REVOLUTIONISING CRICKET INFRASTRUCTURE: PIONEERING THE STANDARD FOR CRICKET PITCH DESIGN

Submitted by

Group Leader - Abdullah Noor - 331234

Shuja Ur Rehman Cheema - 339664

Usman Ul Hassan - 331763

Muhammad Ali - 334602

In partial Fulfillment of the requirements for the Degree of

BACHELOR'S OF CIVIL ENGINEERING

This is to certify that the

Final Year Design Project Titled

REVOLUTIONISING CRICKET INFRASTRUCTURE: PIONEERING THE STANDARD FOR CRICKET PITCH DESIGN

submitted by

Abdullah Noor	**331234**
Shuja Ur Rehman Cheema	**339664**
Usman Ul Hassan	**331763**
Muhammad Ali	**334602**

has been accepted towards the requirements for the undergraduate degree

in

CIVIL ENGINEERING

Dr. Badee Alshameri ______________________________

(Associate Professor)

HoD of Geotechnical Engineering

NUST Institute of Civil Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology (NUST)

Islamabad, Pakistan

DEDICATION

To our loving parents, who have continuously provided their moral, spiritual, emotional, and material support, have served as a constant source of inspiration and strength during trying times when we were about to give up, and to whom this study is sincerely dedicated. To all of our family members and friends who have offered words of wisdom and motivation to complete this research. For their oversight and direction, which were both provided by our supervisor and co-supervisor and without which this study would not have been possible. Finally, we honor the Almighty God for his fortitude, mental fortitude, protection, abilities, and for providing us with a healthy existence. We are yours to keep, and we will come back to you.

DECLARATION

All work referred to in this thesis was written by us, it is hereby respectfully and truthfully declared, and it has never, in whole or in part, been submitted by any institution in an application for a degree. Every mention of research conducted by another individual or university has been properly cited.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Beneficent, the Most Merciful as well as peace and blessings be upon Prophet Muhammad (P.B.U.H). Without the encouragement, inspiration, and leadership of our supervisor Dr. Badee Alshameri this research endeavor would not have been possible. Additionally, we would like to express our gratitude to the Geotechnical lab staff for their cooperation and consideration while we were undergoing testing there. A special thanks also goes to lab engineer Mr. Maqsood from the Geotechnical Engineering department, who helped us with the testing issues. Additionally, we consider ourselves extremely fortunate to be surrounded by others, including our professors, friends, and family. Last but not least, we are appreciative of the National University of Sciences and Technology (NUST) for giving us the space to realize our dreams and for enabling us to contribute to the advancement of society.

ABSTRACT

The quality of cricket pitches significantly impacts the game, with bounce being a crucial attribute influencing play. This study targets the enhancement of Nandipur soil, traditionally used for pitch construction in Pakistan, to achieve bounce characteristics comparable to high-performance Australian pitches. The technical approach began with detailed video analysis of Perth ground pitches and subsequent simulations using Simulink software to determine a key value (k value) relevant to soil performance. Guided by the k value, laboratory experiments were conducted to improve the soil using specific admixtures. Molasses and bentonite were selected for their potential to enhance soil properties. Through systematic experimentation, an optimal mix was developed, consisting of 74.42% Nandipur soil, 18.60% bentonite, and 6.98% molasses. The addition of these admixtures resulted in a significant increase in the liquid limit from 49.2 to 60.1 and the plastic limit from 22.6 to 28.1, with a corresponding rise in the plasticity index from 26.6 to 32. Additionally, the unconfined compressive strength more than doubled, increasing from 238.4 kPa to 497.6 kPa. Laboratory tests, which included preparing a soil model with dimensions of 1 by 1 foot and 8 inches in depth, simulating real pitch conditions, demonstrated a marked improvement in the bounce and stiffness of the treated Nandipur soil, with stiffness values increasing from 3.93 million ($N/m^2/m$) to 5.3 million ($N/m^2/m$). This study's findings suggest that targeted admixture applications can effectively modify local soil properties, aligning them with international cricket pitch standards and enhancing the overall playing experience. This thesis provides a detailed account of the methodology, experimental outcomes, and the technical basis for soil improvement techniques aimed at optimizing cricket pitch performance.

TABLE OF CONTENTS

TABLE OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1. Background

Cricket pitch quality is a pivotal element in the sport, significantly influencing the game's dynamics and outcomes. One of the most critical attributes of a cricket pitch is its bounce, which affects both bowlers and batsmen. High-quality pitches, such as those in Australia, provide consistent and high bounce, contributing to a competitive and engaging game (Seed, 1964). In contrast, the Nandipur soil used in Pakistan for pitch construction has been observed to deliver suboptimal bounce, negatively impacting the quality of cricket played on these surfaces. Addressing this issue is essential for advancing cricket in Pakistan. Australian cricket pitches, particularly those in Perth, are renowned for their excellent bounce and overall performance. These pitches are the result of precise construction and maintenance practices, involving specific soil compositions and meticulous preparation techniques (Frank, 2016). The soil in these pitches exhibits unique physical properties that contribute to their superior performance. Understanding and replicating these properties in local soils, such as Nandipur soil, is a complex yet necessary endeavor to elevate the standard of cricket pitches in Pakistan. This project started with identification of factors that define better pitches, with reference to Australia and the Perth ground. Using high-definition video sensors in combination with Simulink's simulation environment we were able to determine the subgrade modulus, or 'k-value' of one of the Australian Pitches. This formed a very useful reference in the management of the modification of the soil type. The subsequent phase was a series of laboratory experimentations with specific regard to the modification of properties of Nandipur soil using various admixtures. Molasses and bentonite were selected in view of enhancing the physical and chemical characteristics of the soil. It is a byproduct from sugar production that is used in boosting the stability and cohesiveness of the soil while bentonite, which is a type of clay enhances the plasticity and the water holding capacity of the soil. To establish the right dosage of these admixtures, systematic testing was done to arrive at this end. This experiment exposed that there was an increase of the elasticity of the treated Nandipur soil as reflected on the bounce test as compared to the initial state. From this project it can be concluded that it is possible to modify the local soil characteristics suitable to international cricket pitch by the application of admixtures through a technique of admixture selection, dosage, and placement. Due to this enhancement, it is possible that the construction and the maintenance practice of the cricket pitches in the country will improve and lead to better pitches and thereby improving the standards of the playing surfaces of a cricket pitch. This thesis outlines the approach that has been taken, the methods which have been employed, and the results which have been obtained effectively giving the scientific basis for subsequent work on the improvement of the soil properties to get the maximum performance of cricket pitch. The aim is to contribute towards the growth of cricket in Pakistan; well-prepared playing surfaces which favour quality cricket, in the interests of players, fans and the game.

1.2. Problem Statement.

The suboptimal bounce characteristics of Nandipur soil, traditionally used for cricket pitch construction in Pakistan, present a significant challenge to the quality of the game (Hashir U., 2016). Unlike the high-performance pitches in Australia, known for their consistent and superior bounce, the Nandipur soil fails to provide the necessary playing conditions that support competitive and engaging cricket matches. This inadequacy impacts both local and international cricket events hosted in Pakistan, hindering the development and standard of the sport in the country (Punjab.gov.pk., 2020). To rectify this problem there is dire need to improve Nandipur soil to the required level of bounce characteristics globally. It is hoped that through this latest project, it is possible to investigate and opt for the right approach to alter the quantity of specific admixtures in Nandipur soil with a view to moderating its bounce. In this regard, the project aims to improve the quality of cricket pitches in Pakistan to improve the condition of play for the advantage of the overall enlargement of the crusade of cricket in the country. These include the extent of lab investigations to properly quantify the admixture dosages by experiments, and the extensive analysis and modeling to check the enhanced characteristics of the treated soil.

