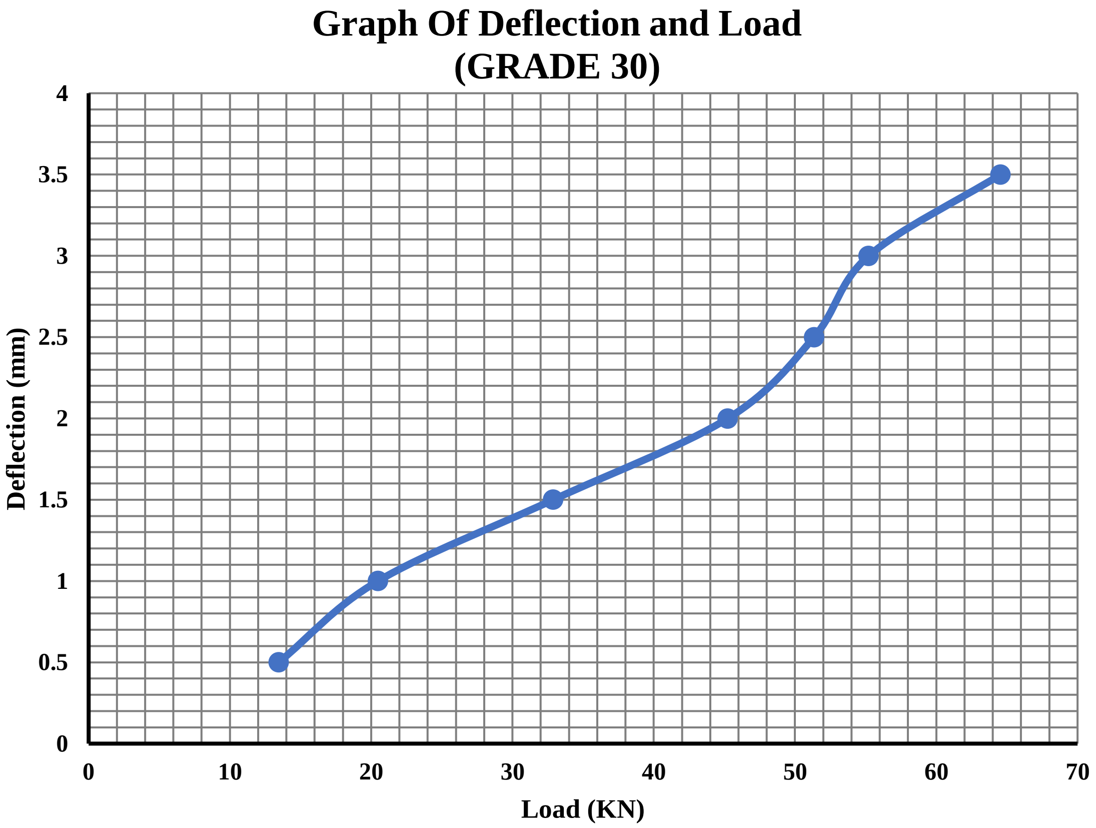


Figure 4.13 Deflection Test for Grade 30 OPC at 28 Days

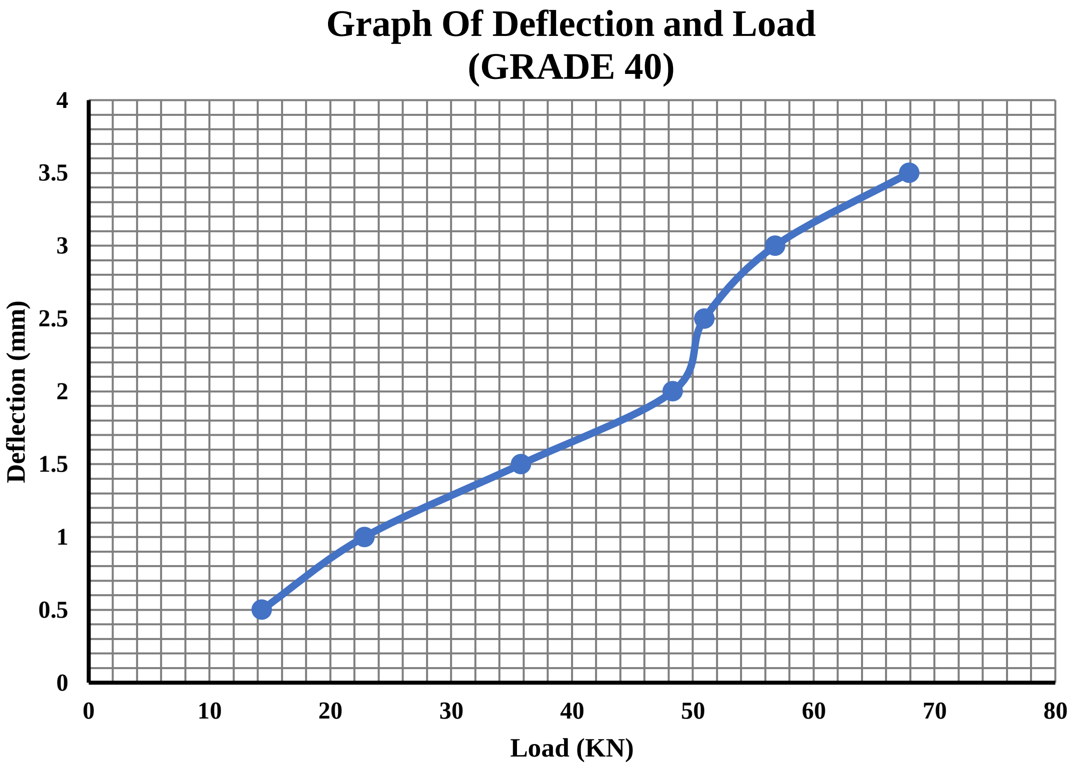


Figure 4.14 Deflection Test for Grade 40 OPC at 28 Days

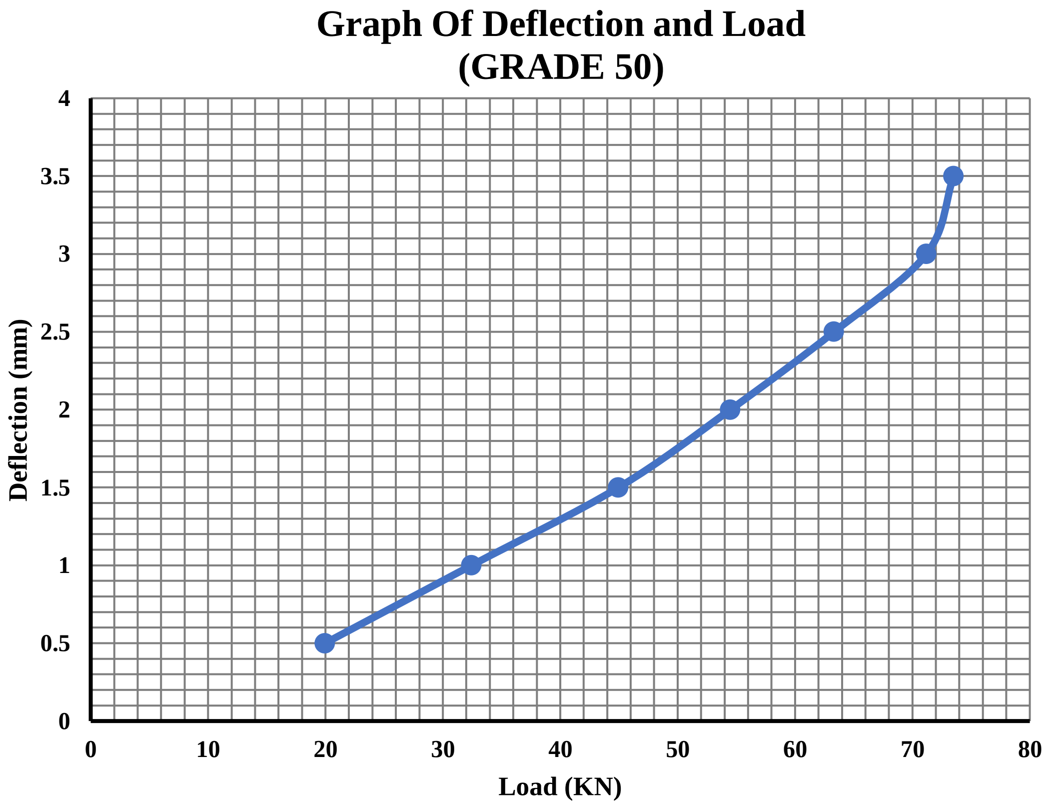


Figure 4.15 Deflection Test for Grade 50 OPC at 28 Days

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The conclusion from this study which sought to compare the deflection characteristics of Prestressed geopolymer concrete and Portland concrete is given thus:

Due to some problems with the apparatus all some parameters required from the experiment to ascertain the deflection characteristics of the beams were not obtained.

From the results obtained, it was determined that the geopolymer concrete beams prepared from 8 molarity of NaOH have higher moment capacity (an average of 482.36 Nm) of those prepared by 10 and 12 molarity (with the range of 338.0 – 349.5 Nm). Also, the 8-molarity concrete has higher compressive strength than that of the 10 and 12 molarity. Due to time constraints and other issues encountered during the project, the OPC concrete beam have not yet beam made and tested, therefore comparison between the GPC beams OPC concrete beams have not yet been conducted

5.2 LIMITATIONS

