Controlling Drying Shrinkage of Concrete Block using By-Product Materials and Fibers

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PROJECT APPROVAL

This is to certify that the thesis entitled **"Controlling Drying Shrinkage of Concrete Block using By-Product Materials and Fibers"** submitted by Md. Minhazul Hoque, Tanveer Ahmad, Md. Moshiur Rahman Rafi and has been approved as partial fulfilment of the requirement for the Degree Bachelor of Science in Civil Engineering at the Islamic University of Technology (IUT).

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DECLARATION

We affirm that the undergraduate research presented in this thesis was carried out under the expert guidance of Professor Dr. Md. Tarek Uddin. We have taken all necessary precautions to ensure the originality of the work. The content herein has not been copied, plagiarized or submitted elsewhere except for publication purposes.

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DEDICATION

To our parents, whose steadfast support, infinite patience and numerous sacrifices have molded us into who we are today. Your unwavering encouragement and faith in us have been our greatest source of inspiration, enabling us to pursue our dreams and accomplish our goals. We are deeply grateful to you and dedicate this work to you with all our love.

We also wish to express our sincere gratitude to our esteemed supervisor, Professor Dr. Md. Tarek Uddin. His continuous encouragement, insightful guidance and unwavering support have been crucial to the completion of this thesis. Without his mentorship, this accomplishment would not have been possible. Thank you for your invaluable contributions and for believing in us.

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ABSTRACT

Utilizing by-products and fibers in concrete blocks can effectively control drying shrinkage and enhance mechanical properties while promoting sustainability. This study evaluates the feasibility of incorporating by-products such as construction waste, brick dust, waste cement fines (WCF), ladle furnace slag and recycled block materials and impact of incorporating jute and polypropylene fibers, into concrete blocks. The primary objective is to reduce drying shrinkage and improve compressive strength.

Methodologies included the Compressive Strength Test, Modulus of Rupture Test, Permeable Voids and Boiling Water Absorption Test and Linear Drying Shrinkage Test. Results indicated that incorporating by-products decreased linear drying shrinkage and boiling water absorption, with varying effects on void content and a general increase in strength. Specifically, brick dust and WCF significantly reduced shrinkage and increased strength, while jute and polypropylene fibers showed mixed results. Jute fibers at a 0.3% dosage and 15 mm length provided higher strength in specific cases.

The study concluded that optimizing mix proportions, curing conditions and fiber dispersion is crucial for performance enhancement. Higher temperatures increased shrinkage, while low temperatures and high humidity reduced it. Polypropylene fibers exhibited higher shrinkage compared to jute fibers. Future research should focus on improving fiber dispersion and exploring hybrid fiber systems to further enhance the mechanical properties and durability of concrete blocks.

Keywords: Drying Shrinkage, By-Products, Concrete Blocks, Jute Fiber, Polypropylene Fiber.

Chapter 1: Introduction

1.1 General

In 2023, the population of Bangladesh was approximately more than 173 million people ("World Bank Open Data," n.d.). Among the top 20 most polluted countries in the world in 2022, Bangladesh ranked first with an average AQI of 172 (M. Kumar, 2023b). In the Dhaka city, emissions from vehicle exhaust (motor cycles, aged busses, three-wheeler passenger vehicles, passenger cars, commercial vans and freight trucks), suspended road dust (due to the vehicular movement) and industries are dominant (Begum et al., 2006). According to air quality data from 2017, nearly half of Dhaka's available hourly readings were at or above unhealthy levels — and brick kilns contribute significantly to PM2.5 concentrations in the cities close to where they operate ("Bangladesh's Air Pollution Problem Grows, Brick by Brick," n.d.). A research report illustrated that a total of released gases and particulate matters from the brick kilns in the Dhaka region of Bangladesh were estimated to be 15,500 tons of SO2, 302,000 tons of CO, 23,300 tons of PM 2.5, 6,000 tons of BC and 1.8 million tons of CO2 emissions (Guttikunda, Begum, & Wadud, 2012). A survey conducted on the brick kiln areas stated that inhabitants near the kilns are more likely to suffer from health hazards caused by pollution of kilns, comparing those who are not living in the areas of the brick kilns (Joshi & Dudani, 2008).

