

**SUBGRADE SOIL STABILIZATION USING BITUMEN AND
LOCALLY AVAILABLE ADMIXTURE (RHA)**



SUPERIOR UNIVERSITY

B.Sc. Civil engineering

Muhammad Azan

Hameed

(BSCEM-F21-005)

Abdul Hannan

(BSCEM-F21-006)

Anmol Shaban

(BSCEM-F21-007)

Supervisor:

Engr. Zoema Basit

Co-Supervisor:

Dr. Anum Khalid

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**DEPARTMENT OF CIVIL ENGINEERING
SUPERIOR UNIVERSITY LAHORE, PAKISTAN**



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A thesis is submitted in partial fulfillment of the requirements for the Degree of
Bachelor of Science in Civil Engineering

Muhammad Azan Hameed

(BSCEM-F21-005)

Abdul-Hannan

(BSCEM-F21-006)

Anmol Shaban

(BSCEM-F21-007)

Supervisor:

Engr. Zoema Basit

Co-Supervisor:

Dr. Anum Khalid

DECLARATION

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature and acknowledgement of collaborative research and discussions. I also declare that this work is the result of my own investigations, except where identified by references and free from plagiarism of the work of others.

Signature:

Muhammd Azan Hameed

Abdul Hannan

Anmol Shaban

Date:

The undersigned hereby certify that they have read and recommend the thesis entitled
“SUBGRADE SOIL STABILIZATION USING BITUMEN AND LOCALLY
AVAILABLE ADMIXTURE (RHA)” Abdul Hannan, Anmol Shaban and Azan
Hameed” for the degree of bachelor of science in Civil Engineering.

Engr. Zoeema Basit

Thesis Supervisor

Engr. Kamran Javed

Thesis Committee Member / FYP Manager

Engr. Muhammad Rizwan Mehr

Thesis Committee Member

Engr. Zeeshan Akbar

Thesis Committee Member

Dr. Anum Khalid

Head of Civil Engineering Department

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“In the name of Allah, the most beneficent the most merciful”

All praises and gratitude to Almighty Allah with whose blessings enable us to accomplish this scientific assignment objectively and successfully.

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Thank You,

Muhammad Azan

Hameed

Abdul Hannan

Anmol Shaban

DEDICATION

We dedicated this Research to our Mighty God that guides us, give strength, power of mind, protection and skills. All of this, we offer to you.

This study is dedicated to our beloved parents, who have been our source of inspiration, guide and give us strength, when we thought of giving up, who continually provide their moral, spiritual, emotional and financial support.

To our teachers who believed that we will be finish this research in time, helping us to make our research better, to inspire us to their inspirational stories when they are students before.

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ABSTRACT

The primary factor in ensuring a stable and durable structure is the stability and strength of its foundation or subgrade. The condition of pavement structures is greatly affected by the properties of the soil layer beneath it. Soils that are either weak or expansive can cause problems for pavement, requiring appropriate stabilization techniques. The stability of the soil beneath the pavement is essential for improving the durability and lifespan of the road surface.

This research examines how using bitumen and locally available admixture (RHA) can Enhance the stability of subgrade soils and contribute to the sustainability of local construction projects.

In order to study the behavior of weak subgrade soil experiments were carried out on untreated and treated soil samples with different percentages of these materials (2%, 4%, 6%, 8%,10% of bitumen and locally available admixture (RHA) with curing period of 7, 14, 21, 28 days) after compaction test. The primary finding of this study highlighted the importance of bitumen and locally sourced admixture (RHA) to improve the stability of subgrade soil.

As a result, this will improve the sustainability, strength of the subgrade soil.

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CHAPTER 1

INTRODUCTION

1.1. Subgrade condition effect:

Subgrade_The 'subgrade' refers to the existing material that the pavement structure is built upon. Subgrade's condition plays a significant role in determining the pavement performance. The subgrade must have sufficient strength to bear the weight of ballast. A poor subgrade can be recognize by soft and sinking track that seeps into the ballast, causing the ties to penetrate into to subgrade and create water-filled pocket (due to water penetration) that can lead to sliding and even can result in complete failure.

The stability of subgrade is recognized by various factors: soil type, water content, degree of compaction and other characteristics. The main target in maintenance and construction is to attain a strong internal friction and shearing strength in coarse-grained and high cohesion in fine-grained soils. Silt and clay face most issues. The quality of subgrade has a major effect on the pavement's ability to support load.

Type of soil, moisture content and drainage are the important factors that affect the stability of subgrade. Subgrade conditions that are adverse like excessive moisture content or expansive clay that can result in premature pavement failure and shorter lifespan for the pavement.

A solid subgrade is essential to support the weight and forces exerted by the pavement structure without significant bending or sagging.

The capacity of soil to hold water is effect by factors such as compaction, moisture content, and soil type. Certain types of soil, particularly clay, can experience volume changes (shrinking and swelling) as a result of moisture fluctuations or freezing conditions.

These modifications can result in the deterioration of the pavement.

- **Moisture and drainage:**

With the Insufficient drainage or excessive moisture in the subgrade can result in softening and pavement distress. When the subgrade becomes saturated, it results in increased of pore pressures due to traffic, which can further weaken its stability.

- **Frost heave:**

In the regions with extremely cold climates, soils with high amount of fine particles can be prone to frost heave, which can result in harmful effect on the pavement.

- **Subgrade soil properties:**

The composition of the subgrade soil, such as clay or sand, and its specific properties, like plasticity and compaction, significantly impact the performance of the pavement.

- **Pavement failures:**

Subgrade conditions that are inadequate can result in different pavement problems, such as Rutting, cracking, and uneven settling. Techniques such as incorporating lime, cement, or other additives can be employed to stabilize the subgrade and enhance its performance.

1.2. **Necessity of Soil Strength Improvement:**

Stable soils serve as a solid base for the foundation of all other project components. After stabilization techniques are applied to weak soils, they can undergo permanent Pozzolanic reactions. Soils are not prone to leaching and have significantly reduced permeability, leading to decreased shrink/swell potential and enhanced resistance to freeze-thaw cycles. In addition, soils that have been stabilized have also undergone some changes. In essence, the soil has undergone physical alterations, making compaction more manageable and reducing its plasticity.

The process of achieving maximum dry density is made easier when the soil is easily compacted. The plasticity index is a crucial geotechnical parameter that assesses the critical water contents of soils. When plasticity in soils is diminished, the soils become more crumbly and easier to manipulate. Failing to properly maintain soil can result in a loss of stability and heightened risks of soil erosion and failure, which can undermine the structural integrity of any buildings constructed on the soil.

Soil strength improvement is of utmost importance for several reasons, primarily to enhance

the stability and performance of construction projects and agricultural practices. Additionally, it was necessary to enhance the ground's ability to support weight, minimize settling, prevent erosion, and enhance soil quality. Let's delve deeper into the reasons why soil strength improvement is crucial:

- **Enhanced load-bearing capability:**

Soil with greater strength can bear heavier loads from buildings, roads, bridges, and other structures, guaranteeing their stability and durability. Enhancing soil strength reduces the amount of sinking (settlement) of structures, which can result in cracks, damage, and even structural collapse. Soil strength improvement techniques can prevent liquefaction, a phenomenon where saturated soil loses its stability and becomes prone to collapse during earthquakes.

- **Erosion control:**

Soil with greater strength is less prone to erosion caused by wind and water, safeguarding infrastructure and preventing harm. Soil with increased strength offers a more favorable habitat for plants, enhancing nutrient cycling, water absorption, and air circulation.

- **Reduced soil degradation:**

Enhancing soil strength can help prevent soil compaction, erosion, and other forms of degradation, resulting in more productive and sustainable agricultural practices. Soil that is healthy and robust has the potential to support greater crop production, which in turn can enhance food security and bring about economic advantages.

Soil stabilization can help lower construction expenses by minimizing the requirement for extensive foundations or repairs. Enhancing soil strength can aid in minimizing soil erosion and runoff, safeguarding water resources and preventing contamination.

1.3. Sustainability:

Sustainability encompasses the approach of creating, constructing, and managing buildings with a primary objective of reducing their negative impact on the environment, while simultaneously maximizing their social and economic advantages. This entails utilizing

sustainable materials, implementing energy-efficient systems, minimizing waste production, and fostering healthy indoor environments. The main objective of sustainable construction is to decrease the consumption of natural resources, lower greenhouse gas emissions, and enhance the welfare of both the people living in the building and the community it serves. As a result, sustainable construction plays a crucial role in modern construction projects and the designs of contemporary buildings. Introducing the Four Pillars of Sustainability.

- **Human**
- **Social**
- **Economic**
- **Environmental**

1.4. Bitumen:

Bitumen is a highly viscous component of petroleum, varying in consistency depending on its composition. It can be sticky, black liquid or a solid mass that behaves like a liquid over extended periods. Before the 20th century, the term Asphaltum was commonly used, derived from the greek word (Asphaltos).

The largest natural reserve of bitumen in the world is the pitch lake of southwest Trinidad, which is believed to hold approximately 10 million tons of this valuable resource. Approximately 70% of the annual bitumen production is allocated for road construction, with its primary purpose being to pave roads. In this application, bitumen is used to bind particles like gravel, creating a substance called asphalt concrete, which is commonly known as asphalt. Its primary applications are in bituminous waterproofing products, including roofing felt and roof sealant.

Bitumen usually consists of 80% carbon, with 10% hydrogen and 6% sulfur. Additionally, natural bitumen often contains organosulfur compounds, such as nickel and vanadium, which are commonly found in petroleum. This compound is amenable to dissolution in carbon disulfide. It is usually molded as a colloid with asphaltene as the dispersed phase and equine as the continuous phase. "it is virtually impossible to separate and identify all the

different bitumen molecules because the number of molecules with different chemical structures is so large."

Geologists worldwide commonly refer to the product as "bitumen."

To prevent any misunderstandings, the terms "liquid asphalt", "asphalt binder", or "asphalt cement" are employed to differentiate asphalt concrete from its counterparts. In everyday language, different types of asphalt are occasionally referred to as "tar", like the name of the la brea tar pits.

Normal composition:

The components of bitumen include four main classes of compounds:

- Naphthene aromatics (naphthalene) consisting of partially hydrogenated polycyclic aromatic compounds
 - Polar aromatics consisting of high molecular weight phenols and carboxylic acids produced by partial oxidation of the material. The softening point of asphalt is directly related to the percentage of saturated hydrocarbons present in it.
 - asphaltenes consisting of high molecular weight phenols and heterocyclic compounds
- Asphalt can be easily mistaken for coal tar, which is a black, plastic-like substance created through the destructive distillation of coal.

During the early and mid-20th century, when town gas was produced, coal tar was readily available and extensively used as the binder for road aggregates. The incorporation of coal tar into macadam roads resulted in the term "tarmac," which is now commonly used to describe materials used in road construction.

Applications of asphalt in earth stabilization:

Bitumen is extensively employed in road construction due to its ability to bind materials together. In soil stabilization, it is commonly employed to enhance soil impermeability, decrease moisture vulnerability, and improve load-bearing capacity. Studies have demonstrated that incorporating bitumen into the subgrade soil enhances its flexibility and strength, while simultaneously minimizing settlement and erosion. Nevertheless, the

petroleum-based composition of bitumen raises environmental concerns, which can be addressed by employing responsible usage and incorporating it with eco-friendly alternatives.

1.5. Rice Husk Ash (RHA):

1.5.1. Introduction to Rice Husk Ash (RHA)

Rice husk ash (RHA) is the residue that remains after the burning of rice husks (the outer layer of rice grains) during the process of milling rice. Rice husks are a plentiful byproduct of agriculture, and finding suitable methods for their disposal can be a difficult task. However, RHA has gained considerable attention in the field of civil engineering and materials science due to its beneficial properties, particularly as a Pozzolanic material in soil stabilization, concrete production, and other construction applications.

Rice husk Ash (RHA) is by heating rice husks at high temperatures (typically between 500°C to 700°C) in a controlled environment, which results in the release of organic components and the transformation of silica (SiO_2) in the husk into an amorphous form. RHA's unique characteristics make it an ideal additive for enhancing the engineering properties of soils and other construction materials.

1.5.2. The chemical makeup of rice husk ash.

The essential element in RHA is silica (SiO_2), in amorphous state, which is responsible for its pozzolanic characteristics. The precise chemical makeup of RHA is affected by factors like the type of rice, the conditions of combustion, and the specific geographical location. Nevertheless, the overall structure comprises:

- **silica (SiO_2):** 70% to 90% of the ash, depending on the combustion temperature and rice variety Silica is mainly accountable for RHA's pozzolanic activity.
- **calcium oxide (CaO):** present in small amounts (2% to 5%)
- **aluminum oxide (Al_2O_3):** 1% to 3%
- **iron oxide (Fe_2O_3):** around 1% to 3%
- **Magnesium oxide (MgO):** Typically around 1%

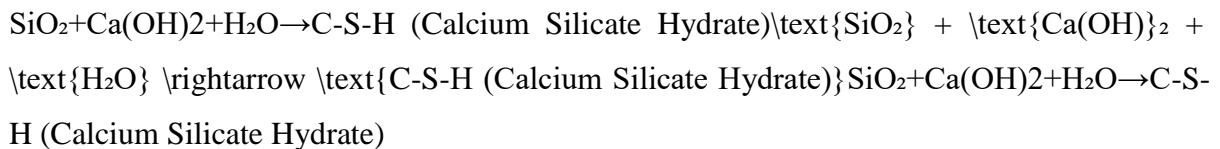
- **Potassium oxide (K₂O) and Sodium oxide (Na₂O):** Present in small quantities, they do not have significant pozzolanic activity but can also affect the workability of mixtures containing RHA.

The high silica content and the amorphous nature of RHA make it highly reactive when mixed with alkaline materials like lime, cement, or water, enabling it to form calcium silicate hydrates (C-S-H), a gel that contributes to strength development in soil stabilization or concrete.

1.5.3. Pozzolanic Properties of RHA

A pozzolanic material is a substance that, in the presence of water and lime, reacts chemically to form compounds possessing cementitious properties. The pozzolanic reaction of RHA is as follows:

- Silica (SiO₂) reacts with calcium hydroxide (Ca(OH)₂) from the breakdown of lime or cement to produce calcium silicate hydrate (C-S-H), which is responsible for the strength-giving properties of concrete and stabilized soils.



This reaction is extremely advantageous in soil stabilization as it enhances the cohesion and strength of soil, decreases its plasticity, and improves its resistance to water.

1.5.4. : Advantages of rice husk ash in soil consolidation.

RHA has several advantageous effects when used as a stabilizing agent for soils, especially in enhancing the engineering properties of subgrade soils for construction purposes. Some of the major benefits include:

1.5.4.1. Improvement of soil strength:

The addition of RHA increases the unconfined compressive strength (UCS) of the stabilized soil by improving its binding capabilities. The reaction which is called pozzolanic reaction which ensures the stronger connection of particles between soil, then this results in soil cohesive and strength properties.

1.5.4.2. Reduction of soil plasticity:

The inclusion of RHA in clayey soils can greatly decrease their index of plasticity, which results in a less sticky and more manageable texture. This will have advantageous effect for enhancing soil workability in construction projects.

1.5.4.3. Enhanced compaction characteristics:

RHA can enhance the soil's compaction properties by increasing its maximum dry density (MDD) and reducing the optimum moisture content (OMC). The tiny particles of RHA fill the empty spaces in the soil, which enhances its ability to withstand pressure.

1.5.4.4. Waterproof:

Enhances the permeability and water resistance of stabilized soil. By creating a solid foundation with the soil, RHA plays a crucial role in preventing water from seeping into the subgrade, which is essential for constructing roads.

1.5.4.5. Decrease in inflammation:

In expansive soils, such as clay, RHA has been discovered to decrease the potential for swelling, making it a suitable choice for regions susceptible to soil expansion due to moisture fluctuations.

1.5.5. Impact of combustion temperature on RHA properties.

The temperature which is necessary and it is important in understanding the characteristics and behavior of RHA, at various temperatures, the following

transformations take place:

- At low temperatures (below 500°C), RHA may contain a significant amount of unburnt organic matter, which reduces its pozzolanic activity. It may not be as efficient in enhancing soil characteristics.
- At moderate temperatures (500°C to 700°C), RHA undergoes a process known as "calcination", where the silica is transformed into an amorphous (non-crystalline) form, which is highly reactive and enhances its pozzolanic activity
- At very high temperatures (above 700°C), the silica in RHA begins to crystallize, leading to a reduction in pozzolanic reactivity. Thus, higher temperatures can lower the effectiveness of RHA in soil stabilization.