The major limitation to this project was that some faults with the apparatus, this prevented the determination of flexural strength of the beams, as some vital parameters in determining it were missing. Also, due to the fact that the technology employed in this study is highly localized, it was difficult to monitor and evaluate the losses encountered during the pretensioning thus less contribution in the losses of the prestress force were made

5.3 RECOMMENDATIONS

It is highly advised and recommended that a much more improved technique or apparatus be developed to increase accuracy and evaluation of prestress losses, testing of larger beam specimen, etc.

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APPENDIX

Table 4.19 The compressive strength for crushing values for 8 molarity of NaOH mix at different maturity duration.

S/N	SPECIMIEN	DENSITY (Kg/m^3)	WEIGHT (Kg)	LOAD (KN)	STRENGTH (N/mm^2)	AVERAGE STRENGTH (N/mm^2)
1 DAY CRUSHING VALUES						
1	AA-1	2500	2.5	347.43	34.743	38.267
2	AA-2	2500	2.5	422.52	42.252	
3	AA-3	2500	2.5	378.07	37.807	
5 DAYS CRUSHING VALUES						
1	AA-4	2530	2.53	425.23	42.523	51.510
2	AA-5	2500	2.50	590.32	59.032	
3	AA-6	2500	2.46	529.74	52.974	
7 DAYS CRUSHING VALUES						
1	AA-7	2510	2.51	544.91	54.491	46.900
2	AA-8	2490	2.49	508.12	50.812	
3	AA-9	2520	2.52	353.97	35.397	
28 DAYS CRUSHING VALUES						
1	AA-10	2410	2.41	560.23	56.023	57.950
2	AA-11	2440	2.44	640.04	64.004	
3	AA-12	2490	2.49	538.22	53.822	

Table 4.20: The compressive strength for crushing values for the required mix at different maturity duration for 10 molarity of NaOH.