1.3. Aims and Objectives

The aim was to enhance the bounce and pace characteristics of Nandipur soil for cricket pitch construction in Pakistan to meet the high-performance standards of Australian pitches, thereby supporting the development of cricket in Pakistan. The aim of this research can be achieved using the following objectives:

- Conduct a detailed analysis of high-performance Australian cricket pitches, particularly focusing on those in Perth.
- Utilize Simulink software to provide a simulation environment and determine the key factor determining bounce in y-direction. (mathworks, 2021).
- Identify and test appropriate soil admixtures, such as molasses and bentonite, for their soil strengthening properties and optimize their quantities (Malanda, 2022)
- Prepare soil models (re-molded soil) with dimensions of 1 by 1 foot and 8 inches in depth to simulate real pitch conditions.
- Analyze results to confirm the effectiveness of the admixtures in enhancing soil properties and ensure the treated soil meets high-performance bounce standards.

1.5. Scope

The scope of this project includes a comprehensive review and analysis of existing literature on cricket pitch construction, soil science, and soil stabilization techniques.

- This entails considering the characteristics of Australians pitches and how they influence the performance of ground particularly when concerning with superior bounce.
- The existence of k value will enable the specification of high-performance pitches and the required laboratory experiments for the improvement of the soils.
- Sourcing of material from a single site only. The effects of different minerals from different sites were not tested.
- Molasses and bentonite have been selected as possible soil additives because of their beneficial effects and quantitative experiment was conducted to establish the rates of the mentioned admixtures for improving bounce properties of the soil.
- Develop a physical model followed by a series of tests to evaluate the impact of the selected admixtures on the soil's physical and dynamic properties.
- Data analysis confirming the effectiveness of the admixtures in achieving the desired soil improvement. Formulate practical guidelines for applying soil improvement techniques in actual pitch construction projects.
- This is where the need to establish recommendations for the maintenance practices that should be adopted in order to sustain the newly acquired pitch quality arises.
- Evaluate how increased pitch standard can possibly have an impact in some local and some international cricket events in Pakistan.
- Explore the broader implications for the development of cricket infrastructure in the region.

CHAPTER 2: LITERATURE REVIEW

2.1. Cricket Pitch

10 feet wide and 22 yards long central strip of the cricket ground is called pitch. (ICC, 2023) Cricket ball's performance and behaviour depend upon the characteristics of the pitch therefore it plays a crucial role in determining a match's outcome. However, to ensure that good bounce, pace, and durability are achieved, the pitch has to be well-prepared. This is because a well-prepared pitch can change the course of the game, the kind of pitch prepared could favor the bowlers or the batters. Items, that go into the preparation of the pitch are soil, clay, and sand. All these items contribute to the special character of the pitch.

2.2. Nandipur Soil

Nandipur soil, found in the region of Nandipur Punjab, is often used to prepare cricket pitches since it is rather suitable. This soil is specifically famous for containing a good quantity of clay, which, on the one hand, provides the ground with firmness while, on the other hand, granting it flexibility. Main characteristics of Nandipur soil are: 1. Moderate plasticity: the soil can be described as relatively plastic – it means that it retains its original shape even under pressure. (2) Good Moisture Retention: If the pitch soil has good moisture retention, then the pitch retains its original condition, and the life of the pitch increases. In other words, it is less prone to wear and tear. (3) A level and hard pitch is produced due to the cohesion between the particles of the clayey soil. The natural soil of Nandipur does not match the superior standards of Australian pitches which are associated with pace and bounce.

2.3. The Gap between Australian and Pakistani Pitches

Owing to the type of soil used in preparing Australian cricket grounds, these grounds have always been regarded as having high bounce and speed. Soils of Perth and Brisbane, have a high proportion of clay, low silt, and low level of organic matter. The above features assist in developing a firm, compact, and very compact playing surface that provides enough pace and bounce.

The soil at Nandipur is comparatively good but it is not like the Australian soil. Nandipur soil may have good moisture retention and plasticity, but it does not match the level of Australian soils. To overlay the deficiency and make Nandipur soil match the Australian pitch standards several additives are added to this soil.

2.4. Bentonite

Bentonite, a claylike mineral capable of great swelling by the absorption of water, consists of montmorillonite. Pitch performance is improved when bentonite is added to Nandipur soil because it increases soil capacity to retain moisture and its plasticity. (1) Role in moisture retention: Moisture retention has great significance. If the soil does hold on to the moisture, the soil loses its plasticity. It becomes brittle, and it is more prone to wear and tear. To ensure that moisture is retained, bentonite is added. Bentonite enhances the water-holding capacity of the soil. Bentonite possesses a very high swelling capacity (Ross, 1926), giving it the ability to hold large volumes of water. Hence, it is crucial for the longevity of the pitch.

(2) Role in plasticity: Bentonite has fine particles which get embedded in the soil particles and offer a stronger and more flexible structure of the soil. The enhanced flexibility increases the life of the cricket pitch, it makes the pitch more resilient to the impacts of the ball as well as the running of batsmen within wickets. A dense surface is created because the fine particles of bentonite fill in the gaps between coarser particles. (Doehler, 1961) The denser surface is more compact and stiffer. As a result, a pitch is produced which offers higher bounce and pace.

2.5. Sugar Cane Molasses

Sugar cane molasses is economical and readily available. It is a by-product of the sugarcane industry. It can greatly improve the stiffness, cohesiveness, and durability of the soil and, thus, is useful in improving cricket pitches. When added to the soil, it plays the role of a natural binder, increasing the cohesion and packing characteristics of the soil particles. This leads to a rigid and more compacted structure of the soil (Malanda, 2022) and it increases the load-bearing capabilities of the pitch besides reducing the movement of the soil. This improves the stiffness and stability that are characteristic of good cricket pitches. The cohesiveness of molasses helps in binding the particles in the soil surface hence reducing the voids. (Sharma, 2020) This makes it possible to use the pitch for several matches without having to go for repairs time and again. Also, molasses promotes grass growth due to the minerals present in it. It provides grass necessary for the maintenance of the high quality of the pitch. Grass reduces the surface's friction with the ball so that the ball is not deprived of its usual velocity. In general, applying sugar cane molasses improves the soil structure and the quality of the cricket pitch.

2.6. Other Admixtures

2.6.1 Lime

By the formation of cementitious compounds, that occurred as a result of the contact of lime and clay particles, there was enhanced stiffness and strength of the soils. Compactness was also enhanced in lime-treated soils. High compaction and the levelness of the surface of the soil can be easily achieved. (M M, 2018) Nevertheless, the following limitations were noted; Increased drying and potential for cracking was due to lime, which led to problems such as de-hydration which reduced the stability of the soil. (Bell, 1996) Also, in some cases, the chemical reactions between lime and soil took time to develop hence; the degree of maximum stiffness would still be slow to be attained. Issues related to the environment included the emission of CO_2 during the processing of lime and polluting the water underground and hence the ecosystem.

2.6.2 Terrazyme

Terrazyme, an enzyme-derived soil stabilizer, therefore this natural enzyme was tested in an experiment to determine its ability to increase soil stiffening by binding the particles at the molecular level. (Tiwari, 2021) The workability and strength of the soil were enhanced by using Terrazyme. But in the process of its practical implementation, it had some difficulties. Lack of Terrazyme or inadequate supply was a disadvantage, that saw it not being used regularly as a soil stabilization mechanism. Moreover, it was determined that the effectiveness of Terrazyme was highly variable to the soil type and condition; the enhancement in soil stiffness was not consistent and thus the Terrazyme was not as effective as a solution across all the sites.

2.6.3 Polypropylene fibers

To provide stiffness to the soil, PP fibers were incorporated into the soil. The presence of the fibers contributed to better distribution of the loads on the ground making the soil stronger and less deformable. (Chaosheng Tang, 2007) In preparing the soil mixture, several difficulties were however noted. A fairly random dispersion of the polypropylene fibers within the soil could not be attained; hence the variation of stiffness enhancement on the pitch. It was also noted that for some types of fibers, strength reduction in the fibers occurred over time and could thus compromise the efficacy of the soil reinforcement. Such mixing issues and arguably fiber decay impaired the general usability of polypropylene fibers as an agent for stiffening soils.