1.5.6. Utilizing Rice Husk Ash for Eco-Friendly Building.

RHA has gained prominence in sustainable construction due to its low cost, availability, and environmental benefits. Some of the factors that contributed to this are:

1.5.6.1. Waste utilization:

By using RHA, rice mills can reduce waste disposal problems and turn agricultural byproducts into valuable materials for construction.

1.5.6.2. Energy Efficiency:

The production of RHA from rice husks involves burning the husks at relatively low temperatures compared to other industrial processes, making it a low-energy process.

1.5.6.3. Carbon Footprint Reduction:

The use of RHA in soil stabilization reduces the need for more energy-intensive materials like cement, thus helping in the reduction of carbon emissions from the construction industry.

1.5.6.4. Recycling and Circular Economy:

RHA contributes to the circular economy by recycling agricultural waste into a valuable product, promoting resource efficiency.

1.5.7. Applications of Rice Husk Ash in Civil Engineering Rice Husk Ash has several applications in civil engineering:

- **Soil Stabilization:**

As mentioned, it improves the properties of subgrade soils for road construction, foundations, and embankments.

- **Concrete Production:**

RHA is sometimes used as a partial replacement for cement in concrete to improve the workability, durability, and strength of the mix.

- **Mortars and Plasters:**

RHA can be used in the preparation of mortars and plasters, improving their resistance to water and enhancing the finish.

- **Agricultural Applications:**

RHA has also been used as a soil conditioner and fertilizer due to its high silica content.

1.6. Problem statement:

- ▶ The subgrade soil in Lahore, Pakistan often exhibits poor strength, high compressibility, and moisture sensitivity, leading to road failures and increased maintenance costs.
- ▶ Traditional stabilizers like cement and lime can be expensive and environmentally challenging.

- ▶ This study explores Bitumen and Rice Husk Ash (RHA) as alternative stabilizers to enhance soil strength, compaction, and moisture resistance.
- ▶ A comparative analysis will assess their effectiveness, cost-efficiency, and environmental impact, aiming to develop a sustainable and locally viable solution for subgrade stabilization in road construction.

1.7. Scope of study:

- In scope of study, first we have to select material like in this design methodology we are using soil, bitumen and rice husk ash, after that we have to prepare sample by specific mixing proportions of 1,2,4,8. After material and sample is prepare, then we have to do sample curing and testing after 7,14,21 and 28 days.
- Different test has been done on these samples to identify the scope of this approach.
- By this methodology, scope of bitumen and rice husk ash can encompass various aspects of civil engineering.

1.8. Key Objectives:

- I. To Evaluate the Sustainability of Bitumen in Subgrade Stabilization.
- II. To Promote the Use of Locally Sourced Eco-friendly Material (RHA).
- III. To discuss the Effectiveness of Bitumen and RHA in Subgrade Stabilization.

CHAPTER 02

REVIEW OF LIERATURE

Soil is one of the most plentiful natural resources utilized in construction, serving as the foundation for various structures. Almost all types of construction are constructed using or built upon the soil. The primary component of a road pavement is the subgrade soil and its ability to withstand pressure. If the subgrade is not of sufficient quality, the entire structure will likely experience failure, such as cracks, and stabilization measures will be necessary. In addition to the bitumen emulsion, stone dust and brick dust are solid waste materials that are produced during the stone crushing industry and brick kilns, respectively. These materials are readily available. It is estimated that each crusher unit produces **15%-20%** stone dust in **2013**. The research paper presents the findings on the strength and compaction properties of bitumen-treated granular soil. **3%, 5% and 7%** bitumen content were considered. The findings indicated that the ideal binder content for attaining the highest maximum dry density (MDD) and california bearing ratio (CBR) is **4%**. It was found that when **6%** bitumen was added, the MDD and CBR values decreased, although the obtained values were higher than those for unstable granular soil. **(2014)**.

RHA is an environmentally friendly material that is cost-effective and also serves as an excellent option for soil stabilization, as it helps reduce environmental pollution. And the expenses for soil stabilizations are increases due to the increase in the prices of stabilization agent like cement and lime. And the cost for stabilization can be reduced by substituting a significant portion of these agent with RHA. It will also reduce the environmental risk.

Based on the observation of the greatest enhancement in strength, a recommended ratio of **10% RHA** content with **6%** cement is considered optimal for practical applications **(2014)**. RHA is composed of silica with a composition of 82-87%, certain material like rice husk ash (RHA), possess a pozzolanic reaction due to their silica concentration **(2019)**.

This research examines the application of rice husk ash (RHA) and coconut shell (CS) as stabilizing agents for clayey soil. The findings suggest that incorporating **20%** RHA and different percentages of CS (**4%, 6%, and 8%**) into the subgrade soil which resulted in the improvement of California bearing ratio (CBR) values, indicating increased strength and stability. **(2013)**

The objective of this study is to study the effectiveness of rice husk ash (RHA) in stabilizing the subgrade soil. Also indicate that adding of RHA as a stabilized agent increases its compaction and strength and also making it a suitable substitute for conventional stabilizers. The author of the article is a researcher from the University of California, Berkeley. **(2023)**.

This research examines the use of rice husk ash and hydrated lime together to improve the stability of subgrade soil that is not ideal. The study emphasizes the possibility of utilizing agricultural waste materials for soil stabilization purposes. **(2024)**.

This study investigates the joint application of cow dung ash and rice husk ash to stabilize the subgrade soil. The research reveals that it enhances the strength and stability of the subgrade soil, providing an economical and eco-friendly approach to soil stabilization in road construction. **(2023)**

Title	Authors	Tests Performed
1.Use of Bitumen emulsion is subgrade soils.(2018)	Zahid Ahmad Pala	Consistency test, Specific Gravity test.
2.Strength and Compaction characteristics of bitumen stabilized granular soil.(2014)	Olumide Moses	Sieve Analysis, Atterberg limit test
3.Soil Stabilization using Rice Husk Ash and Cement.(2014)	Aparna Roy	California bearing ratio, UCS
4.Rice Husk Ash as Ecofriendly material.(2019)	Nguyen	UCS, Compaction test
5.Improvement of Clayey soil characteristics using RHA.(2023)	Mohammed Y. Fattah	Liquid limit, Plastic limit test

Title	Author	Test Performed
6. Performance evaluation of bituminous mix and mastic containing rice husk ash.(2020)	Tapas Kumar	Consistency test, Sieve Analysis
7. Evaluation of rice husk ash as filler in hot mix Asphalt concrete.(2013)	Mehmet Sultan	Atterberg limit test, Optimum Moisture Content (OMC)
8. Soil Stabilization using Bitumen emulsion mixture in Road Base Construction.(2013)	Amir-ud-din	UCS (Unconfined Compression Test)
9. Rice Husk Ash as Eco-friendly material.(2019)	Moayedi	UCS, Compaction test
10. Stabilization of Sandy Soil with Use of Bitumen Emulsion .(2018)	Prof. Rajesh Jain	Specific Gravity, Sieve Size Analysis, Marshall Stability

METHODOLOGY

3.1. Material selection:

3.1.1. Soil:

- collect subgrade soil samples from the site.
- A-6 group of soil.
- Diana baro area sample.



Figure 1: SAFE SOIL SITE

3.1.2. Bitumen:

- Use standard-grade quality bitumen, which is readily available in Lahore.
- Eagle Star Tar-coal Bitumen.
- (Black Japan Bitumen).
- Already available in market liquid bitumen.



Figure 2: USED BITUMEN FOR SAMPLING

3.1.3. Rice Husk Ash (RHA):

We obtain rice husk ash from data rice mill where it remains as a byproduct.

Collect from:

Rice Mill Name: Data Rice Mill

Contact: 0321-3333533

Location: Near Jallo Road, Lahore, Punjab 54921



Figure 3: SITE OF USED RHA

3.2. Sample preparation:

3.2.1. Mixing Proportions: Prepare soil samples with different proportions of **bitumen** and **RHA**.

- Bitumen: **2%, 4%, 6%, 8%, 10%** by weight of soil.
- RHA: **2%, 4%, 6%, 8%, 10%** by weight of soil.
- Create combinations such as: 2% Bitumen + 2% RHA, 4% Bitumen + 4% RHA, etc.

Use **Standard Proctor Compaction method** to determine the **maximum dry density (MDD)** and **optimum moisture content (OMC)** for each sample mix.

3.3. Curing:

Curing Periods: Allow the stabilized soil samples to cure in a controlled environment for 7, 14, 21, and 28 days(B) and one day (RHA).

Keep the samples in **sealed plastic bags** to prevent moisture loss and ensure proper curing of both the bitumen and pozzolanic reactions of RHA.



Figure 4: CURING OF SAMPLES

3.4. Testing:

- **Sieve Analysis:**

This test is performed to determine the percentage of different grain sizes contained within a soil. It is performed to determine the distribution of the coarse and fine particles in the soil sample. It helps in predicting the soil behavior. For soil classification, we performed sieve analysis, determined the values of **plastic limit** and **liquid limit** of soil and then classified soil according to **AASHTO** and **USCS**.



Figure 5: SIEVING APPARATUS



Figure 6: USED APPARATUS IN TESTING

- **Hydrometer test**

“The Hydrometer Test is used to determine the particle size distribution of fine-grained soils, particularly silt and clay that are smaller than 0.075 mm. It's a type of sedimentation analysis based on Stokes' Law, which relates the settling velocity of particles in a fluid to their size”.

Purpose:

To measure the percentage of fine particles (silt and clay) in a soil sample by observing how they settle in a liquid over time.

Hydrometer Test Performance:

1. **Sample Preparation:**

- Take ~50g of fine soil (passing 2mm sieve).
- Mix with water and a dispersing agent (e.g., sodium hexametaphosphate)

2. Dispersion:

- Stir the mixture thoroughly using a mixer.
- Pour into a 1-liter sedimentation cylinder and fill with water.

3. Shaking:

- Shake or stir to create uniform suspension.

4. Hydrometer Reading:

- Insert hydrometer and record readings at time intervals (e.g., 0.5, 1, 2, 5, 15, 30, 60, 120 min, etc.).
- Measure temperature alongside.

5. Blank Test:

- Run a test with water and dispersing agent only (no soil) for correction.

6. Calculations:

- Use readings to calculate particle size (Stokes' Law) and % finer particles.

7. Plot Result:

- Draw a grain size distribution curve.



Figure 7:HYDROMETER TEST APPARATUS

- **Atterberg Limits:**

ASTM DESIGNATION: D-4318

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil that is its shrinkage limit, plastic limit, and liquid limit. .

Plastic Limit Test:

Plastic limit test is one of the laboratory tests used to differentiate or classify soils into groups. The boundary of soil between the plastic and solid state means, the limit at which the

soil starts to behave as a plastic

Liquid Limit Test:

The boundary water content between the liquid state and the plastic state is called the liquid limit. This is the stage when the sample change from possessing no shear strength to having an very low shear strength



Figure 8: ATTERBERG TEST APPARATUS

- **Standard Proctor Test:**

ASTM D698/AASHTO T99

Compact the soil mixture into molds using the **Standard Proctor test** procedure (using a 2.5 kg hammer with 25 blows per layer for 3 layers) to determine the **maximum dry density (MDD)** and **optimum moisture**

content (OMC).

“The Proctor compaction test is a laboratory method used to determine the maximum dry density and optimal moisture content of a soil sample.

It involves compacting soil samples in a mold, using a standardized compactive effort at various moisture contents, and then measuring the resulting dry density”

Purpose:

The Proctor Compaction Test determines the optimum moisture content and maximum dry density of a soil, crucial for achieving desired compaction in construction projects like embankments, pavements, and structural fills.

We did Standard Proctor test on our samples after mixing different proportions of bitumen with soil.

Sample Preparation:

- Soil total quantity for which we have to do proctor test is 5kg(5000g)then we add that 2%, 4%, 6%, 8% and 10% bitumen quantity in that soil to make samples.
- At First, we have to mix the soil and bitumen by mixing proportions of 2%, 4%, 6%, 8% and 10% means first we add 2% bitumen quantity in soil, then 4% bitumen is added to soil and in the same manner other percentages are added (6%, 8% and 10%).

STANDARD PROCTOR TEST

1. Sample Preparation:

- Air-dry the soil and break clods (if any).
- Sieve soil through a 4.75 mm sieve and take about 3–4 kg for the test.

2. Determine Initial Moisture Content:

- Take a small sample (~100 g) and determine moisture content using an oven-dry method.

3. Add Water:

- Add 4–6% water by weight and mix thoroughly.

4. Compact the Soil:

- Place the Proctor mold on a solid base.
- Fill the mold in 3 equal layers.
- Each layer is compacted by 25 blows of the 2.5 kg rammer dropped from 30 cm height.
- Trim excess soil using a straight edge.

5. Weigh the Mold:

- Weigh the mold with compacted soil and note the weight.

6. Moisture Content Determination:

- Take a sample from the mold for moisture content determination.

7. Repeat for Different Moisture Contents:

- Increase the water content in increments (2–3%).
- Repeat steps 4–6 for each increment until the dry density starts decreasing.



Figure 9: REMOVING LUMPS FROM SOIL



Figure 10: SIEVING OF SOIL FOR PROCTOR TEST



Figure 11: SOIL AFTER SIEVING



Figure 12: WEIGHING APPARTUS FOR PROCTOR TEST



Figure 13: TOTAL WEIGHT OF SOIL AFTER SIEVING



Figure 14: WEIGHT OF SOIL FOR PROCTOR TEST



Figure 15: WEIGHING THE PERCENTAGE OF WATER



Figure 16 : ADDING WATER INTO SOIL



Figure 17: MIXING FOR PROCTOR TEST



Figure 18: AGAIN WEIGHING CALCULATED WATER PERCENTAGE



Figure 19: APPLING NUMBER OF BLOWS



Figure 20: REPEATING THE SAME (WATER PERCENTAGE)



Figure 21: APPARATUS USED FOR PROCTOR TEST



Figure 22: PROCTOR TEST APPARATUES

- **Unconfined Compressive Strength (UCS) Test:**

ASTM D 1632-33, ASTM D 1074-02 and ASTM D2166-06

Perform UCS tests after 7, 14, 21, and 28 days of curing to evaluate the strength development of the bitumen and RHA-stabilized soils.

The Unconfined Compressive Test (UCT) is a laboratory method used to determine the unconfined compressive strength (UCS) of cohesive soils and rocks. It involves applying axial compressive stress to a cylindrical specimen without any lateral support until it fails.

A. FOR BITUMEN

UCS Test Performance:

- After Soil-Bitumen mix samples of different proportions of 2%, 4%, 6%, 8%, 10% are made then we have to perform unconfined compressive strength on that samples at different curing periods like 7, 14, 21 and 28 days to check their developed unconfined compressive strength and plot bitumen strength comparison.

Unconfined Compressive Strength:

1. Sample Preparation:

- Prepare a cylindrical soil specimen.
- Trim the ends to make them smooth and flat.
- Measure and record Initial diameter (d_0), Initial length (L_0), Initial weight (W_0) (optional for density)

2. Placing the Sample:

- Place the specimen vertically in the UCS machine.
- Align it properly between the upper and lower platens.
- Zero the dial gauge or displacement system.

3. Load Application:

- Apply axial load at a constant strain rate of 1% to 2% per minute.
- Record Axial load (in N or kg) Axial deformation (mm)
- Continue the test until the sample fails (breaks, bulges, or shears), or the axial strain reaches 15–20% .