S/N	SPECIMIEN	DENSITY (Kg/m^3)	WEIGHT (Kg)	LOAD (KN)	STRENGTH (N/mm^2)	AVERAGE STRENGTH (N/mm^2)
3 DAYS CRUSHING VALUES						
1	AA-1	2500	2.5	185.60	18.560	29.262
2	AA-2	2500	2.5	343.42	34.342	
3	AA-3	2500	2.5	348.83	34.883	
14 DAYS CRUSHING VALUES						
1	AA-7	2500	2.35	426.13	42.613	36.423
2	AA-8	2500	2.40	358.70	35.870	
3	AA-9	2500	2.40	307.86	30.786	
28 DAYS CRUSHING VALUES						
1	AA-10	2500	2.44	404.00	40.400	42.902
2	AA-11	2500	2.37	400.52	40.052	
3	AA-12	2500	2.40	482.56	48.256	

Table 4.21: The compressive strength for crushing values for the required mix at different maturity duration for 12 molarity of NaOH.

WEIGHT (KG)	1 DAY (KN)	WEIGHT (KG)	3 DAYS (KN)	WEIGHT (KG)	28 DAYS (KN)
2.548	419.18	2.634	381.52	2.577	344.98
2.565	315.89	2.657	328.73	2.435	88.480

Table 4.22: The compressive strength for crushing values of the various mix design of ordinary Portland cement.

GRADE	WEIGHT (KG)	7 DAYS (KN)	WEIGHT (KG)	14 DAYS (KN)	WEIGHT (KG)	28 DAYS (KN)
C-30	2.458	100.92	2.488	130.02	2.454	179.91
	2.592	139.12	2.426	152.99	2.448	255.23
	2.503	107.59	2.618	189.24	2.485	264.16
C-40	2.300	151.45	2.370	214.20	2.365	330.97
	2.317	183.57	2.298	209.98	2.459	369.94
	2.469	166.76	2.347	219.62	2.333	346.83
C-50	2.372	245.26	2.454	217.36	2.479	225.81
	2.539	134.18	2.556	185.55	2.379	360.59
	2.454	202.55	2.501	185.16	2.471	391.95
C-60	2.374	201.19	2.461	277.13	2.365	330.97
	2.368	276.14	2,343	179.61	2.459	369.94
	2.379	315.12	2.366	357.42	2.333	346.83

SPECIMIEN A1 (Distance to crack- 270mm.)

Table 4.23: Result of Deflection for Specimen A1

LOAD(KN)	DEFLECTION (mm)	HOW FAILURE OCCURS
0	0.00	Failed from bottom, Cable didn't cut (slipped)
1	1.04	
2	4.63	