2.6.4 Fuji Beton

Another product that was evaluated was Fuji Beton, it is a high-performance soil stabilizer that was used to achieve high stiffness and durability. (Mohanan, 2023) It improved the properties of the soil by chemically bonding between the soil particles. Great improvements in the characteristics of beton-treated soil were noted. Nonetheless, due to its expensive nature, large-scale application of the Fuji Beton was difficult; especially in the regions of low resources. These factors pointed out the difficulties of using Fuji Beton as a standard method of soil stabilization even though it had very good performance parameters.

2.7. Summary

In conclusion, several materials were investigated for the improvement of stiffness of the Nandipur soil for using it for cricket pitches, each having some drawbacks. Lime when used in chemical stabilization worsened the situation by drying up the soil and contributed to the loss of moisture in the pitch. Terrazyme containing enzymes did not seem a very viable option due to availability issue in Pakistan and because it was initially very costly. Polypropylene fibers enhanced tensile strength, but there were difficulties in proper mixing and necessitated expensive equipment. Fuji Beton, despite the high performance of this material, it was very costly and generally not available. Bentonite and sugar cane molasses were selected because of their functional advantages. Workability was enhanced and a denser surface was achieved because Bentonite improved the moisture retention and the plasticity. It could expand causing it to hold large quantities of water which was necessary for moisture retention and because of its fine particles, it easily fitted into gaps making the soil dense. Molasses acted as a binder and held the soil particles together in a manner that packed them together more closely, thus providing the pitch with a stiffer condition to bear more load and was also more durable. These properties made bentonite and molasses suitable for constructing good quality cricket pitches, offered good and even playing surfaces, and had reasonable durability and met the requirements. Bentonite which helped in retaining moisture and being plastic in nature along with molasses which helped in increasing the stiffness factor and better particle packing made sure that the soil was meeting cricket standards in terms of performance and durability.

CHAPTER 3: METHODOLOGY

3.1 Research methodology

The purpose of this study was to firstly highlight the parameters that dictate the quality assessment factors of a cricket pitch, and then improve them respectively. According to the International Cricket Council, a good pitch offers high pace, high bounce, and considerable grass on top (ICC, 2019). Hence, the relevant identifiable factors were the soil stiffness, moisture retention, and soil fertility (which controls the growth of grass hence reducing friction between the surface and the ball upon contact).

The first step in the approach was to set a benchmark, which would directly dictate the progress in reaching the optimum results for improvement of the cricket pitch. Upon deeply reading through articles and blogs, we arrived at a conclusion that the pitches in Australia are having the highest quality and offer the most bounce and pace, hence the properties of such pitches were qualitatively analyzed. These pitches use vertisols found in Australia and contain a high percentage of clay compared to other soils around the world (media, 2024).

The second step was to convert the physical properties of the foreign pitches into quantifiable properties. For this purpose, a simulation environment built on Simulink using MATLAB was used (mathworks, 2021). This simulation has multiple variables to determine the re-bouncing of the ball on a surface e.g. weight and geometric properties of the ball, damping of the surface, and most importantly the subgrade modulus of the surface. In order to use a software of this nature to our advantage, a reverse-engineering methodology was opted, i.e. a video file which contained the bounce test performed in Australia was inserted, analyzed and plotted on a graph which was then re-iterated to the simulation to determine the optimized parameters. These optimized parameters were obtained by keeping other variables constant.

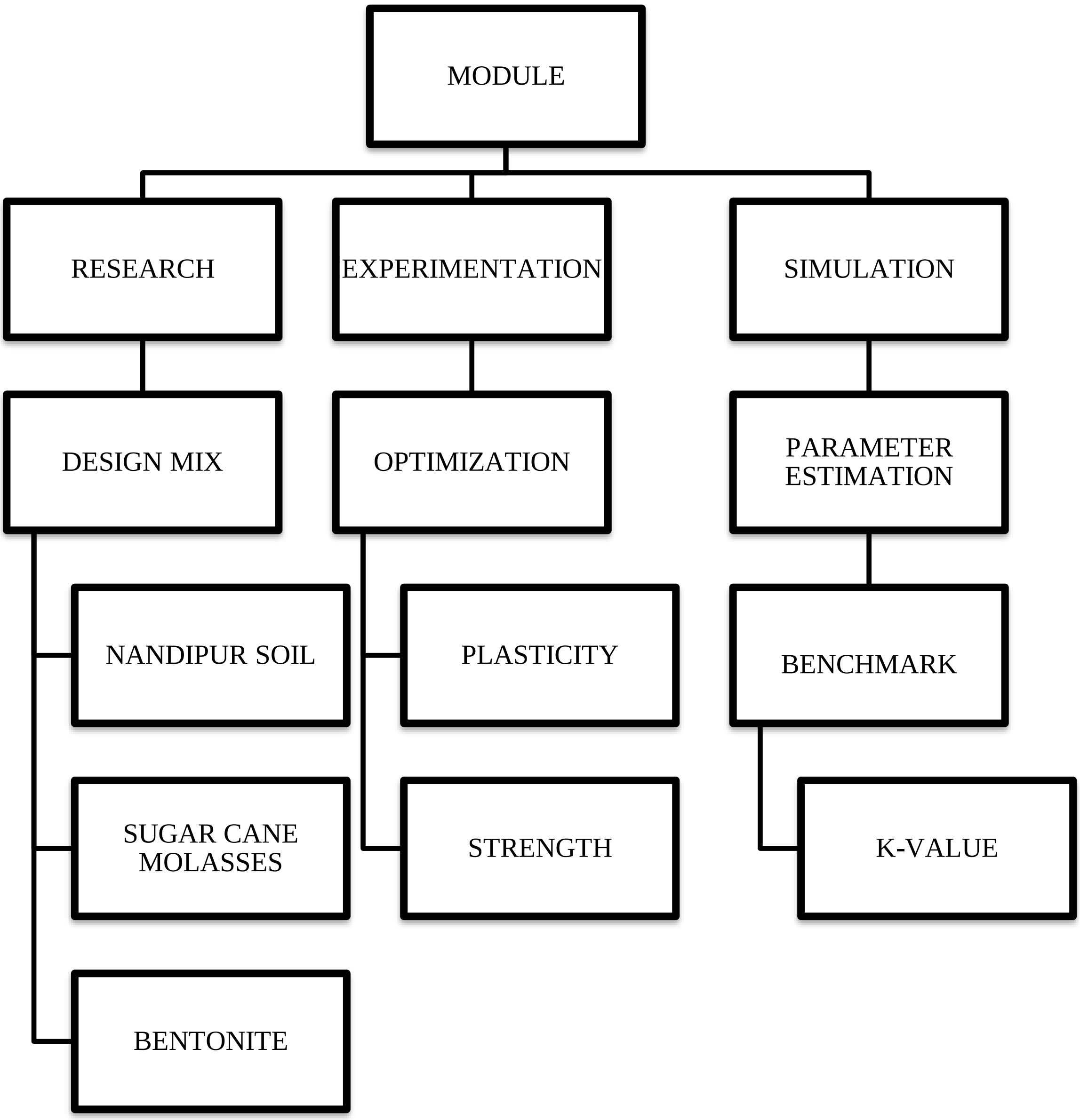

Figure 1: Flowchart of execution methodology

3.2 Execution methodology

Following the aforementioned research, the next step was to draw out a plan for execution of the project. The third step was to now assess the condition of the pitches constructed in Pakistan. This research led us to conclude that the pitches in Pakistan are made up of soil extracted from Nandipur, Gujranwala (Punjab.gov.pk., 2020). To quantify the properties of this soil, a sample of 80 kilograms was procured and tested in the geotechnical laboratories.