Unconfined Compressive Strength Apparatus:

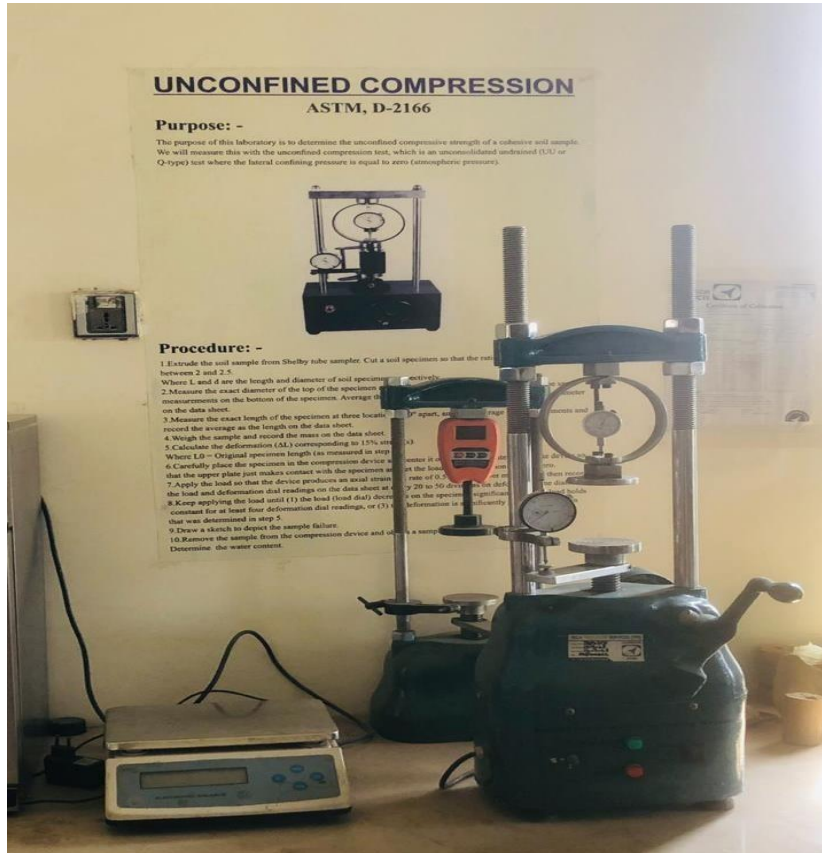


Figure 25: UCS APPARATUS-11

Unconfined Compressive Strength Samples:



Figure 26: SAMPLES AFTER MIXING

Unconfined Compressive Strength Samples:



Figure 27: APPLYING LOADING ON BITUMEN SAMPLES

B. FOR RHA:

UCS Test Performance:

- After Soil-RHA mix samples of different proportions of 2%, 4%, 6%, 8%, 10% are made then we have to perform unconfined compressive strength on

that samples at curing period like one day to check their developed unconfined compressive strength and plot RHA strength comparison.

Unconfined Compressive Strength:

1. Sample Preparation:

- Prepare a cylindrical soil specimen.
- Trim the ends to make them smooth and flat.
- Measure and record Initial diameter (d_0), Initial length (L_0), Initial weight (W_0) (optional for density)

2. Placing the Sample:

- Place the specimen vertically in the UCS machine.
- Align it properly between the upper and lower platens.
- Zero the dial gauge or displacement system.

3. Load Application:

- Apply axial load at a constant strain rate of 1% to 2% per minute.
- Record Axial load (in N or kg) Axial deformation (mm)
- Continue the test until the sample fails (breaks, bulges, or shears), or the axial strain reaches 15–20%



Figure 28 : SOIL AFTER SIEVING



Figure 29 : MIXING OF RHA AND SOIL SAMPLE



Figure 30: ADDING WATER IN SAMPLE OF RHA



Figure 31: APPARATUS FOR SAMPLING



Figure 32 : WITH 2% RHA SAMPLE



Figure 33: WITH 4% RHA SAMPLE



Figure 34: WITH 6% RHA SAMPLE



Figure 35 :WITH 8% RHA SAMPLE



Figure 36 : WITH 10% RHA SAMPLE



Figure 37: CURING OF SAMPLES (I)



Figure 38: CURING OF SAMPLES (II)



Figure 39: CURING OF SAMPLES (III)



Figure 40: WEIGHT OF SAMPLE WITH 2% RHA



Figure 41: APPLYING LOADING ON SAMPLE WITH 2%



Figure 42: WEIGHT OF SAMPLE WITH 4% RHA



Figure 43: APPLYING LOADING ON SAMPLE WITH 4% RHA



Figure 44: WEIGHT OF SAMPLE WITH 6% RHA



*Figure 45: AFTER LOADING ON
SAMPLE WITH 4% RHA*



Figure 46: WEIGHT OF SAMPLE WITH 8% RHA



Figure 47: APPLYING LOADING ON SAMPLE WITH 8% RHA



Figure 48: WEIGHT OF SAMPLE WITH 10% RHA



*Figure 49: APPLYING
LOADING ON SAMPLE WITH
10% RHA*

3.5. Data Analysis:

3.5.1. Atterberg's Limits:

ASTM Designation:

Table 1: LIQUID LIMIT:

Can	No. of Blows	Wt. of empty can	Wt. of can + wet soil	Wt. of can + dry soil	Wt. of wet soil	Wt. of dry soil	Wt. of water	Moisture content
#	#	W1	W2	W3	Wb= W2-W1	Ws= W3-w1	Ww= Wb-Ws	ω = Ww/Ws*100
		g	g	g	g	g	g	%
85	44	23.2	52.6	45.9	29.3	22.3	7.05	31.5
66	33	31.3	47.2	43.4	15.9	12.1	3.79	31.2
26	23	11.5	30.3	25.5	18.8	14.4	4.76	33.9
39	14	11.5	29.9	25.0	18.4	13.4	4.82	35.7
118	8	33.2	54.3	48.7	21.0	15.4	5.51	36

Table 2: PLASTIC LIMIT DETERMINATION:

Can	Wt. of empty can	Wt. of can + wet soil	Wt. of can + dry soil	Wt. of wet soil	Wt. of dry soil	Wt. of water	Moisture content ω	Plastic Limit
	g	g	g	g	g	g	%	-
127	31.77	41.20	40.03	9.43	8.26	1.17	14	14

Plasticity Index:

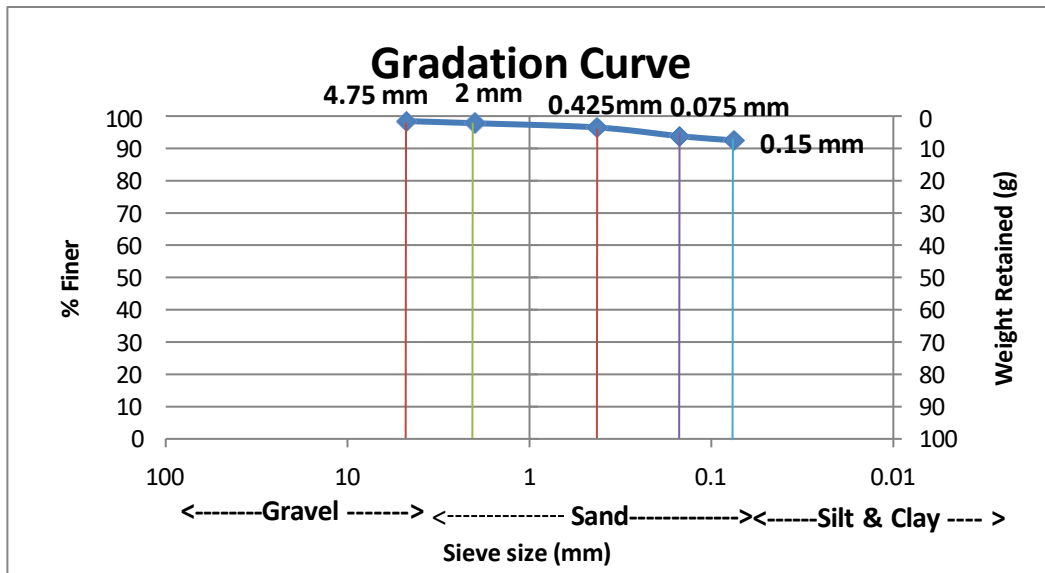
$$LL-PL = 32-19 = 13$$

3.5.2. Sieve Analysis:

Table 3: SIEVE ANALYSIS CALCULATION

Total weight= 100 g

Sieve No.	Sieve size (mm)	Wt. Retained (g)	% Wt. Retained	Cumulated Weight (%)	% Finer
4	4.75	1.55	1.55	1.55	98.45
10	2.00	0.66	0.66	2.21	97.79
40	0.425	1.31	1.31	3.52	96.48
100	0.150	2.69	2.69	6.21	93.79
200	0.075	1.34	1.34	7.55	92.45



GRAPH 1: FOR ATTERBERG'S TEST

Classification:

% Finer 200 > 35% Hence it is fine grained soil.

AASHTO Classification:

- % passing # 200 > 35% Hence it is fine grained soil (A4 – A7)
- Liquid Limit = 34 (A4 – A7)
- PI = 19 (A7) (Clayey soil)
- Group Index = 16
- Classification: A6

USCS Classification:

- Passing through sieve # 200 > 50% Hence it is fine-grained soil.
- Liquid Limit = 32 < 50
- PI = 13, plots above A-line

- Group Symbol = CL
- <7% retained on no. 200
- It is Lean Clay

3.5.3. Hydrometer results

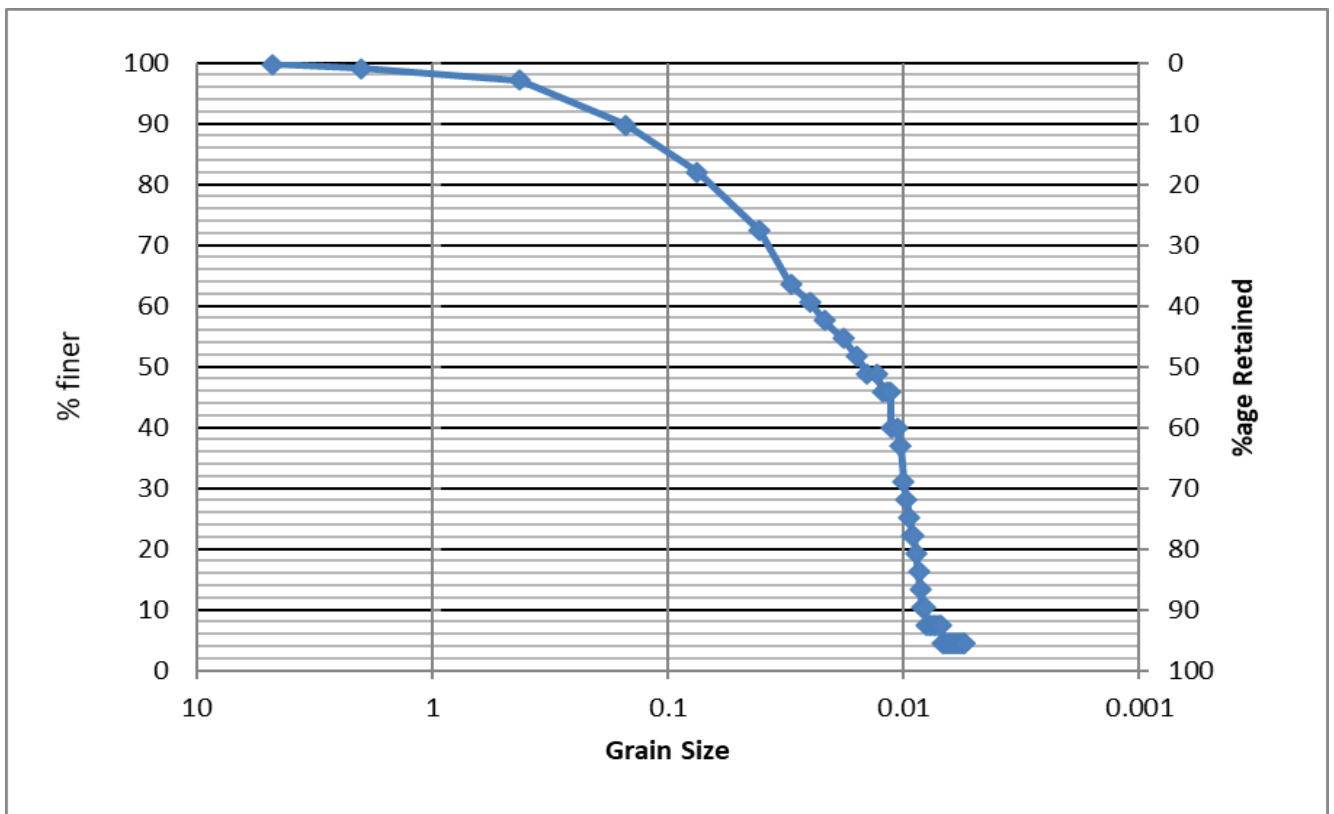
Table 4: HYDROMETER TEST RESULT CALCULATION

Sieve size	%age finer	%age weight retained
4.75	99.72	0.14
2	99.05	0.335
0.425	97.17	0.94
0.15	89.7	3.735
0.075	82.05	3.825
0.040685	72.377731	27.62226897
0.0299679	63.5151517	36.48484828
0.0248259	60.5609586	39.43904138
0.0217037	57.6067655	42.39323448
0.0179677	54.6525724	45.34742759
0.0157712	51.6983793	48.30162069
0.0142305	48.7441862	51.25581379
0.0129906	48.7441862	51.25581379
0.0121828	45.7899931	54.2100069
0.0117697	45.7899931	54.2100069
0.011396	45.7899931	54.2100069
0.0112875	39.8816069	60.1183931
0.0106769	39.8816069	60.1183931
0.0102789	36.9274138	63.07258621
0.0100148	31.0190276	68.98097241
0.0097152	28.0648345	71.93516552

0.0094526	25.1106414	74.88935862
0.0091871	22.1564483	77.84355172
0.0090327	22.1564483	77.84355172
0.0088398	19.2022552	80.79774483
0.008636	16.2480621	83.75193793
0.0084797	13.293869	86.70613103
0.0083373	10.3396759	89.66032414
0.0081262	10.3396759	89.66032414
0.007983	7.38548276	92.61451724
0.0077995	7.38548276	92.61451724
0.0076281	7.38548276	92.61451724
0.0074674	7.38548276	92.61451724
0.0073166	7.38548276	92.61451724
0.0071745	7.38548276	92.61451724
0.0070404	7.38548276	92.61451724
0.0069135	7.38548276	92.61451724
0.00686	4.43128966	95.56871034
0.0067447	4.43128966	95.56871034
0.006635	4.43128966	95.56871034
0.0065305	4.43128966	95.56871034
0.0064308	4.43128966	95.56871034
0.0063355	4.43128966	95.56871034
0.0062444	4.43128966	95.56871034
0.006157	4.43128966	95.56871034
0.0060732	4.43128966	95.56871034
0.0059928	4.43128966	95.56871034
0.0059155	4.43128966	95.56871034
0.0058411	4.43128966	95.56871034
0.0057694	4.43128966	95.56871034
0.0057003	4.43128966	95.56871034

0.0056336	4.43128966	95.56871034
0.0055692	4.43128966	95.56871034
0.005507	4.43128966	95.56871034

Hydrometer Test Result Graph



GRAPH 2: FOR HYDROMETER TEST

3.5.4. UCS RESULTS

A. FOR BITUMEN

Strength Gain Analysis:

Analyze the **strength development** (UCS values) at different curing times (7, 14, 21, and 28 days) for the different mix proportions of bitumen.