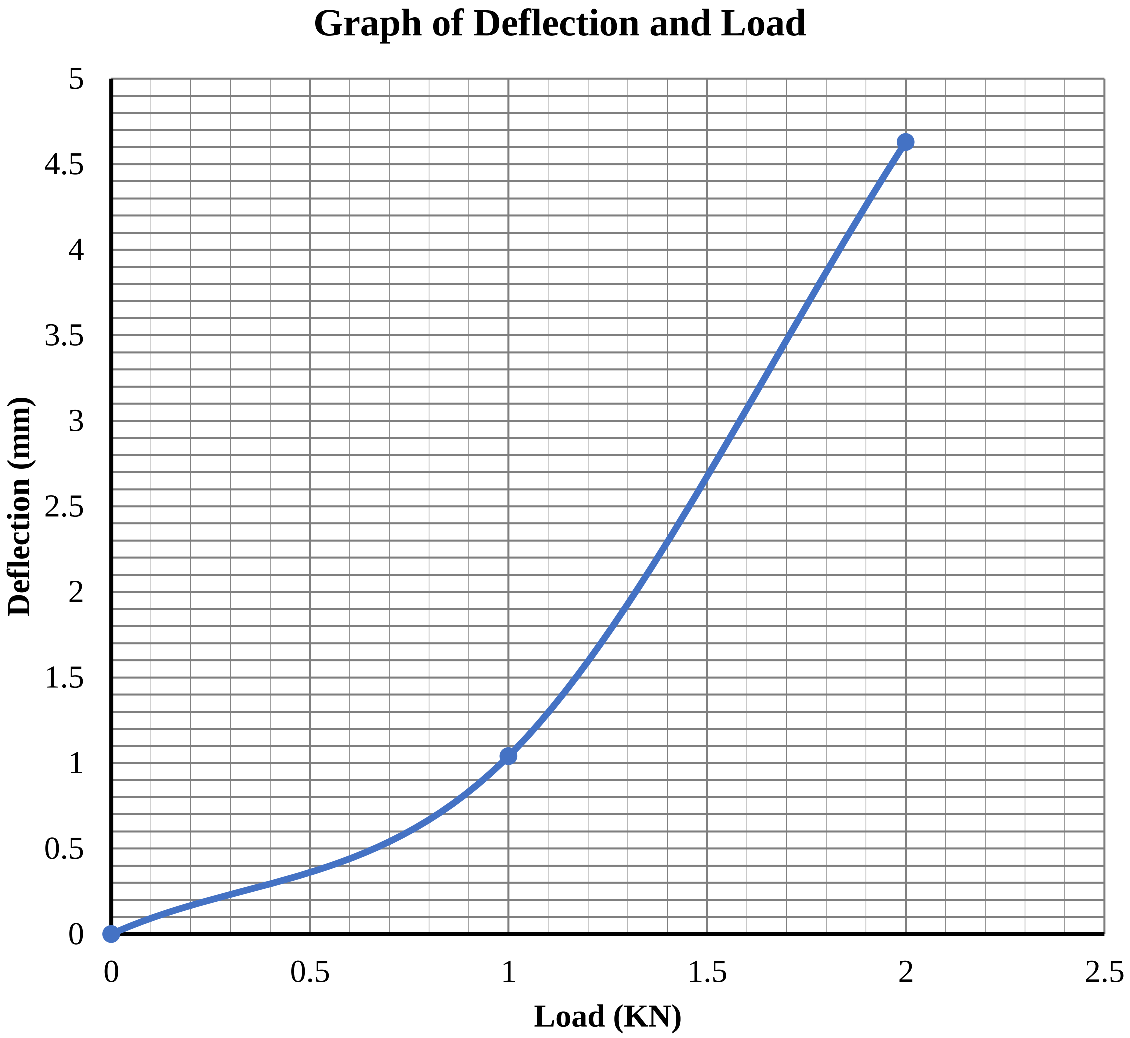

Figure 4.16 Deflection Test Results (A1)

SPECIMIEN A2 (Distance to crack- 280mm)

Table 4.24: Result of Deflection for Specimen A1

LOAD(KN)	DEFLECTION (mm)	HOW FAILURE OCCURS
0	4.7	Failed from bottom, Cable didn't cut (slipped)
0.5	3.78	
1	2.07	

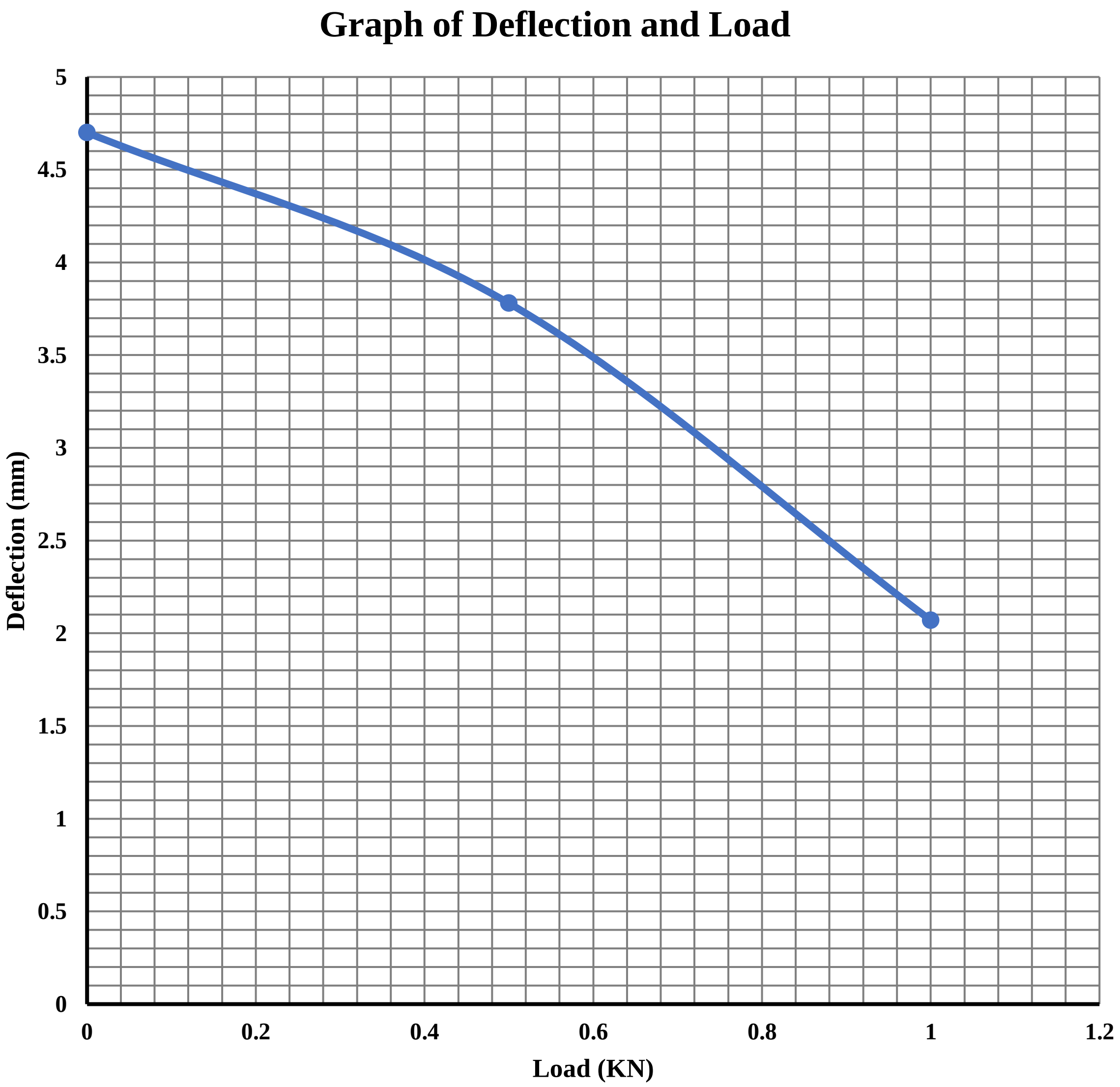

Figure 4.17 Deflection Test Results (A2)

SPECIMIEN A3 (Distance to crack- 280mm)

Table 4.25: Result of Deflection for Specimen A3

LOAD(KN)	**DEFLECTION (mm)**	**HOW FAILURE OCCURS**
0	4.67	Same failure as A2
0.5	4.08	
1	1.12	