The findings were defiant of the concept that Nandipur soil alone can suffice to the high quality of the Australian soil as the clay content and stiffness properties were lower than that of the benchmark. This outcome led to even more research about improving the soil's relevant factors. Research was carried out (refer to chapter 2 of the thesis) on admixtures, which were then procured and again tested in the geotechnical laboratories. Upon optimizing the dosages of the additives, two physical representative models were created in controlled environments. One of which was made out of pure Nandipur soil compacted at 95% MDD and the respective OMC, and the other model was constructed using our lab results again compacted at 95% MDD and the respective OMC (ASTM D 698).

Bounce tests were performed on both of these models using semi-new leather (hard) balls weighing 156 grams each. These balls were dropped from a height of 8 feet and the re-bounce was recorded and measured using a camera sensor.

A comprehensive difference of 40% in stiffness and almost twice as much re-bounce was achieved, closest to the benchmark of Australian pitches as first improvement in Pakistan.

3.3. Sample Collection

The soil from Nandipur is used for cricket pitches all over Pakistan, as well as for academic purposes, hence, a local vendor in Gujranwala (refer to figure 2) was contacted who delivered us 80 kilograms of the soil used for cricket pitches in Islamabad. Bentonite was then procured from a vendor in Lahore, who has supplied the said product to various major construction products and is a leading seller in the market. They delivered a 50-kilogram bag of fine bentonite (refer to figure 3) to us in Islamabad.

Sugarcane molasses was also procured from Lahore. The credible seller claimed that it was obtained directly from the sugarcane industry hence it was untreated and unmixed product (refer to figure 4). Around 10 liters of molasses were delivered. After this, we proceeded with our testing process.

Figure 2: Soil site in Nandipur

Figure 3: Sample of Bentonite

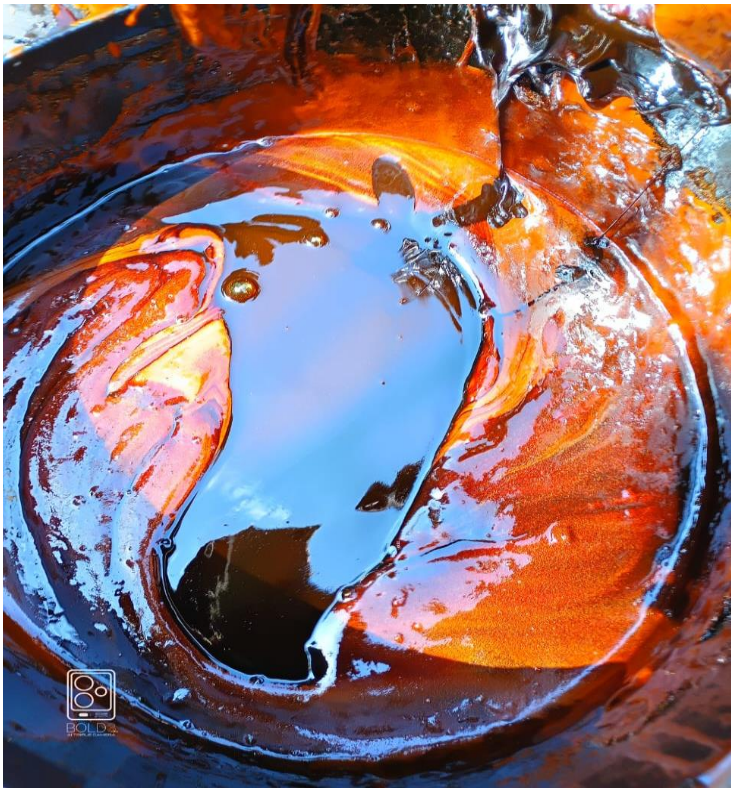

Figure 4: Sample of Molasses

3.4. Lab Tests

A summary of tests and standards. The tests that were performed for this research have been mentioned here. A sieve analysis was performed according to (ASTM D422, 2007) to calculate the particle size distribution of soil sample. The grain size distribution curve was then plotted using the particle size distribution data.

Atterberg's limits: The Atterberg limits Tests were performed according to (D4318, 2010) to obtain Liquid, Plastic, Shrinkage Limits and Plasticity Index of soil samples. The optimum percentages of bentonite were added to soil for performing Atterberg's Limit Test. This test helped us to compare index properties of untreated soil with that of admixed soil.

Standard Proctor Test was performed according to (ASTM D698-12, 2021; ASTM D1557-12, 2021) to determine Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of soil. Both virgin soil as well as admixed soil was tested.

The Unconfined Compression Strength (UCS) Test was performed according to (ASTM D2166-06, 2006) standards to calculate unconfined compression strength which was then used to get the stiffness of the soil using correlations. Tests were performed on specimens at different curing ages. The curing time was (0 and 7) days for untreated soil samples and (0 and 7) days for admixed soil.

Table 1: Number of tests and their ASTM standards

Tests	No. of tests	Standard used
Sieve analysis	02	ASTM D422
Hydrometer analysis	02	ASTM D7928
Atterberg limits	08	ASTM D4318
Standard Proctor Test	20	ASTM D698-12
UCS	14	ASTM D2166-06

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

The simulation output provided the target k-value. In order to bring the current stiffness value closer to the target value, molasses and bentonite were added to the Nandipur soil as admixtures. The optimum dosage of molasses and bentonite was calculated through various tests which include Casagrande tests (Quintela, 2014) (Connelly, 2008) for liquid limits, Proctor tests (Connelly, 2008) for optimum moisture content and Unconfined Compresstion Test (UCS) (Malanda, 2022). Each test was performed multiple times for high accuracy and the results dictated the quantities of Bentonite and Molasses. The final design mix after these calculations was set as Nandipur Soil: 74.42%, Bentonite: 18.60%, Molasses: 6.98%, with 20% optimum moisture content, having a plastic limit of 28.1, liquid limit of 60.1, plasticity index of 32 and a maximum unconfined compressive strength (qu) of 497.6 kPa.

4.2 Atterberg-Limits

The Atterberg limits provide important insights into the behavior of soil by illuminating its malleability and moisture retention capabilities (Seed, 1964). This test is useful for obtaining the soil index properties, as well as to determine the optimum dosage of Bentonite for our design mix. A liquid limit of 60 was set as the target liquid limit, which corresponds to the optimum dosage of Bentonite. This ensured the soil remained in the high plastic region in the plasticity chart even after the addition of molasses which reduces liquid limits by about 1-2% per percent of molasses added.

4.2.1 Bentonite

Bentonite serves several essential functions in the optimization of cricket pitch design. Firstly, it was employed to attain a target Liquid Limit of 60, a critical parameter ensuring the desired consistency of the soil. Additionally, Bentonite was utilized to enhance the plasticity of Nandipur Soil, thereby improving its workability and ability to withstand stress during gameplay. Furthermore, the inclusion of Bentonite contributes to effective moisture retention within the pitch, ensuring consistent hydration levels crucial for maintaining pitch performance over time. = Bentonite also facilitates better compaction of the mix, by acting as a lubricant resulting in improved structural integrity and stability of the cricket pitch surface. (Rehman, 2020)

In order to determine the optimum dosage of Bentonite, four Casagrande tests were performed on different mixes: The 100% nandipur soil, 85:15 (nandipur: bentonite), 80:20 (nandipur: bentonite) and 75:25 (nandipur: bentonite). The results of the liquid limit tests are given in (Figures: 5-8)