The government has decided to phase out the use of bricks by 2025 in all its construction works to reduce the air pollution as brick kilns are one of the major sources of air pollution in Bangladesh (Molla, 2019). Compared to traditional bricks, concrete blocks offer a robust and durable alternative for construction, suitable for load-bearing applications such as foundations and structural walls.

However, one of the significant challenges associated with concrete blocks is their tendency to undergo drying shrinkage, which can lead to cracking and structural integrity issues. Drying shrinkage is a volumetric reduction due to the loss of water from the concrete matrix, often resulting in micro-cracks that can propagate into larger cracks, compromising the structural performance and longevity of concrete block elements (Kumar, 2021; Olaoye, Oluremi, & Ajamu, 2014).

To mitigate the adverse effects of drying shrinkage, various strategies have been explored, including the incorporation of supplementary materials and fibers into concrete block mixes. By-product materials such as brick dust, construction waste, ladle furnace slag and waste cement fines are commonly used as partial replacements for cement, offering both economic and environmental benefits. Additionally, fibers, including synthetic fibers like polypropylene and natural fibers like jute, have been studied for their ability to enhance the mechanical properties and reduce shrinkage in concrete blocks (Ali, Khan, & Aslam, 2023; Soroushian & Marikunte, 1992).

The primary focus of this research is to evaluate the effectiveness of these by-product materials and fibers in reducing drying shrinkage and improving the overall performance of concrete blocks. This study aims to provide a comprehensive understanding of the mechanisms through which these materials influence the shrinkage behavior and to identify optimal combinations that can be employed in practical applications (Wang, Zhang, & Wang, 2001).

1.2 Background

Drying shrinkage in concrete blocks is a phenomenon that occurs as the water used in the hydration process gradually evaporates. This evaporation leads to a reduction in the volume of the concrete blocks, causing tensile stresses that result in cracking. The extent of drying shrinkage is influenced by several factors, including the water-cement ratio, aggregate type, environmental conditions and curing practices (Kumar, 2021). High water-cement ratios tend to increase the likelihood of drying shrinkage, as more water in the mix results in greater volume reduction when it evaporates.

A study shows that incorporating marble waste aggregates in cementitious material led to a significant 30% reduction in drying shrinkage with 40% replacement level with fine aggregates. (Oti et al., 2011)

Another study shows that 20% Brick Dust Waste (BDW) as a partial substitute in unfired clay bricks showed reduction in drying shrinkage by 15% (Liu et al., 2011). A study on recycled powder sintered clay bricks (SCBs) showed fine and medium SCB powder reduces shrinkage by 13% (Vardhan et al., 2011). Another study shows 75% crushed clay brick aggregate of total aggregate demonstrates significant reductions in drying shrinkage, reaching up to 57.1% in certain cases of concrete blocks (Xiao et al., 2011). A study shows that incorporating jute fibers (0.1%-0.4%) in concrete significantly reduces drying shrinkage cracks, achieving up to 61% reduction in crack area and 62% reduction in maximum crack width (Zardari et al., 2011). A study shows that incorporating jute fibers (0.1%-0.4%) in concrete reduces plastic shrinkage cracks by 75-99% compared to non-fiber reinforced concrete. (Khan et al., 2011). A study shows that incorporating 2.0 weight% of 15 mm length jute fibers (JFs) into adobe mixtures (AMs) significantly improves drying shrinkage cracking control, reducing crack density ratio by 93%. (Islam et al., 2011). A study shows that cement-sand samples with 2% polypropylene of cement weight exhibit about 24% less shrinkage than reference mortar samples. (Antico et al., 2011). A study shows that incorporating 0.2% jute fibers (13mm) and 10% rice husk in concrete effectively reduces drying shrinkage cracks to near zero (Roy et al., 2011). The practical implications of using by-product materials and fibers in concrete blocks are significant. By reducing drying shrinkage and improving durability, these materials can extend the lifespan of concrete block structures, reducing maintenance costs and enhancing safety. The use of by-product materials also supports sustainable construction practices by minimizing waste and conserving natural resources (Meyer, 2009). Additionally, the incorporation of natural fibers like jute aligns with the growing emphasis on environmentally friendly construction materials.