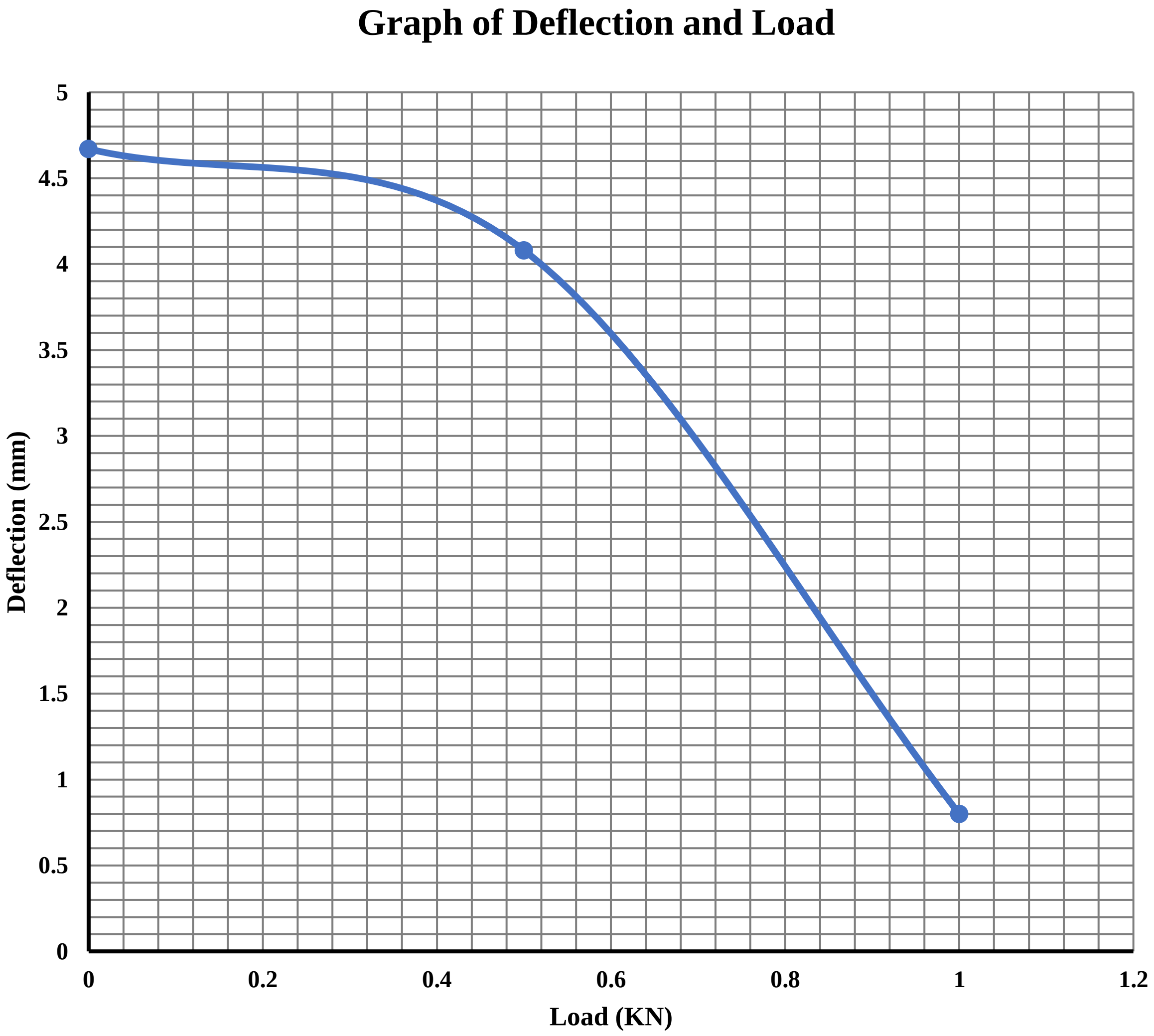

Figure 4.18 Deflection Test Results (A3)

SPECIMIEN A4 (Distance to crack- 290mm)

Table 4.26: Result of Deflection for Specimen A4

LOAD(KN)	**DEFLECTION (mm)**	**HOW FAILURE OCCURS**
0	4.67	Same failure as A2
1	3.55	
1.4	-7.42	