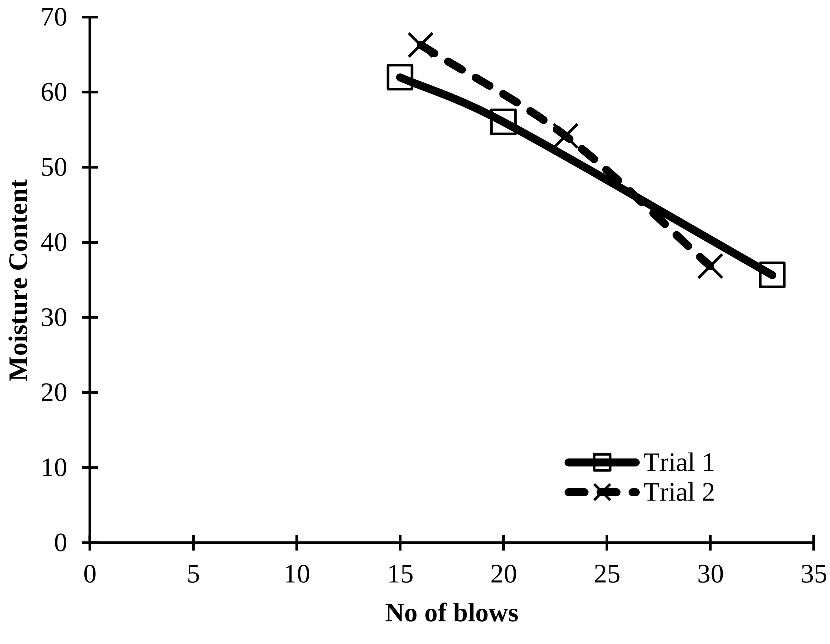

Figure 5: The results of Casagrande tests performed on 100% Nandipur

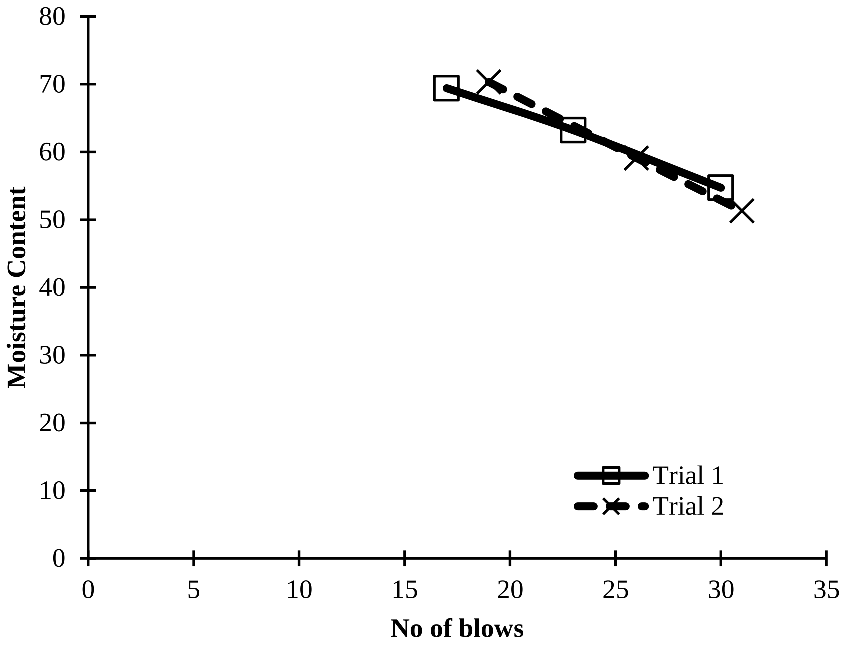

Figure 6: The results of Casagrande tests performed on 80/20 mix

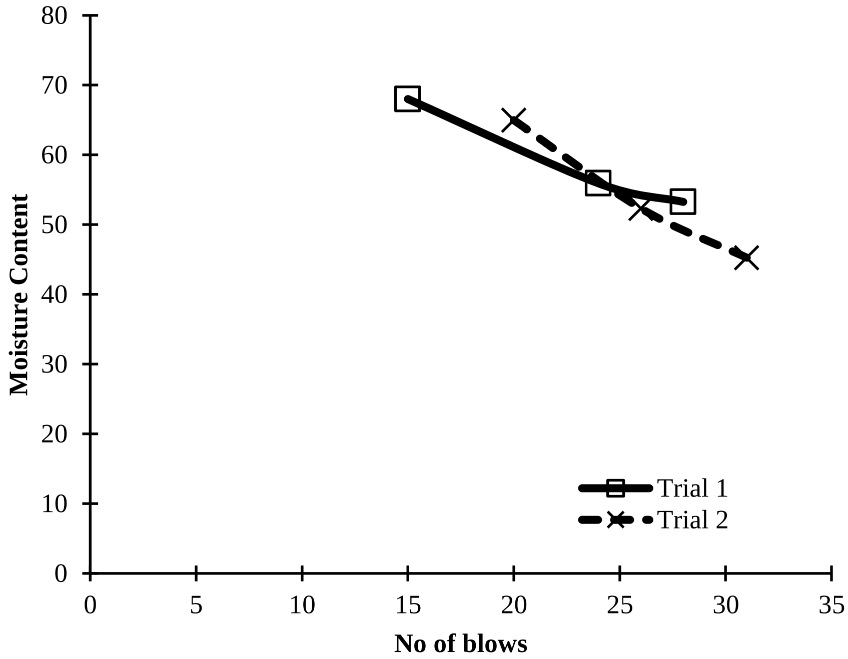

Figure 7: The results of Casagrande tests performed on 85/15 mix.

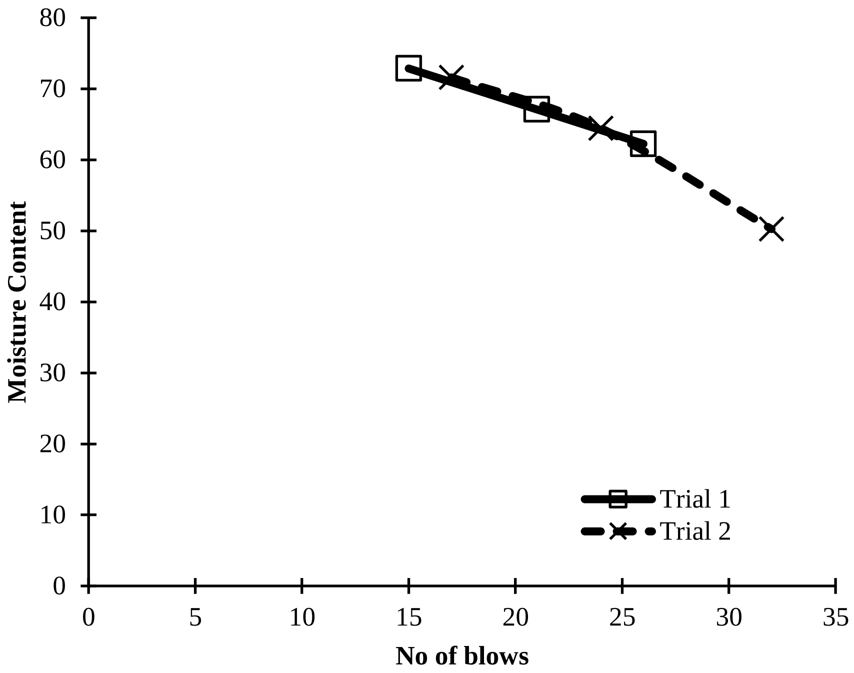

Figure 8: The results of Casagrande tests performed on 75/25 mix.

These liquid limits were calculated using the Casagrande apparatus by determining the moisture content corresponding to 25 blows at which the groove closes (Quintela, 2014). For this purpose, values of three different blows were taken in the ranges 15-25, 20-30 and 25-35. These values were plotted on a graph and using interpolation we found the moisture liquid corresponding to 25 blows. This moisture content gave us the resulting liquid limit.