Raw Bitumen:
0
33.41632132
142.7414007
260.8283257
449.0288714
518.1996823
539.9471612

1. BITTUMEN STRENGHT AT 7 DAYS

Table 5: BITUMEN STRENGHT AT 7 DAYS

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
7	25	0.03822	0.25

30	50	0.1638	0.5
55	75	0.3003	0.75
95	100	0.5187	1
110	125	0.6006	1.25
115	150	0.6279	1.5

strain $\epsilon = \Delta/L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	33.41632132
0.00656168	0.656167979	0.00114753	142.7414007
0.00984252	0.984251969	0.001151332	260.8283257
0.01312336	1.312335958	0.00115516	449.0288714
0.016404199	1.640419948	0.001159013	518.1996823
0.019685039	1.968503937	0.001162892	539.9471612

❖ **B-2-7**

Table 6: BITUMEN STRENGTH AT 7 DAYS (2%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
5	25	0.0273	0.25
10	50	0.0546	0.5
15	75	0.0819	0.75
20	100	0.1092	1
30	125	0.1638	1.25
44	150	0.24024	1.5
60	175	0.3276	1.75
75	200	0.4095	2
99	225	0.54054	2.25

120	250	0.6552	2.5
strain $\epsilon=\Delta/L_0$	% Strain	Corrected Area $A= A_0/1-\epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	23.86880094
0.00656168	0.656167979	0.00114753	47.58046692
0.00984252	0.984251969	0.001151332	71.13499793
0.01312336	1.312335958	0.00115516	94.53239398
0.016404199	1.640419948	0.001159013	141.3271861
0.019685039	1.968503937	0.001162892	206.5884791
0.022965879	2.296587927	0.001166797	280.7687526
0.026246719	2.624671916	0.001170728	349.7824285
0.029527559	2.952755906	0.001174686	460.1571695
0.032808399	3.280839895	0.00117867	555.8806465

❖ **B-4-7**

Table 7: BITUMEN STRENGTH AT 7 DAYS (4%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
12	25	0.06552	0.25
70	50	0.3822	0.5
180	75	0.9828	0.75
230	100	1.2558	1
strain $\epsilon=\Delta/L_0$	% Strain	Corrected Area $A= A_0/1-\epsilon$	Stress kPa

		1-ε	
0	0	0	0
0.00328084	0.32808399	0.001143752	57.28512225
0.00656168	0.656167979	0.00114753	333.0632684
0.00984252	0.984251969	0.001151332	853.6199751
0.01312336	1.312335958	0.00115516	1087.122531

❖ B-6-7

Table 8: BITUMEN STRENGTH AT 7 DAYS (6%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
yu\y	25	#VALUE!	0.25
18	50	0.09828	0.5
46	75	0.25116	0.75
55	100	0.3003	1
80	125	0.4368	1.25
100	150	0.546	1.5
120	175	0.6552	1.75
130	200	0.7098	2
		Corrected Area A= Ao/	
strain ε=Δ/Lo	% Strain	1-ε	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	#VALUE!
0.00656168	0.656167979	0.00114753	85.64484045
0.00984252	0.984251969	0.001151332	218.147327
0.01312336	1.312335958	0.00115516	259.9640834

0.016404199	1.640419948	0.001159013	376.8724962
0.019685039	1.968503937	0.001162892	469.5192706
0.022965879	2.296587927	0.001166797	561.5375052
0.026246719	2.624671916	0.001170728	606.2895428

❖ B-8-7

Table 9: BITUMEN STRENGHT AT 7 DAYS (8%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
5	25	0.0273	0.25
10	50	0.0546	0.5
15	75	0.0819	0.75
30	100	0.1638	1
40	125	0.2184	1.25
59	150	0.32214	1.5
88	175	0.48048	1.75
110	200	0.6006	2
132	225	0.72072	2.25
136	250	0.74256	2.5

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	23.86880094
0.00656168	0.656167979	0.00114753	47.58046692
0.00984252	0.984251969	0.001151332	71.13499793
0.01312336	1.312335958	0.00115516	141.798591
0.016404199	1.640419948	0.001159013	188.4362481

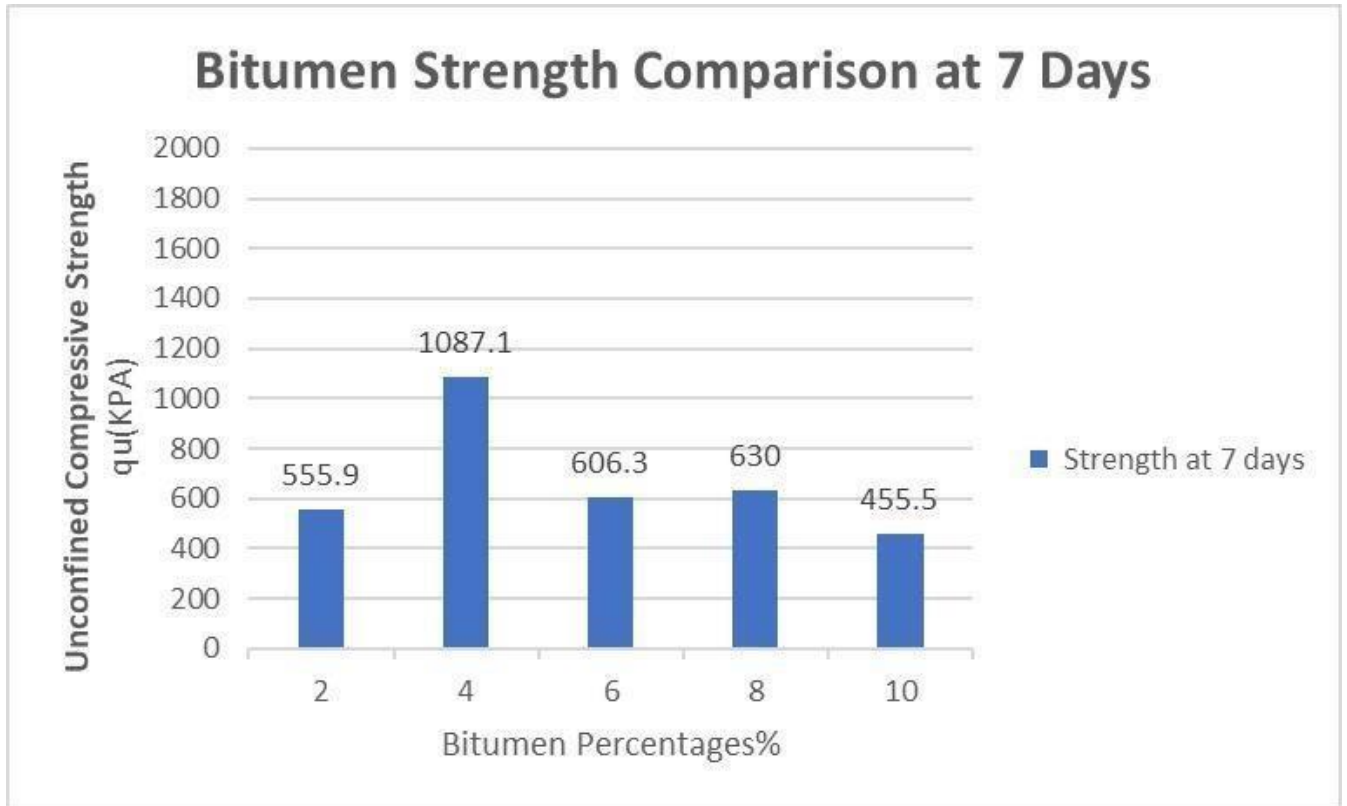
0.019685039	1.968503937	0.001162892	277.0163697
0.022965879	2.296587927	0.001166797	411.7941705
0.026246719	2.624671916	0.001170728	513.0142285
0.029527559	2.952755906	0.001174686	613.5428927
0.032808399	3.280839895	0.00117867	629.998066

3

❖ **B-10-7**

Table 10: BITUMEN STRENGTH AT 7 DAYS (10%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
6	25	0.03276	0.25
15	50	0.0819	0.5
24	75	0.13104	0.75
40	100	0.2184	1
52	125	0.28392	1.25
70	150	0.3822	1.5
84	175	0.45864	1.75
95	200	0.5187	2
98	225	0.53508	2.25



GRAPH 3: FOR BITUMEN AT 7 DAYS

The graph depicts the correlation between the percentage of bitumen and the unconfined compressive strength (qu) in kilopascals (kpa) after 7 days. The x-axis displays the bitumen percentages, ranging from 2% to 10%, while the y-axis represents the unconfined compressive strength, ranging from 0 to 2000 kpa.

Main points:

4. The graph displays a clear peak in unconfined compressive strength at 4% bitumen content, with a value of 1087.1 KPa
5. The lowest unconfined compressive strength is observed at 10% bitumen content, with a value of 455.5KPa

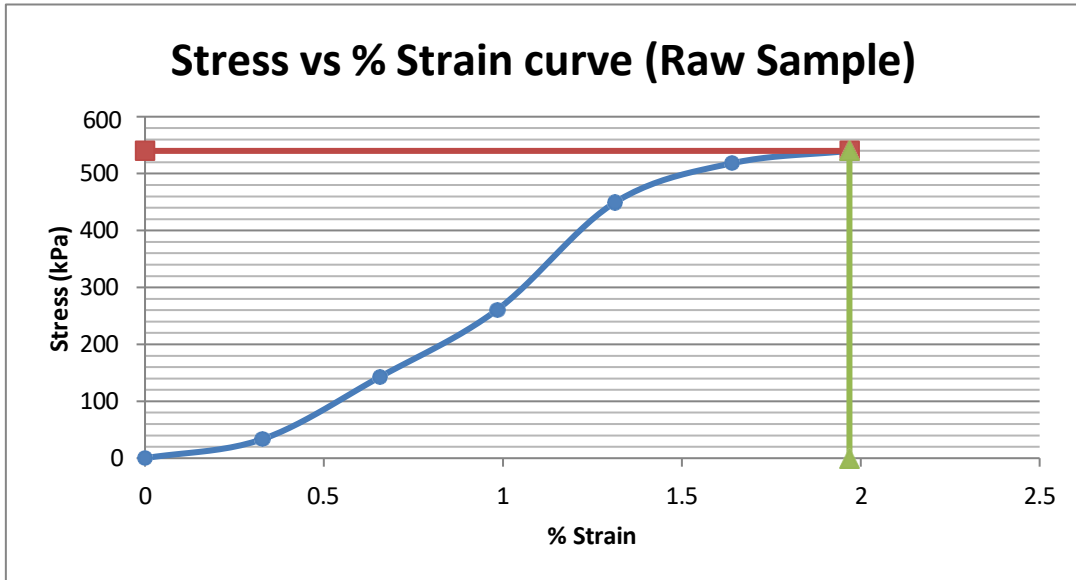
- The data points are as follows:
 - 2% bitumen: 555.9 kPa
 - 4% bitumen: 1087.1 kPa
 - 6% bitumen: 606.3 kPa
 - 8% bitumen: 630 kPa
 - 10% bitumen: 455.5 kPa

Trend Analysis:

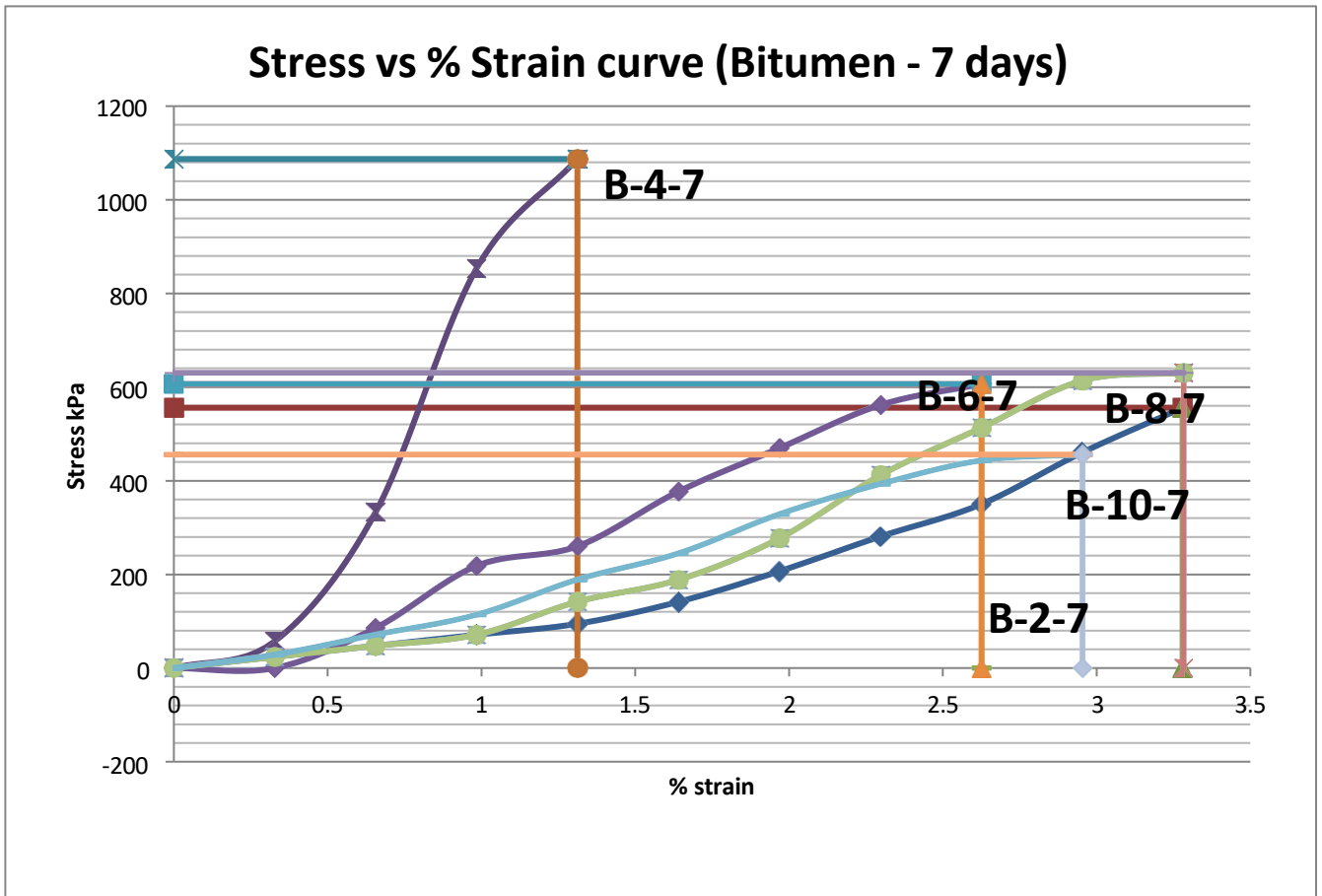
- The initial increase in unconfined compressive strength is observed as the bitumen percentage rises from 2% to 4%, reaching its peak value at 4%.
- beyond 4%, the unconfined compressive strength decreases as the bitumen percentage continues to increase, with a slight fluctuation between 6% and 8% before dropping to its lowest point at 10%.

Result:

The graph indicates that the ideal bitumen percentage for attaining the maximum unconfined compressive strength at 7 days is 4%. This knowledge can be beneficial in construction and civil engineering projects where bitumen is utilized as a binding agent.



GRAPH 4: FOR RAW



GRAPH 5: FOR BITUMEN AT 7 DAYS(S-S)

2. BITTUMEN STRENGHT AT 14 DAYS

❖ B-2-14

Table 11: BITUMEN STRENGHT AT 14 DAYS (2%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
5	25	0.0273	0.25
10	50	0.0546	0.5
115	75	0.6279	0.75
210	100	1.1466	1
305	125	1.6653	1.25
315	150	1.7199	1.5

strain $\epsilon = \Delta/L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	23.86880094
0.00656168	0.656167979	0.00114753	47.58046692
0.00984252	0.984251969	0.001151332	545.3683174
0.01312336	1.312335958	0.00115516	992.5901368
0.016404199	1.640419948	0.001159013	1436.826392
0.019685039	1.968503937	0.001162892	1478.985702

❖ B-4-14

Table 12: BITUMEN STRENGHT AT 14 DAYS (4%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0

5	25	0.0273	0.25
15	50	0.0819	0.5
355	75	1.9383	0.75

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / (1 - \epsilon)$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	23.86880094
0.00656168	0.656167979	0.00114753	71.37070037
0.00984252	0.984251969	0.001151332	1683.528284

❖ B-6-14

Table 13: BITUMEN STRENGTH AT 14 DAYS (6%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
20	25	0.1092	0.25
40	50	0.2184	0.5
70	75	0.3822	0.75
115	100	0.6279	1
145	125	0.7917	1.25
255	150	1.3923	1.5
255	175	1.3923	1.75
255	200	1.3923	2

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / (1 - \epsilon)$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	95.47520376

0.00656168	0.656167979	0.00114753	190.3218677
0.00984252	0.984251969	0.001151332	331.9633237
0.01312336	1.312335958	0.00115516	543.5612654
0.016404199	1.640419948	0.001159013	683.0813994
0.019685039	1.968503937	0.001162892	1197.27414
0.022965879	2.296587927	0.001166797	1193.267199
0.026246719	2.624671916	0.001170728	1189.260257

❖ B-8-14

Table 14: BITUMEN STRENGTH AT 14 DAYS (8%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
20	25	0.1092	0.25
55	50	0.3003	0.5
90	75	0.4914	0.75
120	100	0.6552	1
125	125	0.6825	1.25
125	150	0.6825	1.5
150	175	0.819	1.75
152	200	0.82992	2

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	95.47520376
0.00656168	0.656167979	0.00114753	261.692568
0.00984252	0.984251969	0.001151332	426.8099876
0.01312336	1.312335958	0.00115516	567.1943639

0.016404199	1.640419948	0.001159013	588.8632753
0.019685039	1.968503937	0.001162892	586.8990883
0.022965879	2.296587927	0.001166797	701.9218815
0.026246719	2.624671916	0.001170728	708.8923885