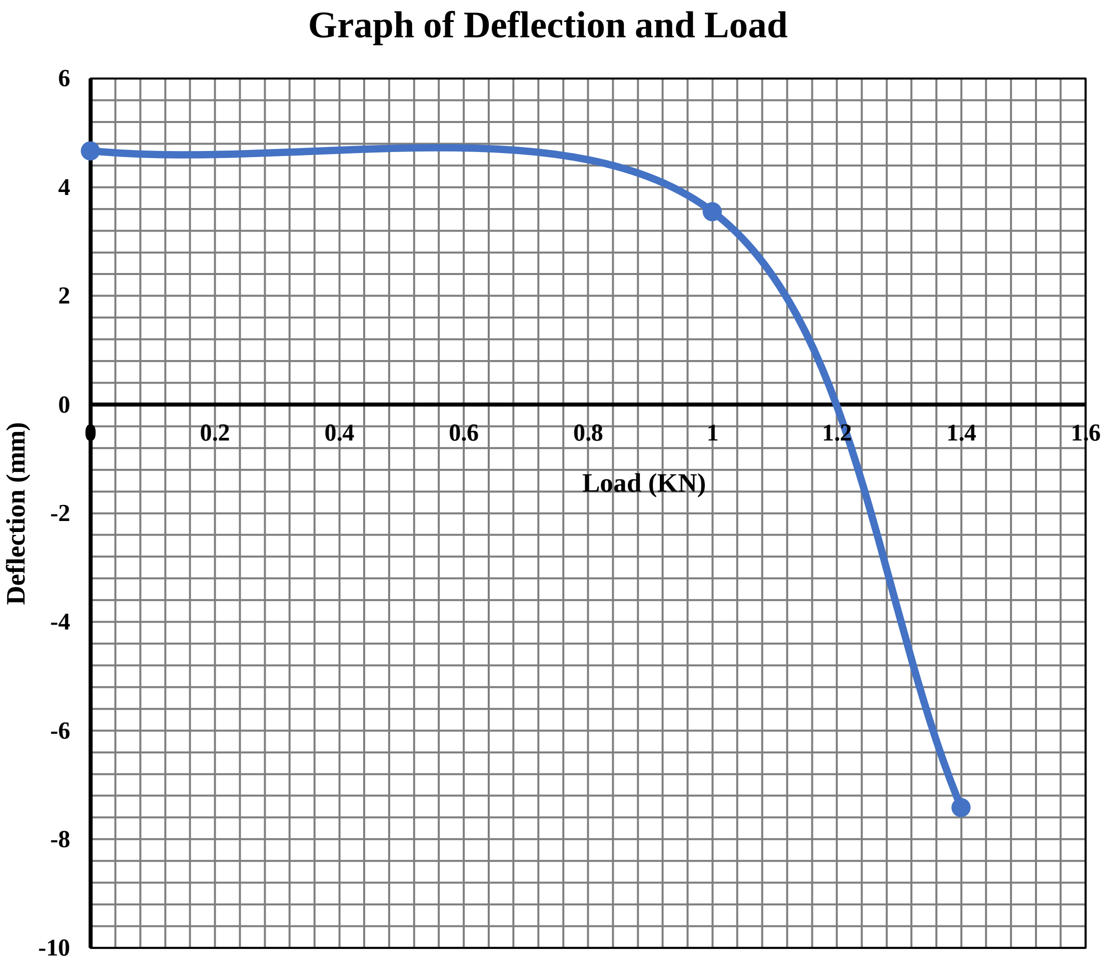

Figure 4.19 Deflection Test Results (A4)

SPECIMIEN A5 (Distance to crack -323mm)

Table 4.27: Result of Deflection for Specimen A5

LOAD(KN)	**DEFLECTION (mm)**	**HOW FAILURE OCCURS**
0	3.31	Same failure as A2
0.5	3.3	
1	3	
1.3	3.11	
1.7	3.6	
2.3	-7.37	
2.5	-5.6	

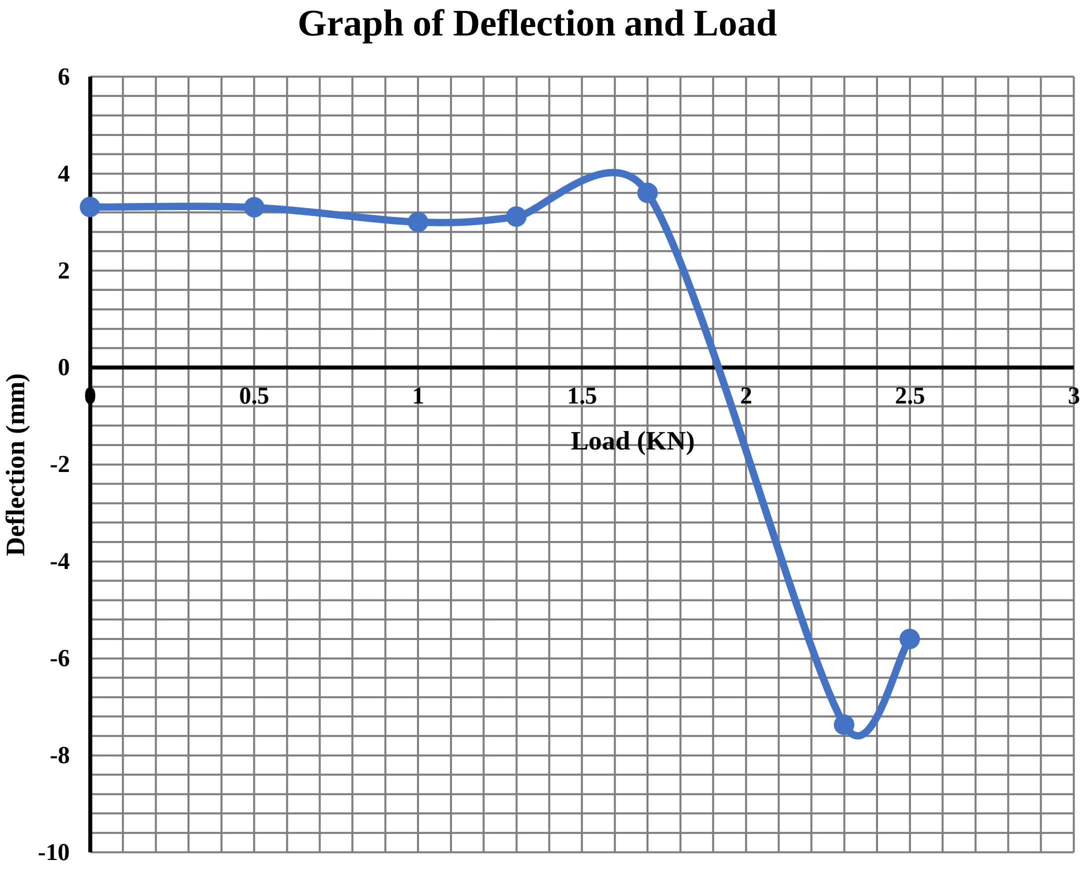

Figure 4.20 Deflection Test Results (A5)

SPECIMIEN A6 (Distance to crack- 312mm)