Based on the liquid on the liquid limit results, the 80/20 (Nandipur: Bentonite) mix was chosen as it achieved the target liquid limit of 60 (Table: 1). Although the 75/25 mix gave a higher liquid limit of 62 (Figure 6), it was discarded because Bentonite is a weak soil, hence the addition of excessive amounts was avoided.

In table 1 the comparison of results before and after the addition of 20% bentonite can be observed.

Table 2: Comparison of results before and after the addition of 20% bentonite

S.NO	Mix	Liquid Limit	Plastic Limit
1	100%	49.2	22.6
2	80/20	60.1	28.1

It was observed that the addition of 20% bentonite increased the liquid limit from 49.2 to 60.1 and the plastic limit from 22.6 to 28.1. Using these, the plasticity index was calculated which increased from 26.6 to 32. Based on these results, optimum dosage of Bentonite chosen was 20%. These tests also provided the index properties of the soil mix which was utilized in further calculations.

4.3 Compaction Characteristics

Determining the parameters that dictate maximum compaction is crucial in the construction of a cricket pitch in the ground. Two major parameters are of concern: The optimum moisture content and the maximum dry density corresponding to that. The optimum moisture content gave us the amount of moisture needed in the mix for the construction of the pitch. The maximum dry density corresponding to that, was also important in determining the amount of compaction to be done in regard to the number of passes and the weight of the rollers. These parameters were analyzed using proctor tests (Connelly, 2008)

Proctor tests were performed on two different mixes: 100% Nandipur Soil and 80/20 (Nandipur: Bentonite) mix.

Figure 9: Proctor Test Apparatus

The 80/20 mix was already selected as the Nandipur: Bentonite mix in the previous step in which Casagrande tests (Quintela, 2014) were performed. Along with this, proctor tests on 100% Nandipur soil were performed as well to provide a comparison of the change in O.M.C (optimum moisture content) and the M.D.D (maximum dry density) before vs after adding 20% Bentonite.

Proper compaction also improves the soil's drainage properties. In this case, a well-compacted pitch would have an appropriate balance between porosity and density, ensuring that water drains effectively without causing waterlogging or surface runoff (Ross, 1926). This was useful in keeping the pitch consistent in various weather conditions.

The results of the two proctor tests performed on the two mixes can be seen in (Figures: 10-11).

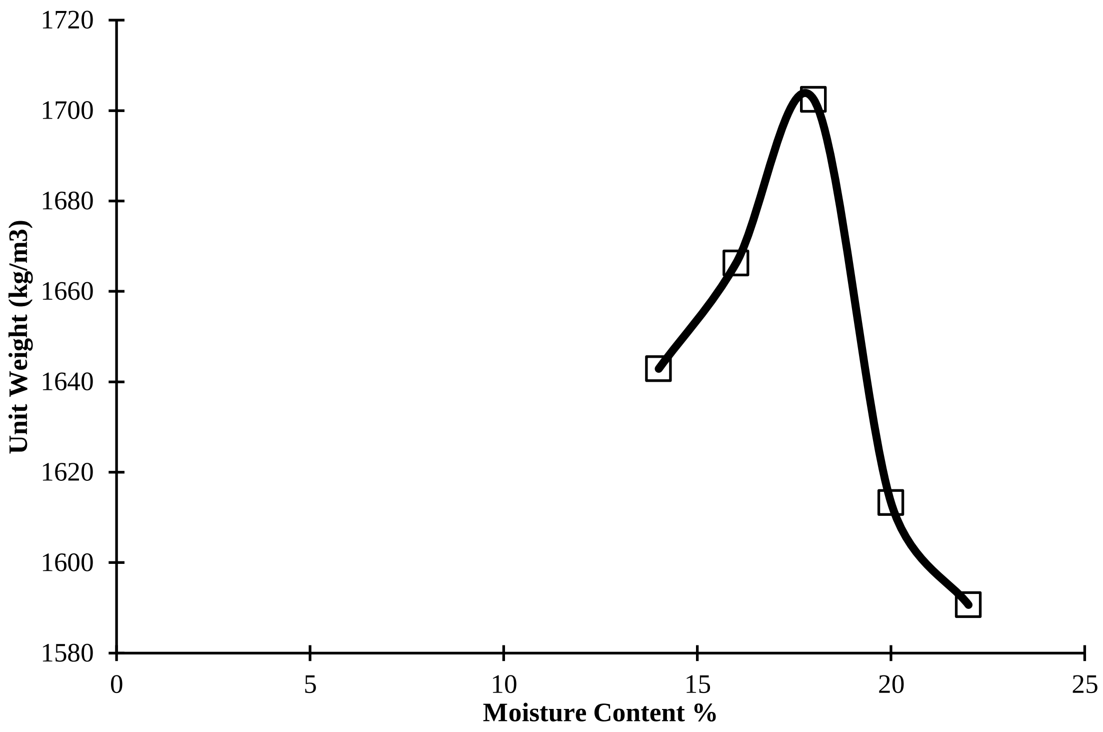

Figure 10: Proctor test results of 100% Nandipur Soil.

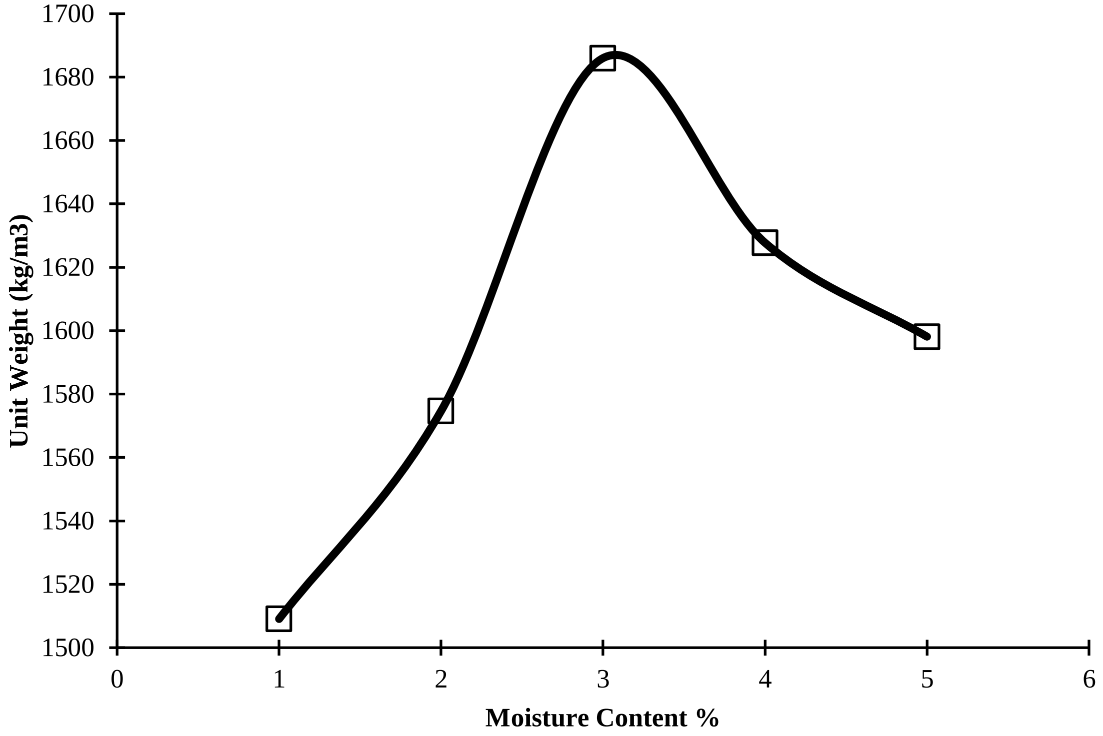

Figure 11: Proctor test results of 80/20 Nandipur/Bentonite mix.