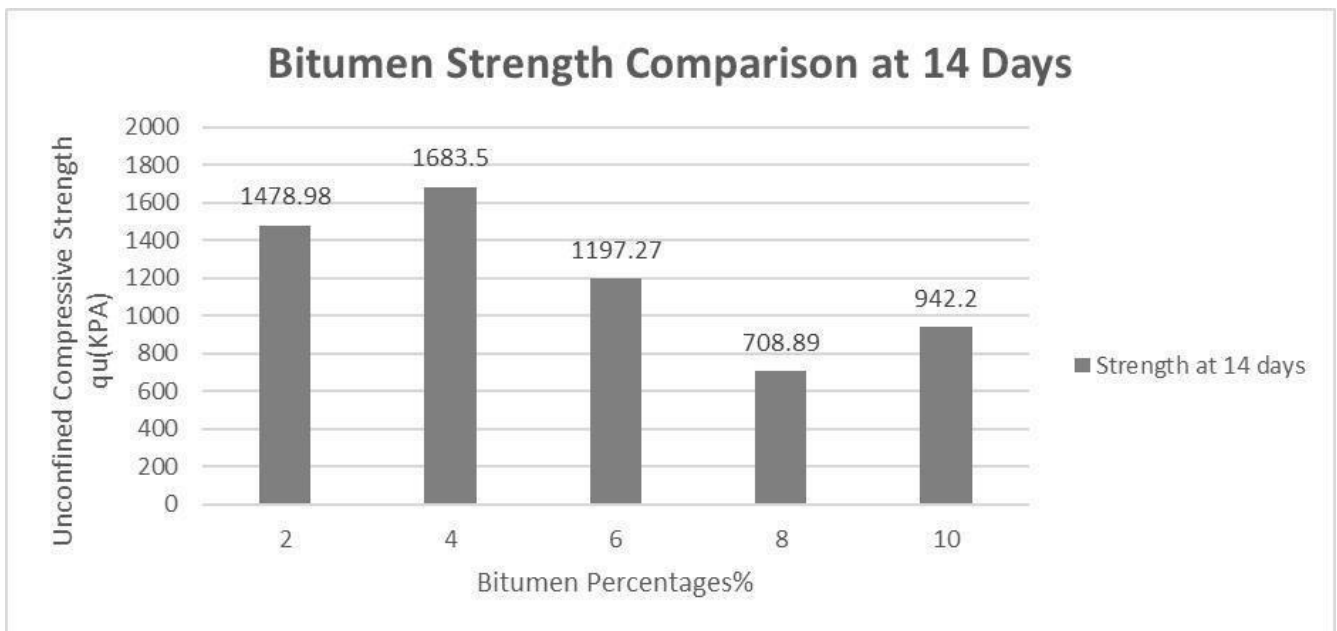
❖ **B-10-14**

Table 15: BITUMEN STRENGTH AT 14 DAYS (10%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
10	25	0.0546	0.25
60	50	0.3276	0.5
115	75	0.6279	0.75
115	100	0.6279	1
200	125	1.092	1.25
200	150	1.092	1.5
200	175	1.092	1.75

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	47.73760188
0.00656168	0.656167979	0.00114753	285.4828015
0.00984252	0.984251969	0.001151332	545.3683174
0.01312336	1.312335958	0.00115516	543.5612654
0.016404199	1.640419948	0.001159013	942.1812405
0.019685039	1.968503937	0.001162892	939.0385412
0.022965879	2.296587927	0.001166797	935.895842

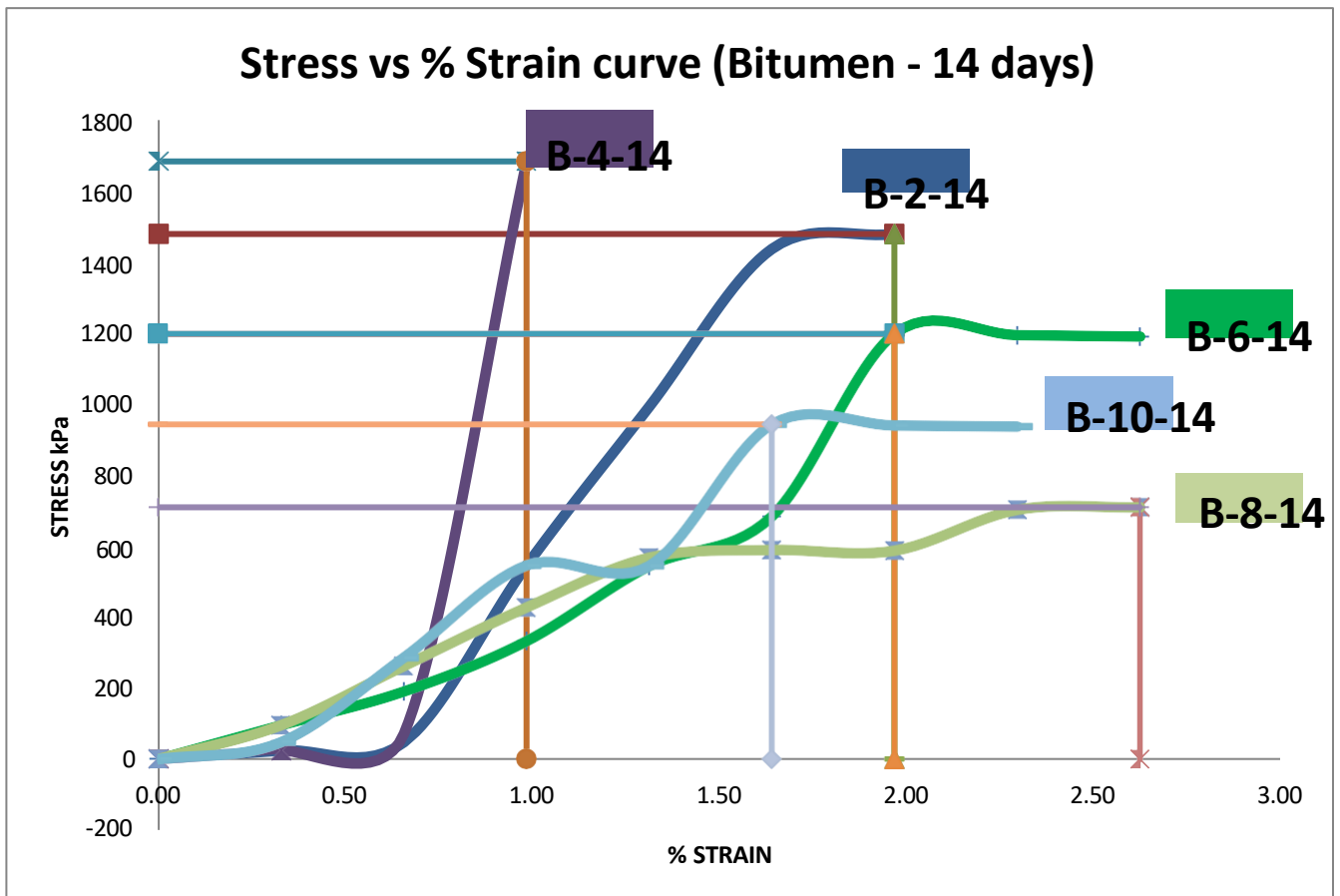
Max Stress (kpa)	Bitumen
555.9	2
1087.1	4
606.3	6
630	8
455.5	10



GRAPH 6: FOR BITUMEN AT 14 DAYS

The x-axis represents the percentage of bitumen in the asphalt mixture, ranging from 2% to 10%, while the y-axis represents the compressive strength of the asphalt, ranging from 0 to 2000 kpa.

- At 4%, the strength reaches its peak at approximately 1683.5KPa The lowest strength is observed at 8%, with a value of approximately 708.89 KPa
- A slight increase in strength is noted at 10%, reaching approximately 942.2KPa



GRAPH 7: FOR BITUMEN AT 14 DAYS(S-S)

3. BITTUMEN STRENGHT AT 21 DAYS

❖ B-2-21

Table 16: BITUMEN STRENGHT AT 21 DAYS (2%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
10	25	0.0546	0.25
35	50	0.1911	0.5
70	75	0.3822	0.75

115	100	0.6279	1
160	125	0.8736	1.25
212	150	1.15752	1.5
222	175	1.21212	1.75
222	200	1.21212	2

strain $\epsilon = \Delta/L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	47.73760188
0.00656168	0.656167979	0.00114753	166.5316342
0.00984252	0.984251969	0.001151332	331.9633237
0.01312336	1.312335958	0.00115516	543.5612654
0.016404199	1.640419948	0.001159013	753.7449924
0.019685039	1.968503937	0.001162892	995.3808537
0.022965879	2.296587927	0.001166797	1038.844385
0.026246719	2.624671916	0.001170728	1035.355988

❖ B-4-21

Table 17: BITUMEN STRENGTH AT 21 DAYS (4%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
5	25	0.0273	0.25
10	50	0.0546	0.5
20	75	0.1092	0.75
50	100	0.273	1
60	125	0.3276	1.25
120	150	0.6552	1.5

160	175	0.8736	1.75
320	200	1.7472	2
410	225	2.2386	2.25

strain $\epsilon = \Delta/L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	23.86880094
0.00656168	0.656167979	0.00114753	47.58046692
0.00984252	0.984251969	0.001151332	94.8466639
0.01312336	1.312335958	0.00115516	236.3309849
0.016404199	1.640419948	0.001159013	282.6543722
0.019685039	1.968503937	0.001162892	563.4231247
0.022965879	2.296587927	0.001166797	748.7166736
0.026246719	2.624671916	0.001170728	1492.405028
0.029527559	2.952755906	0.001174686	1905.701409

❖ **B-6-21**

Table 18: BITUMEN STRENGTH AT 21 DAYS (6%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
10	25	0.0546	0.25
45	50	0.2457	0.5
140	75	0.7644	0.75
200	100	1.092	1
250	125	1.365	1.25
320	150	1.7472	1.5
400	175	2.184	1.75

strain $\epsilon=\Delta/L_0$	% Strain	Corrected Area $A= A_0/ 1-\epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	47.73760188
0.00656168	0.656167979	0.00114753	214.1121011
0.00984252	0.984251969	0.001151332	663.9266473
0.01312336	1.312335958	0.00115516	945.3239398
0.016404199	1.640419948	0.001159013	1177.726551
0.019685039	1.968503937	0.001162892	1502.461666
0.022965879	2.296587927	0.001166797	1871.791684

❖ **B-8-21**

Table 19: BITUMEN STRENGTH AT 21 DAYS (8%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
12	25	0.06552	0.25
15	50	0.0819	0.5
50	75	0.273	0.75
80	100	0.4368	1
100	125	0.546	1.25
140	150	0.7644	1.5
160	175	0.8736	1.75
170	200	0.9282	2
250	225	1.365	2.25
270	250	1.4742	2.5

0	0	0	0
0.00328084	0.32808399	0.001143752	57.28512225
0.00656168	0.656167979	0.00114753	71.37070037
0.00984252	0.984251969	0.001151332	237.1166598
0.01312336	1.312335958	0.00115516	378.1295759
0.016404199	1.640419948	0.001159013	471.0906203
0.019685039	1.968503937	0.001162892	657.3269789
0.022965879	2.296587927	0.001166797	748.7166736
0.026246719	2.624671916	0.001170728	792.8401713
0.029527559	2.952755906	0.001174686	1162.013054
0.032808399	3.280839895	0.00117867	1250.731455

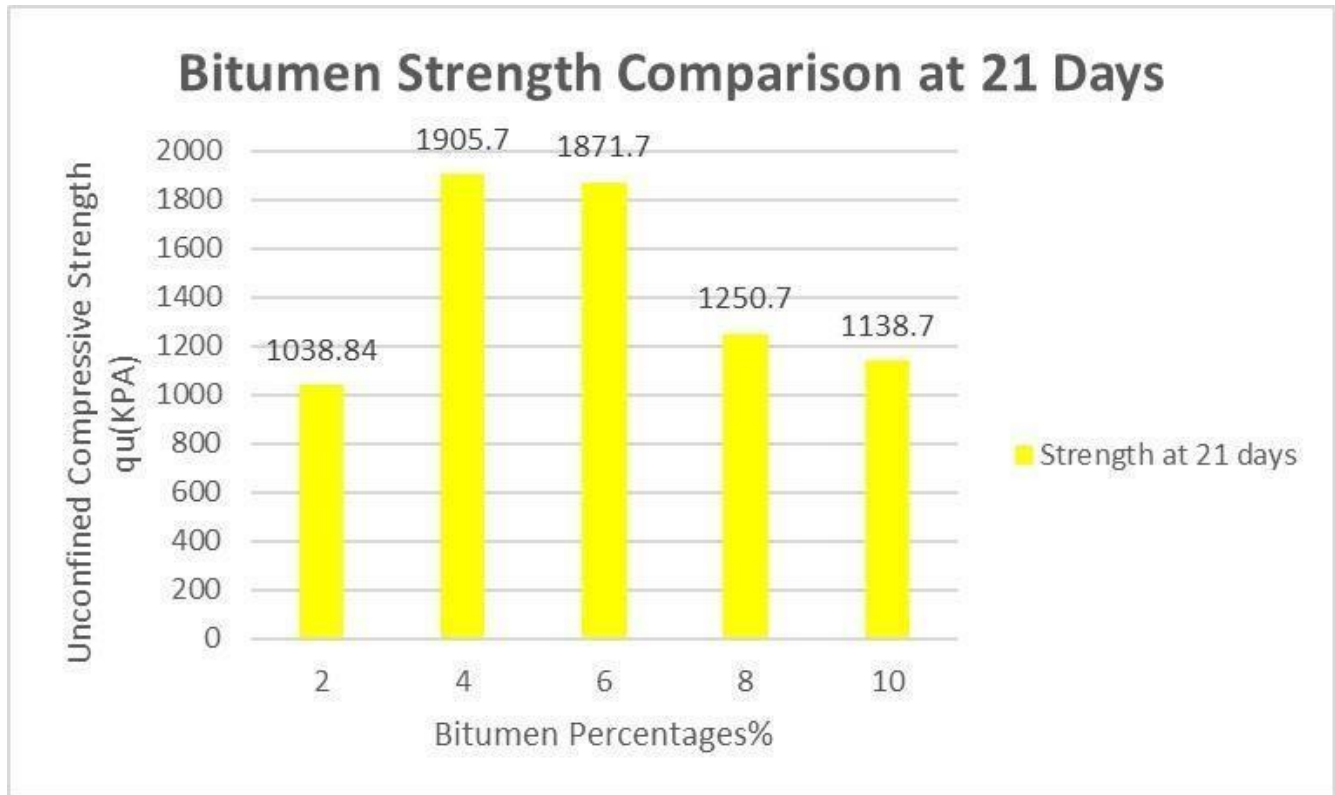
❖ **B-10-21**

Table 20: BITUMEN STRENGTH AT 21 DAYS (10%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
20	25	0.1092	0.25
70	50	0.3822	0.5
100	75	0.546	0.75
150	100	0.819	1
180	125	0.9828	1.25
210	150	1.1466	1.5
220	175	1.2012	1.75
240	200	1.3104	2
245	225	1.3377	2.25
235	250	1.2831	2.5

0	0	0	0
0.00328084	0.32808399	0.001143752	95.47520376
0.00656168	0.656167979	0.00114753	333.0632684
0.00984252	0.984251969	0.001151332	474.2333195
0.01312336	1.312335958	0.00115516	708.9929548
0.016404199	1.640419948	0.001159013	847.9631165
0.019685039	1.968503937	0.001162892	985.9904683
0.022965879	2.296587927	0.001166797	1029.485426
0.026246719	2.624671916	0.001170728	1119.303771
0.029527559	2.952755906	0.001174686	1138.772793
0.032808399	3.280839895	0.00117867	1088.599599