Table 4.28: Result of Deflection for Specimen A6

LOAD(KN)	DEFLECTION (mm)	HOW FAILURE OCCURS
0	4.2	Same failure as A2
0.5	4.1	
1	3.2	
1.25	0	

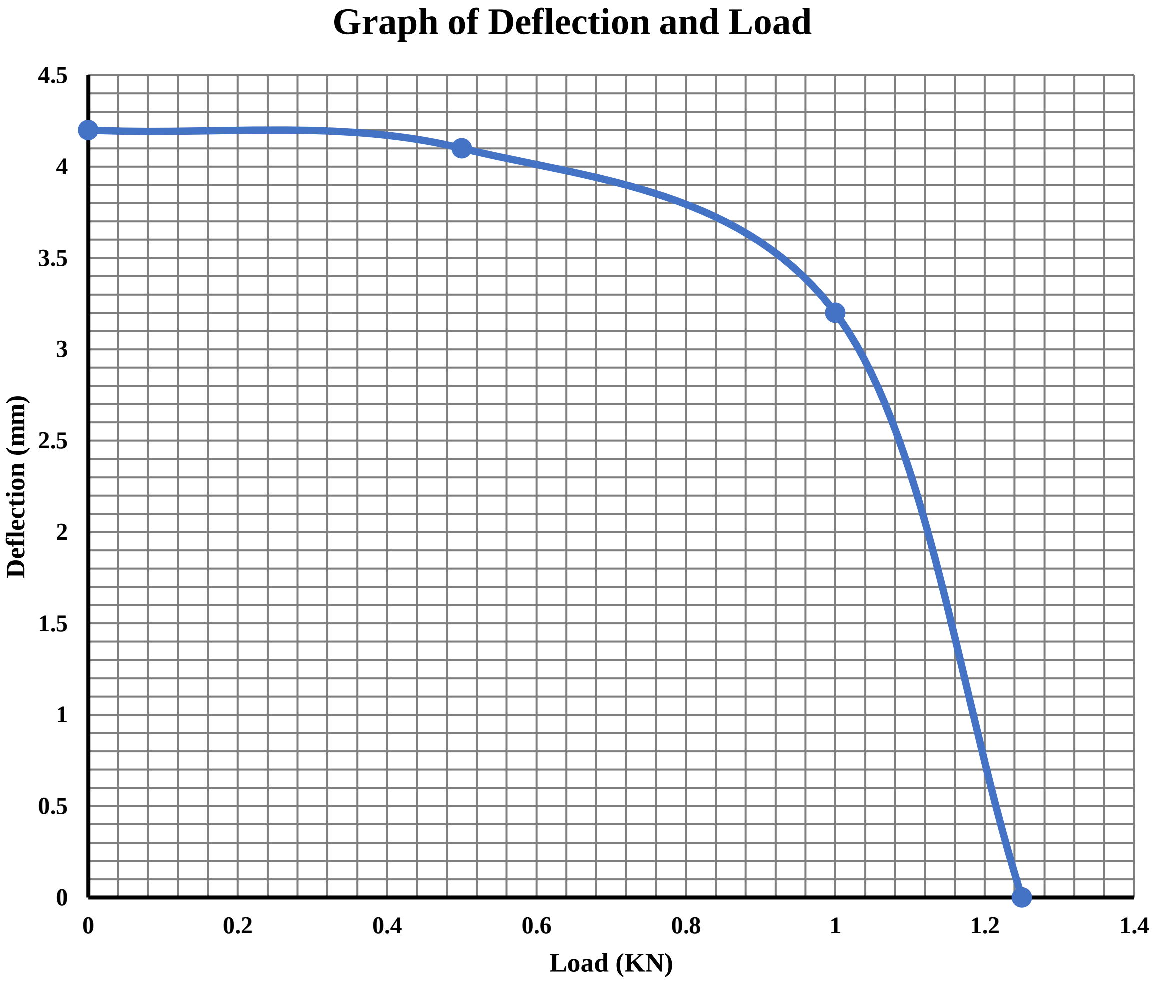

Figure 4.21 Deflection Test Results (A6)

SPECIMIEN A7 (Distance to crack- 270mm)

Table 4.29: Result of Deflection for Specimen A7

LOAD(KN)	**DEFLECTION (mm)**	**HOW FAILURE OCCURS**
0	4.23	Same failure as A2
0.5	3.84	
1	1.98	
1.25	0.75	
1.4	-8.45	
1.5	-7.3	
1.7	-2.4	
2	-2.4	