From the results, it can be observed that the optimum moisture content (O.M.C) of the soil increased from 18% (Figure: 10) to 20% (Figure: 11) by adding 20% Bentonite to the Nandipur soil. This was due to the high-water retention properties of bentonite. Moreover, the maximum dry density reduced by a small margin, from 1700 kg/m3 to 1686 kg/m3. This was attributed to Bentonite being a weak soil in nature – hence larger additions of bentonite were undesirable (Ross, 1926).

4.4 Unconfined Compressive Strength Test

After Bentonite, the next additive was Molasses. Molasses was primarily chosen for its strength increasing properties, which it achieves by augmenting the packing density of the soil particles in addition to its adhesive properties. Furthermore, Molasses also increased the maximum dry density of the soil which further improved compaction.

Another key benefit of molasses was that because it is a waste product of organic nature, it increased the soil fertility which in turn promotes grass growth. The growth of grass on the cricket pitch was another key target, as grass helps maintain a uniform surface quality which provides consistent pace and bounce. Molasses also aided in the moisture retention properties of the pitch which maintains its hardness (Malanda, 2022).

The target was to observe the effect of the addition of different dosages of molasses on the unconfined compressive strength of the soil mix. The optimum dosage of molasses was then selected based on the dosage that gave the highest strength.

In order to find the compressive strength, the unconfined compressive strength (UCS) tests were performed on 100% Nandipur Soil, 80/20 Nandipur/Bentonite mix, and 80/20 Mix + Molasses [dosage ranging from (2.5-12.5)% with an interval of 2.5%]

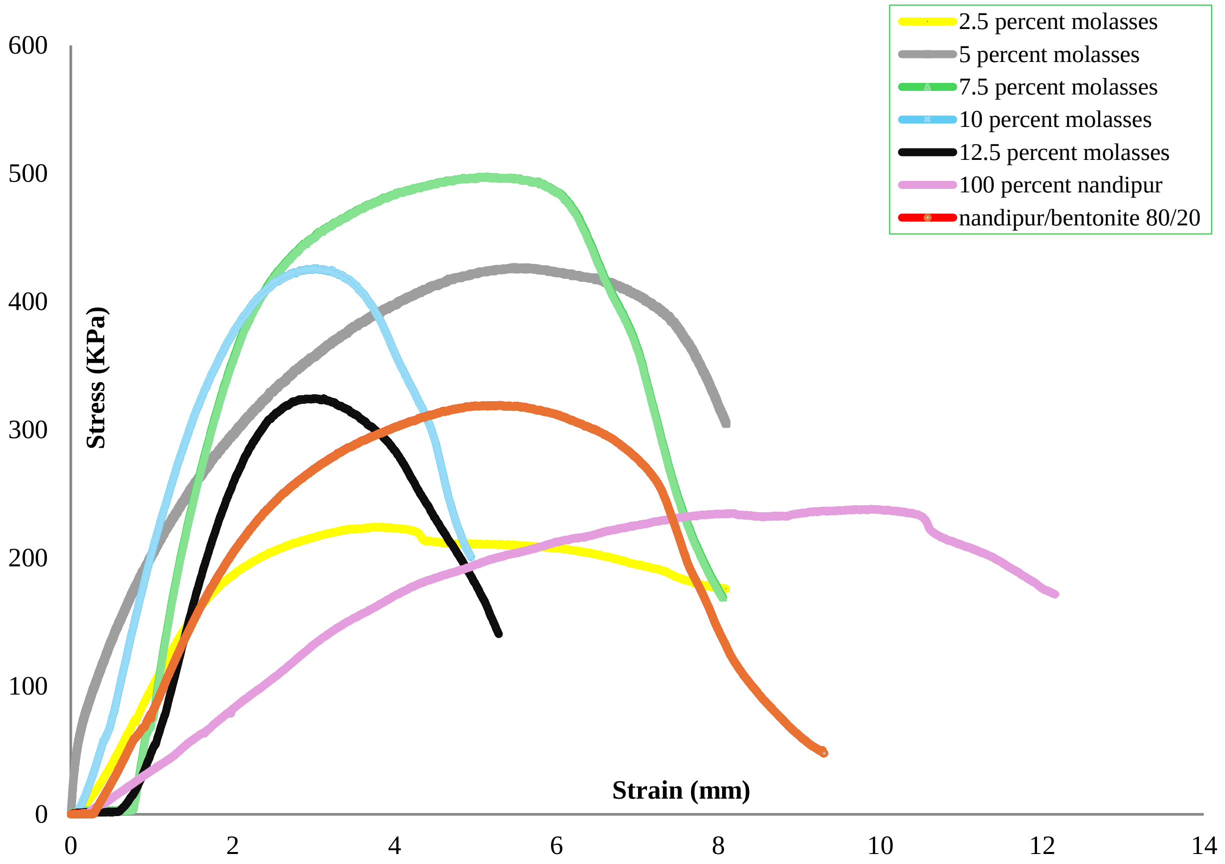

Figure 12: Results of the UCS test on different dosages of molasses

The results of the UCS tests in (Figure 12) show the comparison of the ultimate confined compressive strength for different dosages of molasses as well as the 100% Nandipur and 80/20 Nandipur/Bentonite mix.

It was observed that the addition of molasses after 2.5% increased the ultimate strength (UCS) of the soil and peaked at a dosage of 7.5% after which it started to decrease with further addition of molasses.

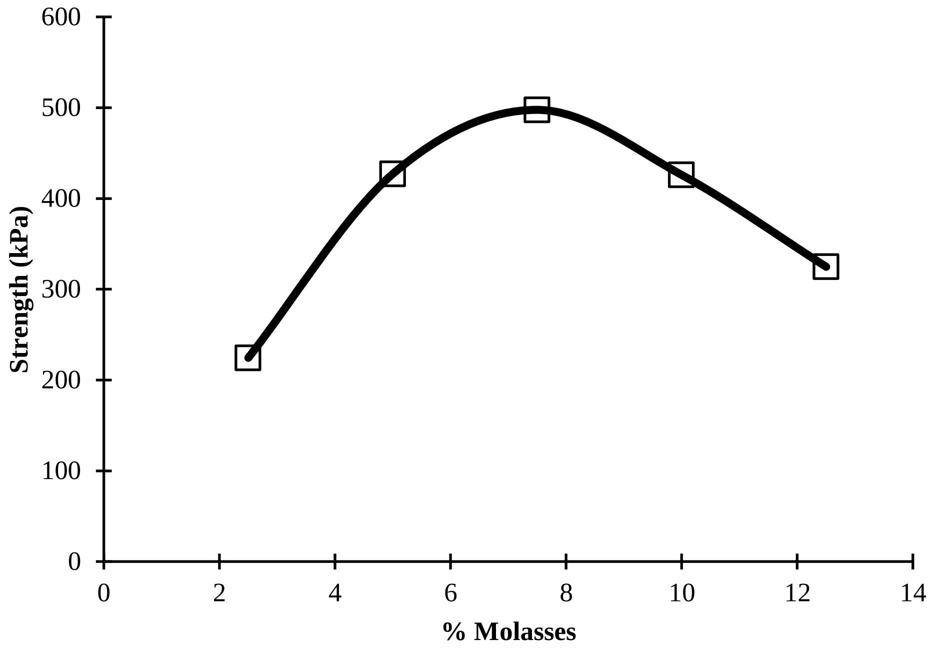

Figure 13: Increase in strength with the addition of molasses

The Addition of 7.5% of molasses into the 80/20 Mix gave an ultimate unconfined compressive strength of about 497.6 kPa whereas the 100% Nandipur soil gave an ultimate strength of only 238.4 kPa (Figure: 13). This showed that the addition of 7.5% dosage of molasses along with 20% Bentonite increased the ultimate unconfined compressive strength of the soil by over 100%. Hence the compressive strength of the soil doubled.

The final selected mix was composed of an addition of 7.5% molasses to the 80% Nandipur and 20% Bentonite mix.