1.3 Objectives of the Study

The primary objectives of this study are:

- Controlling Drying Shrinkage of Concrete Blocks using By-Products (Construction Waste, Brick Dust, Waste Cement Fines, Ladle Furnace Slag, Recycled Block etc.)
- Controlling Drying Shrinkage of Concrete Blocks using Jute Fiber and Polypropylene Fiber.
- To explore - Mechanical Properties (Compressive Strength, Modulus of Rupture, Linear Drying Shrinkage) of Concrete Blocks made with different By-Products and Fibers.

1.4 Research Flow Diagram

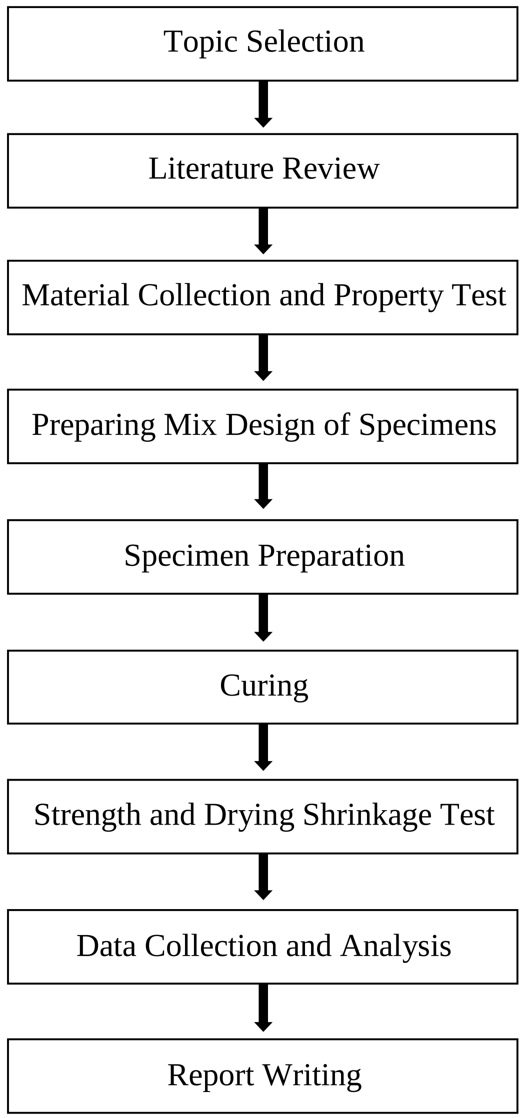


Figure 1: Research Flow Diagram

1.5 Layout of the Thesis

The thesis consists of the following layout:

Chapter 1: Introduction – The current chapter that discusses about the theory, background, objectives, scope of the study, research flow diagram.

Chapter 2: Literature Review – The chapter describes the related research in the field of our study by former authors and their findings.

Chapter 3: Methodology - This chapter describes the procedures and steps that were followed to conduct our study.

Chapter 4: Results and Discussion - Collected data and processing of the data, results were included in the chapter.

Chapter 5: Conclusion and Recommendations - General discussion, limitations, recommendations and future scopes of work was discussed here.