Max Stress (kpa)	Bitumen
555.9	2
1087.1	4
606.3	6
630	8
455.5	10

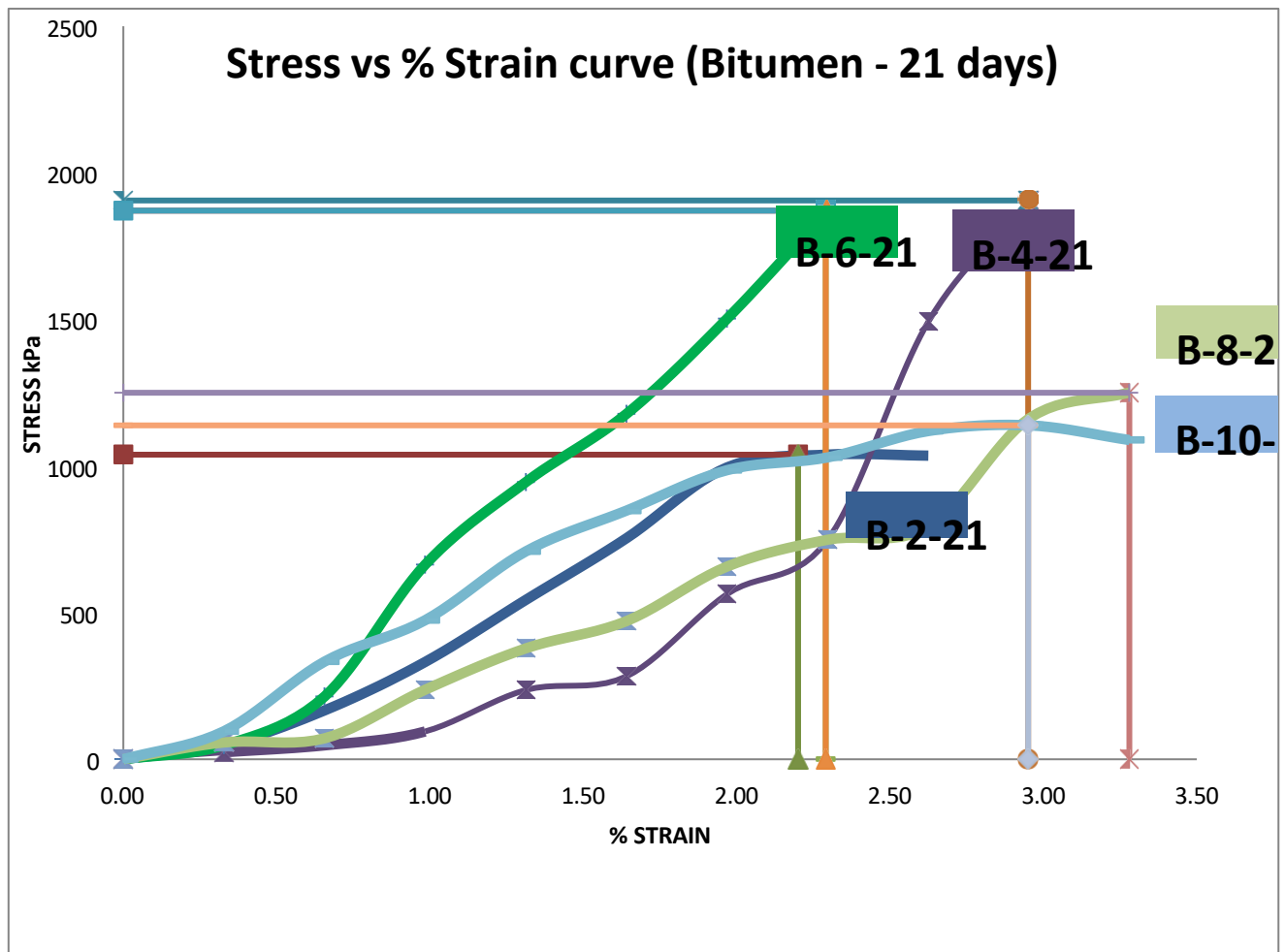


GRAPH 8: FOR BITUMEN AT 21 DAYS

The x-axis represents the percentages of bitumen, ranging from 2% to 10%, while the y-axis represents the ucs in kilopascals (kpa).

- The highest ucs is observed at a bitumen percentage of 4%, with a value of 1905.7
- The lowest ucs is recorded at a bitumen percentage of 2%, with a value of 1038.84
- The ucs increases as the bitumen percentage increases from 2% to 4%, but then decreases as the bitumen percentage continues to increase beyond 4%
- At 6% bitumen, the ucs is 1871.7
- The ucs further decreases to 1250.7

The graph exhibits a non-linear trend, with an initial increase in ucs followed by a decline as the bitumen percentage increases



GRAPH 9: FOR BITUMEN AT 21 DAYS(S-S)

4. BITTUMEN STRENGHT AT 28 DAYS

❖ **B-2-28**

Table 21: BITUMEN STRENGHT AT 28 DAYS (2%)

Load dial guage	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
10	25	0.0546	0.25

20	50	0.1092	0.5
30	75	0.1638	0.75
55	100	0.3003	1
90	125	0.4914	1.25
140	150	0.7644	1.5
180	175	0.9828	1.75
270	200	1.4742	2

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	47.73760188
0.00656168	0.656167979	0.00114753	95.16093383
0.00984252	0.984251969	0.001151332	142.2699959
0.01312336	1.312335958	0.00115516	259.9640834
0.016404199	1.640419948	0.001159013	423.9815582
0.019685039	1.968503937	0.001162892	657.3269789
0.022965879	2.296587927	0.001166797	842.3062578
0.026246719	2.624671916	0.001170728	1259.216743

❖ **B-4-28**

Table 22: BITUMEN STRENGTH AT 28 DAYS (4%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ (mm)
0	0	0	0
40	25	0.2184	0.25
90	50	0.4914	0.5
210	75	1.1466	0.75

strain $\epsilon=\Delta/L_0$	% Strain	Corrected Area $A= A_0/ 1-\epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	190.9504075
0.00656168	0.656167979	0.00114753	428.2242022
0.00984252	0.984251969	0.001151332	995.889971

❖ **B-6-28**

Table 23: BITUMEN STRENGTH AT 28 DAYS (6%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
25	25	0.1365	0.25
60	50	0.3276	0.5
140	75	0.7644	0.75
210	100	1.1466	1
270	125	1.4742	1.25
320	150	1.7472	1.5
335	175	1.8291	1.75
		Corrected Area $A=$	
strain $\epsilon=\Delta/L_0$	% Strain	$A_0/ 1-\epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	119.3440047
0.00656168	0.656167979	0.00114753	285.4828015
0.00984252	0.984251969	0.001151332	663.9266473
0.01312336	1.312335958	0.00115516	992.5901368
0.016404199	1.640419948	0.001159013	1271.944675

0.019685039	1.968503937	0.001162892	1502.461666
0.022965879	2.296587927	0.001166797	1567.625535

❖ **B-8-28**

Table 24: BITUMEN STRENGTH AT 28 DAYS (8%)

Load dial guage reading	Deflection dial guage	Load LDR*PRC	Deflection Δ(mm)
0	0	0	0
10	25	0.0546	0.25
30	50	0.1638	0.5
60	75	0.3276	0.75
110	100	0.6006	1
160	125	0.8736	1.25
180	150	0.9828	1.5
190	175	1.0374	1.75

strain $\epsilon = \Delta / L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	47.73760188
0.00656168	0.656167979	0.00114753	142.7414007
0.00984252	0.984251969	0.001151332	284.5399917
0.01312336	1.312335958	0.00115516	519.9281669
0.016404199	1.640419948	0.001159013	753.7449924
0.019685039	1.968503937	0.001162892	845.1346871
0.022965879	2.296587927	0.001166797	889.1010499

❖ **B-10-7**

Table 25: BITUMEN STRENGTH AT 28 DAYS (10%)

Load dial guage	Deflection dial	Load	Deflection
-----------------	-----------------	------	------------

reading	guage	LDR*PRC	Δ (mm)
0	0	0	0
30	25	0.1638	0.25
90	50	0.4914	0.5
140	75	0.7644	0.75
215	100	1.1739	1
260	125	1.4196	1.25
290	150	1.5834	1.5
340	175	1.8564	1.75
350	200	1.911	2

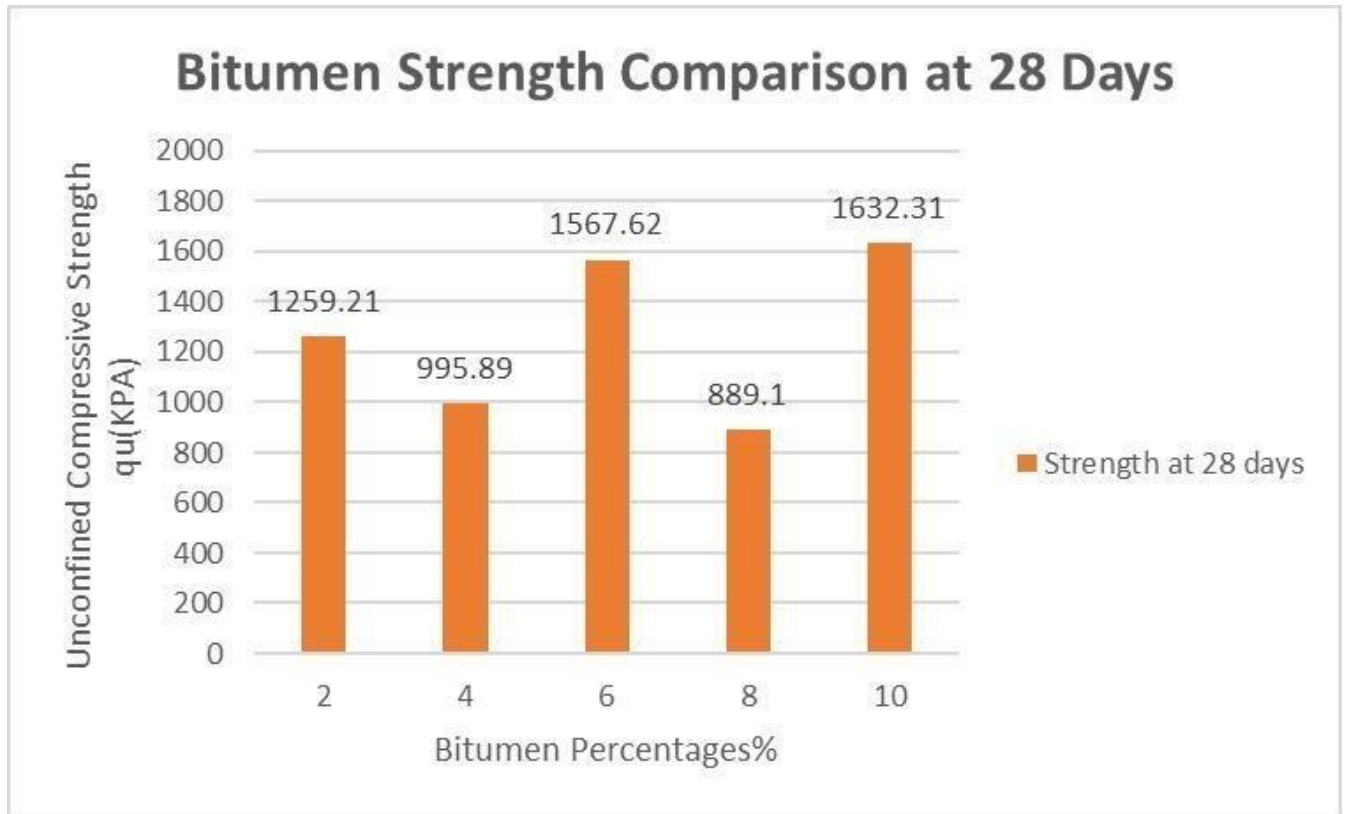
strain $\epsilon = \Delta/L_0$	% Strain	Corrected Area $A = A_0 / 1 - \epsilon$	Stress kPa
0	0	0	0
0.00328084	0.32808399	0.001143752	143.2128056
0.00656168	0.656167979	0.00114753	428.2242022
0.00984252	0.984251969	0.001151332	663.9266473
0.01312336	1.312335958	0.00115516	1016.223235
0.016404199	1.640419948	0.001159013	1224.835613
0.019685039	1.968503937	0.001162892	1361.605885
0.022965879	2.296587927	0.001166797	1591.022931
0.026246719	2.624671916	0.001170728	1632.318

Table 26: COMPARISON BETWEEN RHA AND BITUMEN

Bitmen	aditive		Bitumen 21
1259.21	2	555.9	1038.84
995.89	4	1087.1	1905.7
1567.62	6	606.3	1871.7
889.1	8	630	1250.7

1632.31	10	455.5	1138.7
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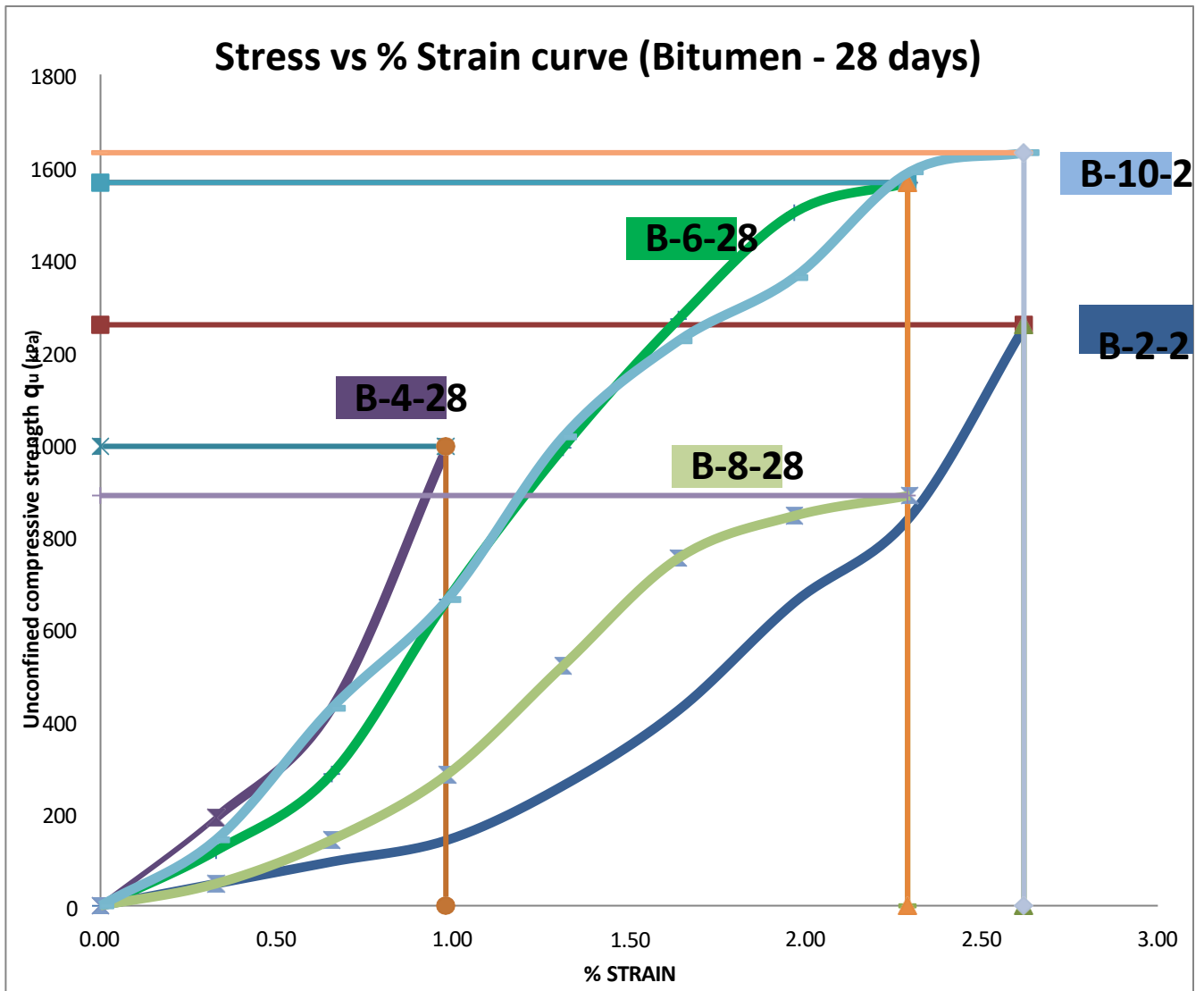
Max Stress (kpa)	Bitumen
1259.21	2
995.89	4
1567.62	6
889.1	8
1632.31	10



GRAPH 10: FOR BITUMEN AT 28 DAYS

The x-axis displays the bitumen percentages, spanning from 2% to 10%, while the y-axis represents the unconfined compressive strength.