4.5 K-Value

After obtaining the design mix ratios, the following empirical formulas were used to calculate stiffness (K), the target parameter.

First, the UCS result (qu) was converted to the resilient modulus (MR) with the use of soil index properties through the following empirical relation (Wu, et al., 2014):

$$MR = 6,113.0 + 95.1 \times (qu) + 173.7 \times PI - 27.8 \times P200 \quad (R^2 \text{ value} = 0.91) \quad (4.5.1)$$

In equation (4.5.1), MR = Resilient modulus, qu = ultimate unconfined compressive strength, PI = plasticity index, and P200 = Passing of #200 sieve. The high R^2 value gives an indication of the reliability of this formula.

Next, the Resilient Modulus (MR) was converted to stiffness (K) through the empirical relation (Hossain, 2015):

$$K = Mr/19.4 \quad (4.5.2)$$

Using these formulas, the stiffness (K) was calculated for both the 100% nandipur soil and the final mix (80/20 Nandipur/Bentonite + 7.5% Molasses). The result of the empirical calculations to find out stiffness (K) for both of these mixes is given in (Table-3). This gave a comparison of the increase in stiffness (K) and thus the overall improvement of the cricket pitch design.

Table 3 Comparison of stiffness results of the original soil vs the design mix:

Soil Mix	**UCS (kPA)**	**K (stiffness) (N/m2/m)**
100% Nandipur Soil	238.4	3,926,980
7.5% Molasses + (80/20 Mix)	497.6	5,368,260

4.6 Summary

Based on these lab tests, the final proportions for the design mix were selected. These proportions were based on the optimum dosage of Bentonite, optimum dosage of molasses, optimum moisture content and the maximum dry density, the unconfined compressive strength, stiffness, as well as the Atterberg limits. Table 4 shows the summary of the final proportions and quantities of various materials used along with their properties.

Table 4: Summary of the final values and proportions

Material/Property	**Value/Proportion**
Nandipur	74.42%
Bentonite	18.60%
Molasses	6.98%
Liquid Limit (LL)	60.1
Plastic Limit (PL)	28.1
Plasticity Index	32
Maximum Dry Density (Pd_{max})	1686 kg/m^3
Optimum Moisture Content (OMC)	20%
Unconfined Compressive Strength (qu)	497.6 kPa
Stiffness (k)	5,368,260 N/m^2/m

CHAPTER 5: CONCLUSION

The 100% Nandipur Soil that is typically used in Pakistani cricket pitches had a stiffness value of around 3.93 million (N/m2/m). In comparison, the new mix designed produced a stiffness of close to 5.3 million (N/m2/m). This indicates a 35% increase in stiffness, and this achieves our goal of bringing the quality of Pakistani Pitches closer to Australian pitches. This was achieved through the addition of 20% Bentonite to 100% Nandipur soil forming an 80:20 Nandipur/Bentonite mix, with further addition of 7.5% molasses to this mix. The addition of 20% Bentonite increased the liquid limit of the Nandipur Soil from 49.2 to 60.1 and the plastic limit from 22.6 to 28.1. Using these, the plasticity index was calculated which increased from 26.6 to 32. Bentonite also increased moisture retention properties of the soil.

Further addition of 7.5% molasses more than doubled the unconfined compressive strength from 238.4 kPa (originally) to 497.6 kPa (improved). Molasses also improved the particle packing properties and promoted grass growth. The final mix selected for the improved pitch was:

Nandipur Soil: 74.42%, Bentonite: 18.60% and Molasses: 6.98%. This improved mix design for a cricket pitch considerably increased the bounce and stiffness of the soil from 3.93 million (N/m2/m) to 5.3 million (N/m2/m).

References

Ali, M., Aziz, M., Hamza, M. & Madni, M.F., 2020, ‘Engineering properties of expansive soil treated with polypropylene fibers’, *Geomechanics and Engineering*, 22(3).

Bell, F.G., 1996, ‘Lime stabilization of clay minerals and soils’, *Engineering Geology*, 42(4).

Bhardwaj, A. & Sharma, R.K., 2020, ‘Effect of industrial wastes and lime on strength characteristics of clayey soil’, *Journal of Engineering, Design and Technology*, 18(6).

Clem, A.G. & Doehler, R.W., 1961, ‘Industrial Applications of Bentonite’, *Clays and clay minerals (National Conference on Clays and Clay Minerals)*, 10.

Connelly, J., Jensen, W., Harmon, P., Connelly, J.;, Jensen, W.;, Paul, H. & Proctor, '', 2008, *Nebraska Department of Transportation Research Reports*.

Hossain, M.S. & Kim, W.S., 2015, ‘Estimation of Subgrade Resilient Modulus for Fine-Grained Soil from Unconfined Compression Test’, *https://doi.org/10.3141/2473-15*, 2473(1), 126–135.

M M, S.H., 2018, ‘Soil Stabilisation using Lime’, *International Journal for Research in Applied Science and Engineering Technology*, 6.

Malanda, N., Mfoutou, N.N., Madila, E.E.N. & Louzolo-Kimbembe, P., 2022, ‘Microstructure of Fine Clay Soils Stabilized with Sugarcane Molasses’, *Open Journal of Civil Engineering*, 12(02).

Malanda, N., Mfoutou, N.N., Madila, E.E.N., Louzolo-Kimbembe, P., Malanda, N., Mfoutou, N.N., Madila, E.E.N. & Louzolo-Kimbembe, P., 2022, ‘Microstructure of Fine Clay Soils Stabilized with Sugarcane Molasses’, *Open Journal of Civil Engineering*, 12(2), 247–269.

M’Ndegwa, J.K., 2011, ‘The Effect of Cane Molasses on Strength of Expansive Clay Soil’, *Journal of Emerging Trends in Engineering*, 2(6).

Polidori, E., 2007, ‘Relationship Between the Atterberg Limits and Clay Content’, *Soils and Foundations*, 47(5), 887–896.

Quintela, A., Costa, C., Terroso, D. & Rocha, F., 2014, ‘Liquid limit determination of clayey material by Casagrande method, fall cone test and EBS parameter', *Materials Technology*, 29(B2), B82–B87.

Rehman, M.A. & Jafri, T., 2020, 'Stabilization of low plastic and high plastic clay using guar gum biopolymer', *Journal of Applied Research on Industrial Engineering*, 7(4), 329–343.

Ross, C.S. & Shannon, E. V., 1926, 'THE MINERALS OF BENTONITE AND RELATED CLAYS AND THEIR PHYSICAL PROPERTIES', *Journal of the American Ceramic Society*, 9(2), 77–96.

Seed, H.B., Woodward, R.J. & Lundgren, R., 1964, 'Fundamental Aspects of the Atterberg Limits', *Journal of the Soil Mechanics and Foundations Division*, 90(6), 75–106.

Shivhare, S. & Mohanan, H., 2023, 'A review on subgrade soil stabilization using bio enzymes', *Arabian Journal of Geosciences*, 16(3).

Tang, C., Shi, B., Gao, W., Chen, F. & Cai, Y., 2007, 'Strength and mechanical behavior of short polypropylene fiber reinforced, and cement stabilized clayey soil', *Geotextiles and Geomembranes*, 25(3).

Tiwari, A., Sharma, J.K. & Garg, V., 2021, *Stabilization of Expansive Soil Using Terrazyme*, *Lecture Notes in Civil Engineering*, vol. 136 LNCE.

Usman, H., Mm, H., Pm, H. & Ahmad, T., 2016, 'Improvement of Geotechnical Properties of Cricket Pitches'.

Pitch it right | ESPNcricinfo.

About ICC Cricket | International Cricket Council.

Evaluation of AASHTO Mechanistic-Empirical Pavement Design Guide for Designing Rigid Pavements in Louisiana - ProQuest.