Chapter 2: Literature Review

Another investigation indicates that incorporating 20% Brick Dust Waste (BDW) as a partial replacement in unfired clay bricks can reduce drying shrinkage by 15% (Liu et al., 2011). Research on recycled powder from sintered clay bricks (SCBs) reveals that fine and medium SCB powder can decrease shrinkage by 13% (Vardhan et al., 2011). Similarly, another study demonstrates that utilizing 75% crushed clay brick aggregate in the total aggregate significantly reduces drying shrinkage, achieving up to a 57.1% reduction in specific cases of concrete blocks (Xiao et al., 2011). Furthermore, it has been shown that incorporating jute fibers (0.1%-0.4%) in concrete substantially minimizes drying shrinkage cracks, leading to a reduction of up to 61% in crack area and 62% in maximum crack width (Zardari et al., 2011). Another study indicates that jute fibers (0.1%-0.4%) can reduce plastic shrinkage cracks by 75-99% compared to concrete without fibers (Khan et al., 2011). Additionally, research highlights that incorporating 2.0 weight% of 15 mm length jute fibers (JFs) into adobe mixtures (AMs) significantly enhances control over drying shrinkage cracking, reducing the crack density ratio by 93% (Islam et al., 2011). It is also observed that cement-sand samples with 2% polypropylene by cement weight exhibit approximately 24% less shrinkage compared to standard mortar samples (Antico et al., 2011). Incorporating 0.2% jute fibers (13 mm) and 10% rice husk in concrete has been shown to effectively eliminate drying shrinkage cracks (Roy et al., 2011).

The practical implications of using by-product materials and fibers in concrete blocks are considerable. By reducing drying shrinkage and enhancing durability, these materials can prolong the lifespan of concrete block structures, thereby lowering maintenance costs and increasing safety. Moreover, the use of by-product materials promotes sustainable construction practices by minimizing waste and conserving natural resources (Meyer, 2009). Additionally, incorporating natural fibers like jute supports the growing trend toward environmentally friendly construction materials, aligning with broader sustainability goals.

Chapter 3: Methodology

3.1 Material Used

In this study a variety of materials were selected and tested to ensure their suitability for the experiment. The primary materials included Cement (C), Water (W), Coarse Sand (CS), Sylhet Sand (SS), Medium Sand (MS), Fine Sand (FS) along with 4 different by-products such as Cement Fines - Waste (WCF), Ladle Furnace Slag (LFS), Construction Waste (CW) and Brick Dust (BD). Additionally, two different fibers, namely Jute Fiber (JF) and Polypropylene Fiber (PF) were incorporated to investigate their reinforcing capabilities and their impact on concrete block properties, particularly in reducing drying shrinkage. These materials were chosen based on their distinct characteristics and potential contributions to the experimental objectives. Here are the figures for some of the materials.

Fine Sand

Coarse Sand

Construction Waste

Brick Dust

Jute Fiber

Polypropylene Fiber

Figure 2: Materials used for the study

For using jute fibers in the concrete blocks, we cut the fibers by hand into three different sizes: 10 mm, 15 mm and 20 mm. The images below show how we cut the jute fibers and what they look like afterward. Additionally, we have collected 10 mm sized polypropylene fiber from the industry. This process helps us see how different fiber lengths affect the mechanical properties of the concrete blocks, especially in reducing drying shrinkage.