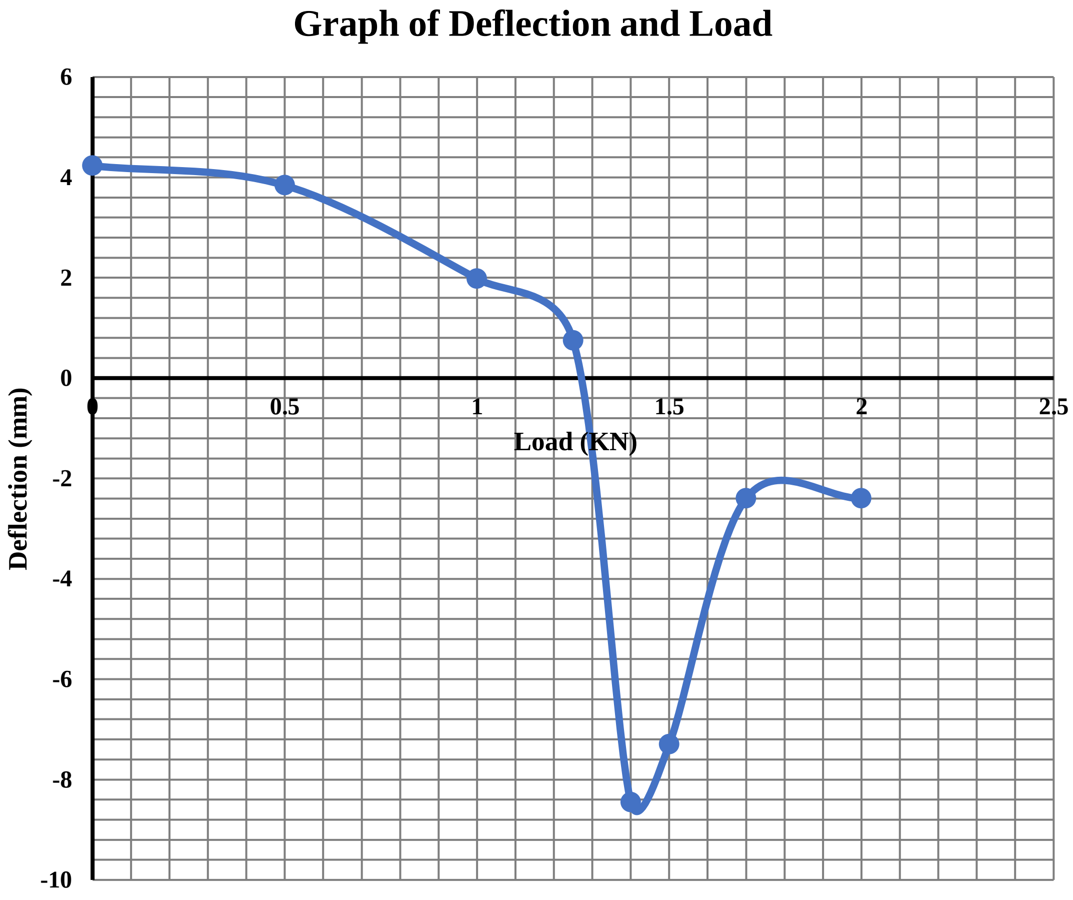

Figure 4.22 Deflection Test Results (A7)

SPECIMIEN A8 (Distance to crack- 260mm)

Table 4.29: Result of Deflection for Specimen A8

LOAD(KN)	DEFLECTION (mm)
0	4.2
0.5	4.9
1	4.5
1.2	2.65
1.25	1.33

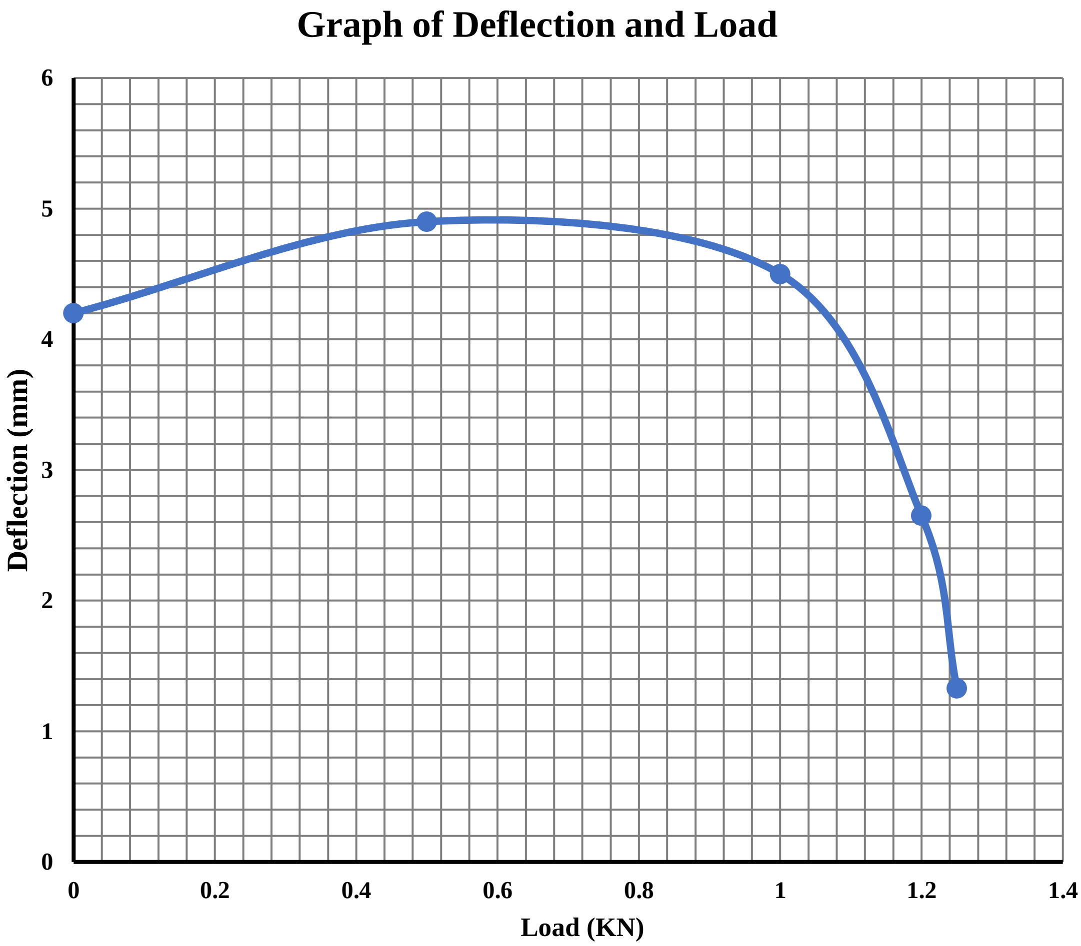

Figure 4.23 Deflection Test Results (A8)