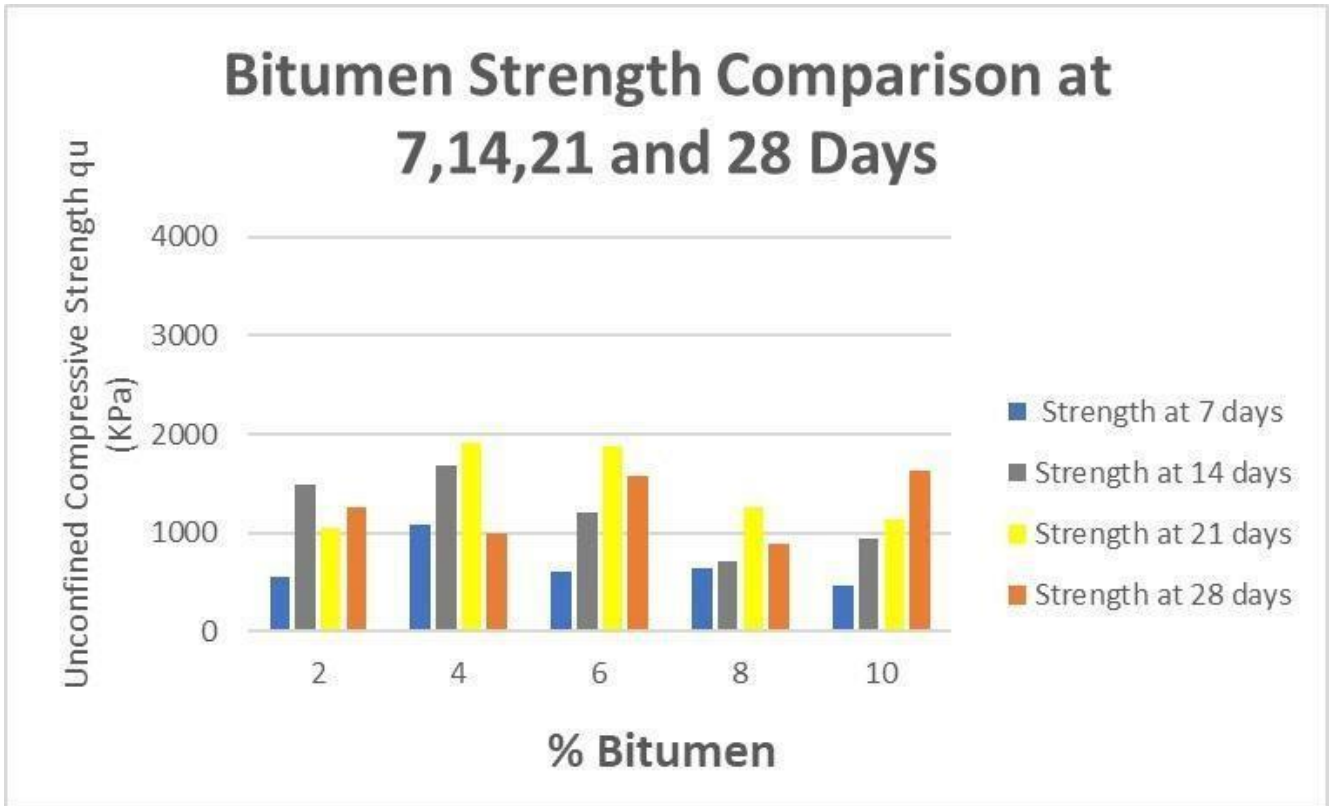
- The graph displays five distinct data points, each corresponding to a specific bitumen percentage: 2%, 4%, 6%, 8%, and 10%.
- The unconfined compressive strength values are as follows:
 - 2%: 1259.21 kPa
 - 4%: 995.89 kPa
 - 6%: 1567.62 kPa
 - 8%: 889.1 kPa
 - 10%: 1632.31 kPa



**GRAPH 11: FOR BITUMEN AT 28 DAYS(S-S)
5. COMPRESION AT 7,14,21,28 DAYS**

Table 27: COMPRESION AT 7,14,21,28 DAYS

Bitumen	Unconfined Compressive strength q_u (kPa)			
	Strength at 7 day	Strength at 14 days	Strength at 21 days	Strength at 28 days
2	555.9	1478.98	1038.84	1259.21
4	1087.1	1683.5	1905.7	995.89
6	606.3	1197.27	1871.7	1567.62
8	630	708.89	1250.7	889.1
10	455.5	942.2	1138.7	1632.31



GRAPH 12: FOR BITUMEN AT 7,14,21,28 DAYS

The graph illustrates the comparison of the unconfined compressive strength (ucs) of bitumen at different percentages (2%, 4%, 6%, 8%, and 10%) over various curing periods (7, 14, 21, and 28 days). The pressure is expressed in kilopascals (kpa).

Main points:

The data is represented using a bar chart, with different colors indicating the strength at different curing periods:

Trends and insights:

- At 2% bitumen content, the ucs increases with curing time, reaching approximately 1200 kpa at 28 days
- For 4% bitumen content, the ucs peaks at around 1900 kpa after 21 days of curing and

then slightly decreases to about 1400 kpa at 28 days

- At 6% bitumen content, the ucs reaches its highest value of approximately 1700 kpa at 21 days, followed by a decline to around 1000 kpa at 28 days
- For 8% bitumen content, the ucs continues to rise with curing time, achieving a value of about 1300 kpa at 28 days
- At 10% bitumen content, the ucs also increases with curing time, reaching around 1400 kpa at 28 days

Result:

The graph illustrates the correlation between the quantity of bitumen and the curing time, and how it influences the unconfined compressive strength of bitumen. The results indicate that the optimal bitumen content and curing period vary, with 4% and 6% bitumen content yielding their highest ucs values after 21 days.

However, the UCS values at 28 days are usually lower than those at 21 days for these percentages. In contrast, the ucs continues to increase with curing time for 8% and 10% bitumen content. These findings suggest that the choice of bitumen content and curing period is influenced by the intended use and desired strength properties.

1. AT 28 DAY STRENGTH COMPARISON BETWEEN BITUMEN AND RAW METRIAL

Raw material qu (kPa)	Additive	Strength qu (kPa) at 28 days
539.9471612	Bitumen	1632.31



GRAPH 13: FOR COMPARISON OF RAW AND BITUMEN AT 28 DAYS

The graph illustrates the raw material strength at 28 days, comparing the total strength gained between two materials: "raw material" and "raw material bitumen." the y-axis represents the total strength gained at 28 days in kilopascals (kpa), ranging from 0 to 1800. The chart illustrates the distinctions between the two materials.

Main revelations:

- Raw material: the blue bar indicates a total strength gained of approximately 550 kpa
- Raw material bitumen: the orange bar shows a significantly higher total strength gained of around 1650 kpa

Comparison and insights:

- The addition of bitumen to the raw material results in a substantial increase in strength, with a difference of approximately 1100 kpa between the two materials
- This implies that the addition of bitumen gradually improves the material's strength

Result::

The graph effectively demonstrates the impact of adding bitumen to raw material on its strength after 28 days. The significant increase in strength observed in the "raw material bitumen" sample highlights the potential benefits of utilizing this composite material in various applications.

B. FOR RHA

Table 28: FOR RHA UNCONFINED COMPRESSION TEST (UCS) TABLE

UNCONFINED COMPRESSION TEST (UCS) TABLE				
RHA %	2%	4%	6%	8%
Displacement	Load (Ring Factor 1.75 N)			
0*0.01mm	0	0	0	0
10	3	6	10	22
20	7	8	16	26
30	12	14	19	29
40	14	16	21	33
50	17	19	24	36
60	21	21	26	39
70	24	24	30	41
80	27	30	36	46
90	31	36	40	49
100	36	38	43	56
110	38	42	48	61
120	41	46	58	68
130	43	49	64	76
140	45	50	67	78
150	47	56	70	83
160	49	58	71	
170	53	63		

180	57			
190				
200				
210				
220				
230				
240				
250				
260				
270				
280				
290				
300				

UNCONFINED COMPRESSION TEST (UCS) TABLE							
10%	Column1	Column2	Strain e=dL/Lo	Stress 2%(N/m2)	for	Stress for 2%(KN/ m2)	Stress for 4% (N/m2)
		Deformati on(mm)				0	0
0			0	0		0	0
30		0.1	0.001429	3118.2		3.118	6236.34
36		0.2	0.002857	7275.7		7.276	8315.12
38		0.3	0.004286	12472.7		12.473	14551.5
43		0.4	0.005714	14551.5		14.551	16630.2
48		0.5	0.007143	17669.6		17.670	19748.4
54		0.6	0.008571	21827.2		21.827	21827.2
58		0.7	0.010000	24945.4		24.945	24945.4

63		0.8	0.011429	28063.5	28.064	31181.7
69		0.9	0.012857	32221.1	32.221	37418
77		1	0.014286	37418.0	37.418	39496.8
88		1.1	0.015714	39496.8	39.497	43654.4
93		1.2	0.017143	42615.0	42.615	47811.9
97		1.3	0.018571	44693.8	44.694	50930.1
		1.4	0.020000	46772.6	46.773	51969.5
		1.5	0.021429	48851.3	48.851	58205.8
		1.6	0.022857	50930.1	50.930	60284.6
		1.7	0.024286	55087.7	55.088	65481.6
		1.8	0.025714	59245.2	59.245	0
		1.9	0.027143	0	0	0
		2	0.028571	0	0	0
		2.1	0.030000	0	0	0
			0	0	0	0

Column1	Column2	Column3	Column4
Stress for 4%(KN/m2)	Stress for 6% (N/mm2)	Stress for 6%(KN/m2)	Stress for 8% (N/m2)
0	0	0	0
6.236340141	10393.90024	10.39390024	22866.58052
8.315120189	16630.24038	16.63024038	27024.14061
14.55146033	19748.41045	19.74841045	30142.31068

16.63024038	21827.19049	21.82719049	34299.87078
19.74841045	24945.36057	24.94536057	37418.04085
21.82719049	27024.14061	27.02414061	40536.21092
24.94536057	31181.70071	31.18170071	42614.99097
31.18170071	37418.04085	37.41804085	47811.94108
37.41804085	41575.60094	41.57560094	50930.11115
39.4968209	44693.77101	44.69377101	58205.84132
43.65438099	49890.72113	49.89072113	63402.79144
47.81194108	60284.62137	60.28462137	70678.5216
50.93011115	66520.96151	66.52096151	78993.64179
51.96950118	69639.13158	69.63913158	81072.42184
58.20584132	72757.30165	72.75730165	86269.37196
60.28462137	73796.69167	73.79669167	0
65.48157148	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0		0

Column5	Column6	Column7
Stress for 8% (KN/mm2)	Stress for 10% (N/m2)	Stress for 10% (KN/m2)
0	0	0
22.86658052	31181.70071	31.18170071
27.02414061	37418.04085	37.41804085
30.14231068	39496.8209	39.4968209
34.29987078	44693.77101	44.69377101
37.41804085	49890.72113	49.89072113
40.53621092	56127.06127	56.12706127

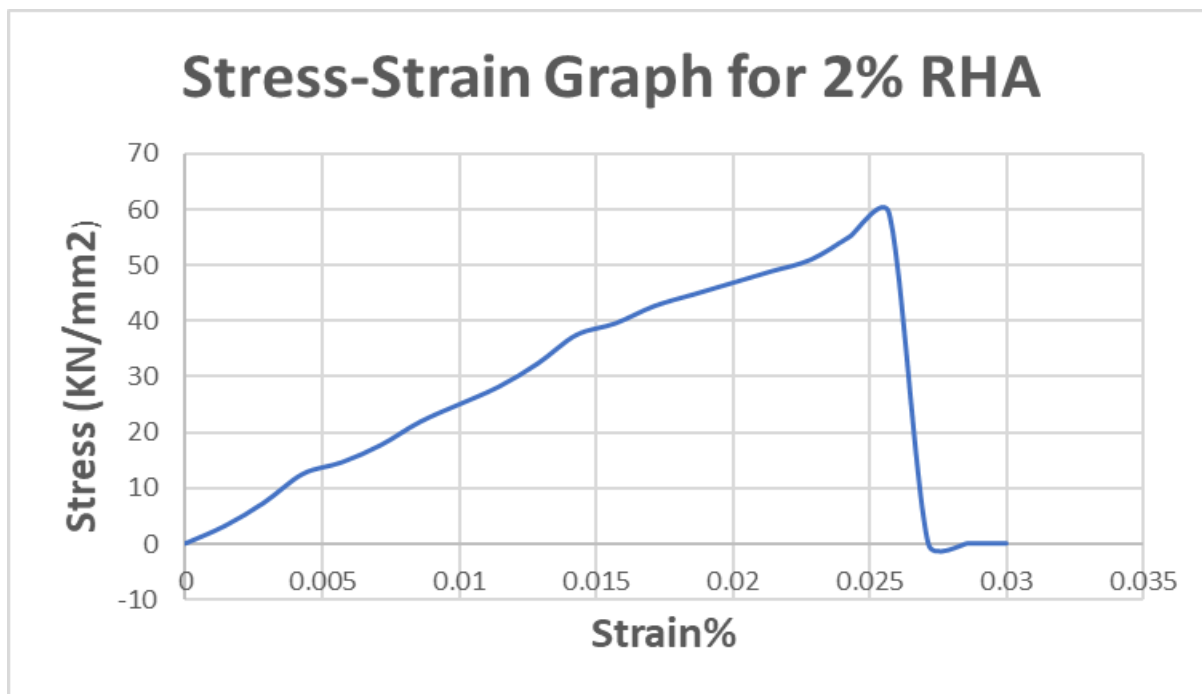
42.61499097	60284.62137	60.28462137
47.81194108	65481.57148	65.48157148
50.93011115	71717.91163	71.71791163
58.20584132	80033.03181	80.03303181
63.40279144	91466.32207	91.46632207
70.6785216	96663.27219	96.66327219
78.99364179	100820.8323	100.8208323
81.07242184	0	0
86.26937196	0	0
0	0	0
0	0	0
0		
0		
0		

0

Column1	Column2	Column3
Sample Details		
Length	70	
Dia	35	
Cross-sectional Area	0.000962103	

UCS Strength Results			In
		KN/m2	Psf
Qu for 2% RHA=	59.24523134	KN/m2	1237.04
Qu for 4% RHA=	65.48157148	KN/m2	1367.255
Qu for 6% RHA=	73.79669167	KN/m2	1540.875
Qu for 8% RHA=	86.26937196	KN/m2	1801.304
Qu for 10% RHA=	100.8208323	KN/m2	2105.139

➤ **STRESS-STRAIN GRAPH FOR 2 % RHA**



GRAPH 14: FOR RHA AT 2 % (S-S)

The graph represents a stress-strain diagram for a material that contains 2% rice husk ash (RHA). The diagram visually represents the connection between the force exerted on the material and the resulting deformation.

Main Aspects of the Chart:

1: The graph begins with a linear region where the stress and strain are directly related to each other. This demonstrates the material's ability to regain its original form after being subjected to stress, indicating its elasticity.

2: The graph does not display a distinct yield point, but it can be deduced that the material starts to undergo plastic deformation when subjected to a strain of 0.005-0.01.

3: Strain hardening: after the initial linear region, the material shows strain hardening, where the stress increases as the strain increases. This is clear from the upward slope of the graph.

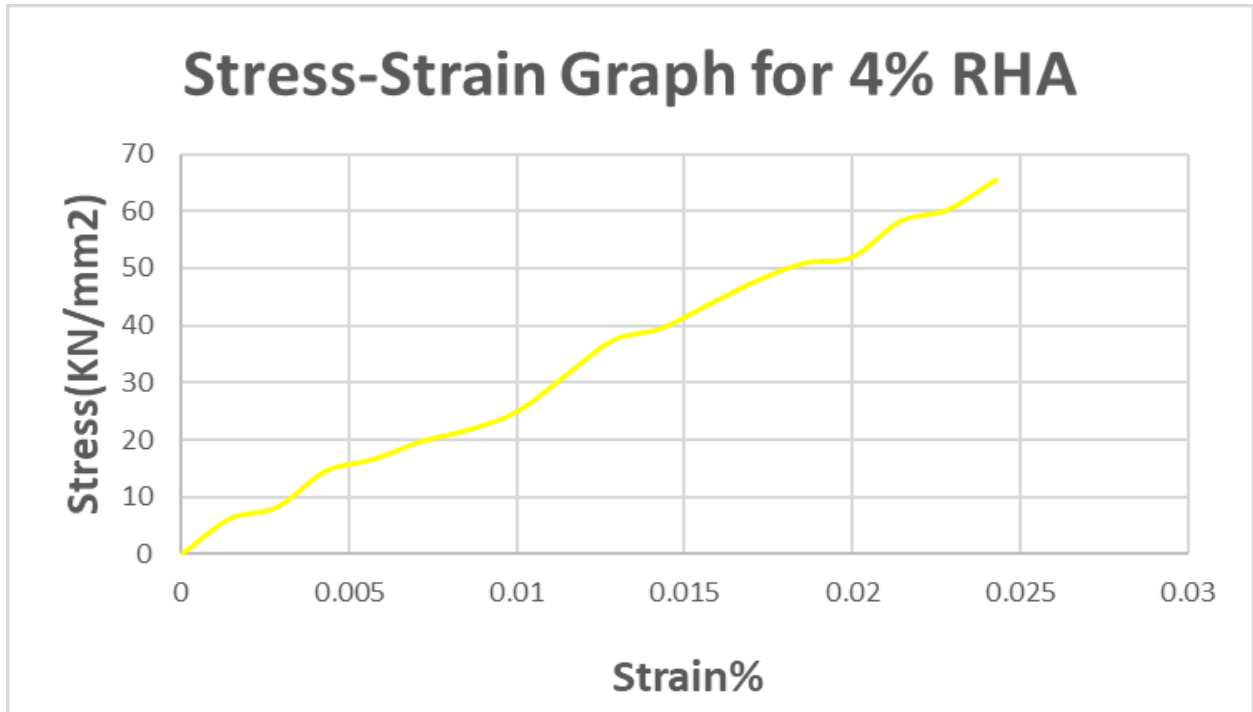
4: The material attains its ultimate strength when subjected to a strain of approximately 0.025, resulting in a stress of around 60 KN/m².

5: Failure: the material suddenly breaks at a strain of around 0.028, experiencing a significant decrease in stress.

Analysis:

The graph indicates that the material with 2% RHA content demonstrates a relatively high ultimate strength and a moderate level of ductility. The unexpected failure at a strain of 0.028 suggests that the material is susceptible to brittle failure.

➤ **STRESS-STRAIN GRAPH FOR 4 % RHA**



GRAPH 15: FOR RHA AT 4 %(S-S)

- **x-axis (strain%):** the x-axis represents the strain, which is a measure of the deformation or elongation of the **material**. The strain is **represented** as a **percentage**.
- **y-axis (stress (KN/m²)):** the y-axis represents the stress, which is a measure of the force applied to the material per unit **area**. The stress is measured in kilonewtons per square meter (**KN/m²**).

Analysis of the chart: -

the graph shows a non-linear relationship between stress and strain, indicating that the material does not follow **hooke's law** (which states that stress is directly proportional to strain) throughout the entire range

of loading

- **The** curve starts with a relatively steep slope, indicating a high initial stiffness.
- **As** the strain increases, the slope of the curve gradually decreases, indicating a **decrease** in **stiffness**.

The graph does not show a clear yield point or ultimate tensile strength, but it appears to be still increasing at the highest strain value **shown**

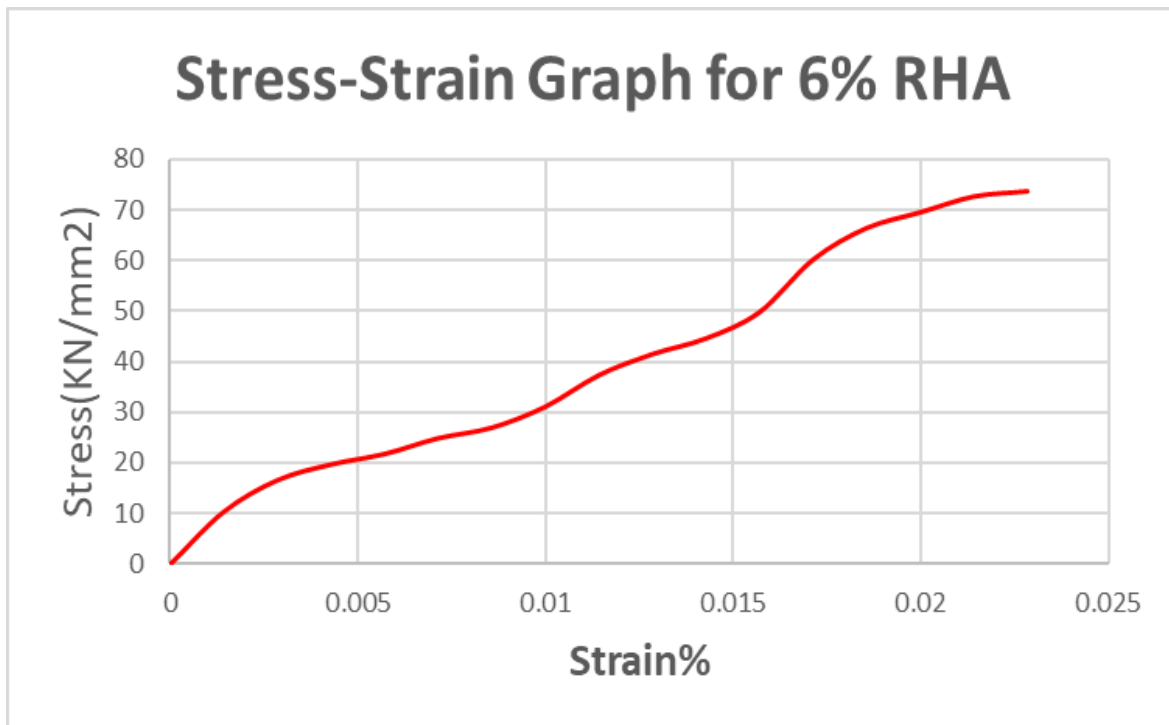
Importance of **RHA**:

RHA stands for rice husk ash, which is a supplementary cementitious material used in concrete

The presence of 4% RHA in the material suggests that it is a modified or blended material, potentially with improved properties compared to the base material

In **summary**: The graph **offers** valuable **insights into** the **material's** mechanical **properties, such as** its stiffness, strength, and **how it deforms under different loads**. The data can be **utilized** to **guide** design **choices, forecast** material **behavior**, and **enhance** material **characteristics** for **particular uses**

➤ **STRESS-STRAIN GRAPH FOR 6 % RHA**



GRAPH 16: FOR RHA AT 6 % (S-S)

The graph is a stress-strain diagram, which **visually depicts the connection** between stress and strain in a material **when subjected to external forces**. The **chart is labeled "stress- strain graph for 6% RHA."**

Graph's Essential Elements

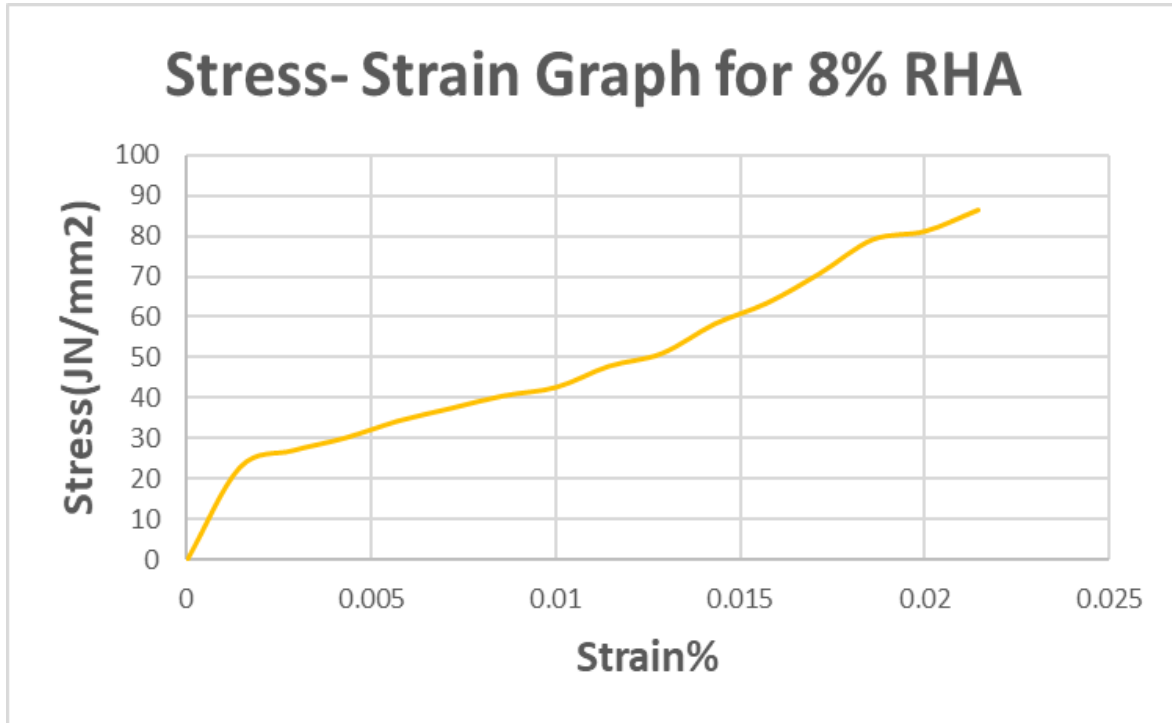
- **x-axis (strain%):** the x-axis represents the strain, which is a measure of the deformation or elongation of the **material** The strain is **represented as a percentage**.

- **y-axis (stress (KN/m²)):** the y-axis represents the stress, which is a measure of the force applied to the material per unit **area**. The stress is measured in kilonewtons per square meter (KN/m²).

Analysis of the chart:

- **The** graph shows a non-linear relationship between stress and strain, indicating that the material does not follow **hooke's law** (which states that stress is proportional to strain) throughout the entire range of **loading**.
- **The** curve starts with a relatively steep slope, indicating a high initial **stiffness**.
- **As** the strain increases, the slope of the curve decreases, indicating a reduction in **stiffness**.
- **The** curve does not exhibit a clear yield point or ultimate tensile strength, but it appears to be approaching a plateau at higher strains.

➤ **STRESS-STRAIN GRAPH FOR 8 % RHA**

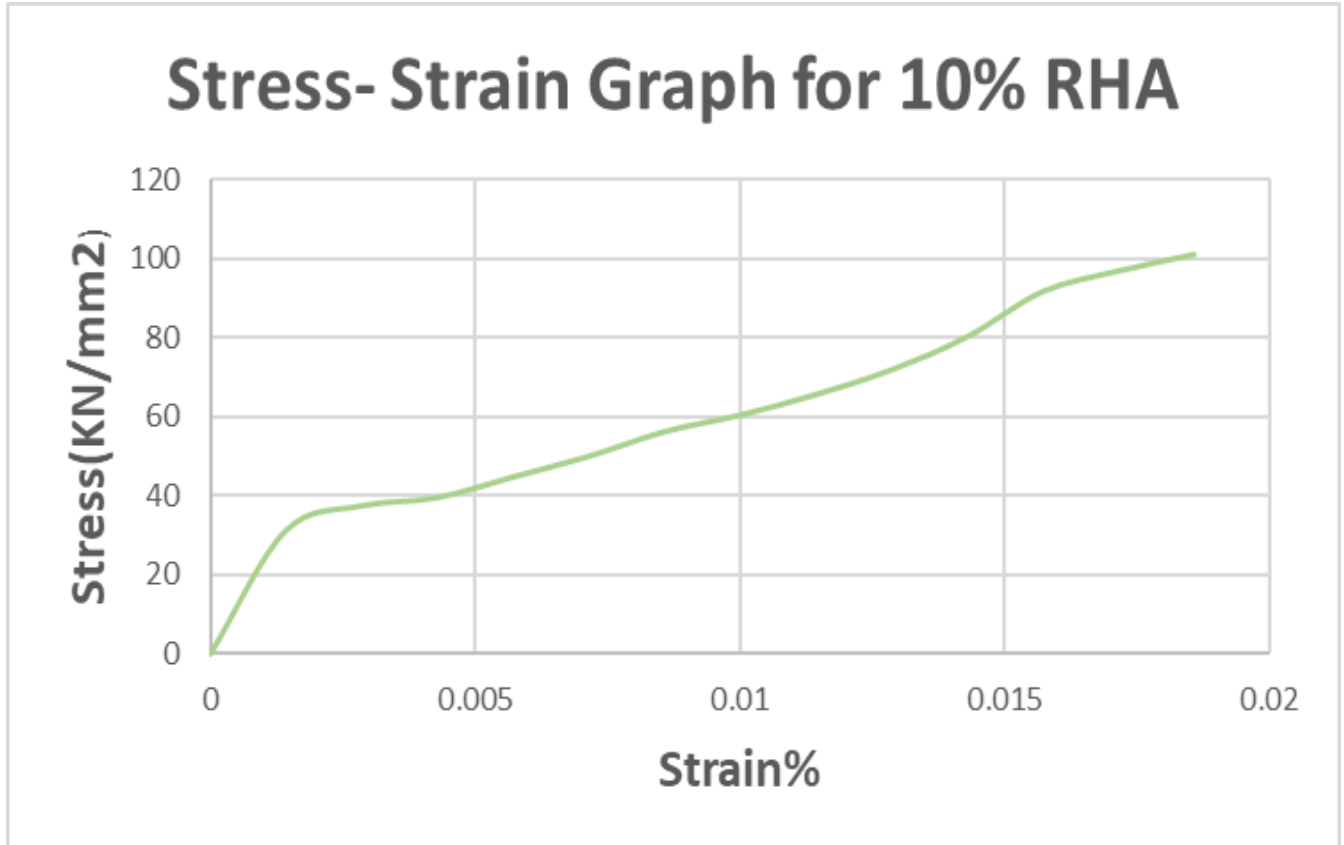


GRAPH 17: FOR RHA AT 8 %(S-S)

The x-axis represents the strain percentage, while the y-axis represents the stress in units of **KN** per square meter (**KN/m²**).

The graph **displays** a non-linear relationship between stress and **strain**.

➤ **STRESS-STRAIN GRAPH FOR 10 % RHA**



GRAPH 19: FOR RHA AT 10 %(S-S)

- x-axis (strain%): the x-axis represents the strain, which is a measure of the deformation or elongation of the material The strain is represented as a percentage.
- y-axis (stress in KN/m²): the y-axis represents the stress, which is a measure of the force applied to the material per unit area The stress is measured in kilonewtons per square meter (KN/m²).

UCS Results Comparison Between RHA And Bitumen

- Rice Husk Ash Maximum Strength gained at 10%
- Bitumen Maximum Strength Gained After Curing At 21 Days

Additive	Max Strength % and Day	Max Strength Gained
Bitumen	4% (21 Days)	1905.7 kPa
Rice Husk Ash	10%	2105.139 kN/m ²

- **UCS Results Comparison Between RHA And Bitumen for Subgrade Soil Improvement**

Criteria	RHA	Bitumen
Soil Type	Best for clays	Best for sandy/gravelly soils
Strength Gain	Higher (long-term)	Moderate (short-term)
Environmental Impact	Sustainable	Petroleum-based (less eco-friendly)
Water Resistance	Moderate	High
Curing Time	Not Required	required
Cost	Low (if locally available)	Higher

Conclusion and recommendation

Conclusion

- The think about centered on assessing the viability of bitumen and rice husk fiery remains (RHA) as soil stabilizing specialists to progress the mechanical properties of frail subgrade soils. Research facility tests were conducted to decide the ideal rate of each added substance that yields most extreme strength.

The key discoveries of this inquire about are as follows:

- The greatest quality for soil treated with bitumen was 1905.7 kPa, accomplished at 4% bitumen substance after 21 days of curing.
- The most extreme quality for soil treated with RHA was 2105.139 kN/m² at 10% RHA substance, showing a marginally predominant execution compared to bitumen in terms of compressive strength.
- Both added substances altogether progressed the quality characteristics of the soil, with RHA appearing marginally higher potential when utilized alone.
- These comes about affirm that both Bitumen and RHA are successful stabilizers, improving the load-bearing capacity and quality of soils. RHA, a byproduct of rural squander, offers an eco-friendly and maintainable elective for soil stabilization, whereas bitumen contributes emphatically by moving forward water resistance and official properties.

Recommendations

Based on the comes about and perceptions from this inquire about, the taking after proposals are made:

- I. Combined Utilize: Encourage investigate ought to examine the combined impact of bitumen and RHA to survey whether a synergistic impact can abdicate indeed more prominent enhancements in soil quality and durability.
- II. Field Usage: Pilot field considers ought to be conducted utilizing the ideal rates (4% bitumen,10%RHA) to assess real-world execution beneath activity loads and natural conditions.
- III. Environmental Contemplations: A consider on the natural affect of utilizing bitumen in soil stabilization ought to be conducted, particularly with respect to leachate and long- term sustainability.

IV. Durability Testing: Extra tests centering on water retention, shrinkage, and freeze-thaw resistance will offer assistance decide the long-term soundness and execution of stabilized soils.

Application to Diverse Soils:

The adequacy of these added substances ought to be tried on a run of soil sorts (e.g., sweeping clay, silty soils) to decide the broader pertinence of the stabilization method.

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