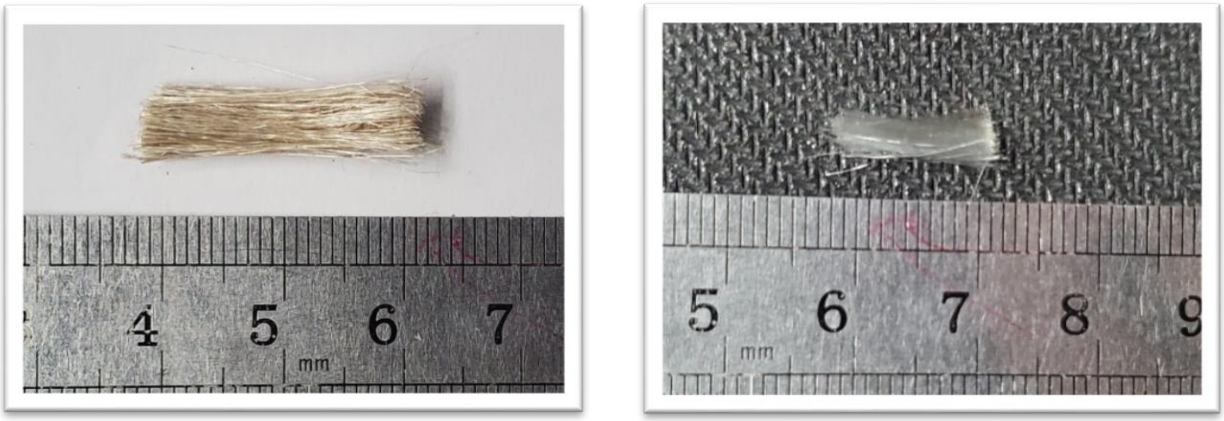
To use jute fibers in our concrete blocks, we first treated the fibers with a 5% (w/v) sodium hydroxide (NaOH) solution for 24 hours. This treatment involves soaking the jute fibers in the NaOH solution to improve their properties, such as increasing their adhesion to the concrete matrix and enhancing their durability. The chemical treatment modifies the surface of the fibers, removing impurities and enhancing their mechanical properties, making them more effective when used as reinforcement in concrete.

Full Jute Fiber

Cutting of Fibers

10mm Jute Fiber

15mm Jute Fiber



20mm Jute Fiber *10mm Polypropylene Fiber*

Figure 3: Jute Fiber cutting and different fiber length

Figure 4 NaOH Treatment of Jute Fiber

Using by-products like Cement Fines (WCF), Ladle Furnace Slag (LFS), Construction Waste (CW), Brick Dust (BD) and fibers such as Jute and Polypropylene Fiber in concrete block production promotes sustainability by reducing industrial and construction waste, conserving natural resources and lowering carbon emissions. These materials enhance mechanical properties such as strength, durability and workability. Incorporating these by-products supports a circular economy and reduces reliance on virgin raw materials, contributing to more environmentally friendly and durable construction solutions.

3.2 Material Properties

A series of tests were conducted on these materials to evaluate the material properties such as specific gravity, fineness modulus, tensile strength of jute fiber and polypropylene fiber and fiber diameter using SEM. These tests contributed essential data on material properties and fiber characteristics, enhancing understanding and applications in reducing drying shrinkage in concrete block.

3.2.1 Specific Gravity Test of Materials

The specific gravity test was conducted in accordance with various standard specifications for each material, ensuring accurate and reliable measurements that adhere to established industry protocols. The specific gravity of the materials is listed in table below:

Materials	Specific Gravity	Specifications Used
Cement (C)	2.96	ASTM C188-87
Aggregate	2.6	ASTM C127-15
Coarse Sand (CS)	2.43	ASTM C127-15
Sylhet Sand (SS)	2.43	ASTM C128-22
Medium Sand (MS)	2.3	ASTM C128-22
Fine Sand (FS)	2.2	ASTM C128-22
Brick Dust (BD)	2.2	ASTM C 128
Cement Fines – RMC Wastes (WCF)	2.31	ASTM C128-22
Ladle Furnace Slag (LFS)	2.59	ASTM C128-22
Recycled Block (RB)	2.1	ASTM C128-22
Construction Waste (CW)	2.2	ASTM C128-22
Jute Fiber (JF)	1.315	ASTM-D 3800–99, 2005
Polypropylene Fiber (PF)	0.91	ASTM-D 3800–99, 2005

Table 1: Specific Gravity Test Result of Materials

3.2.2 Fineness Modulus Test of Materials

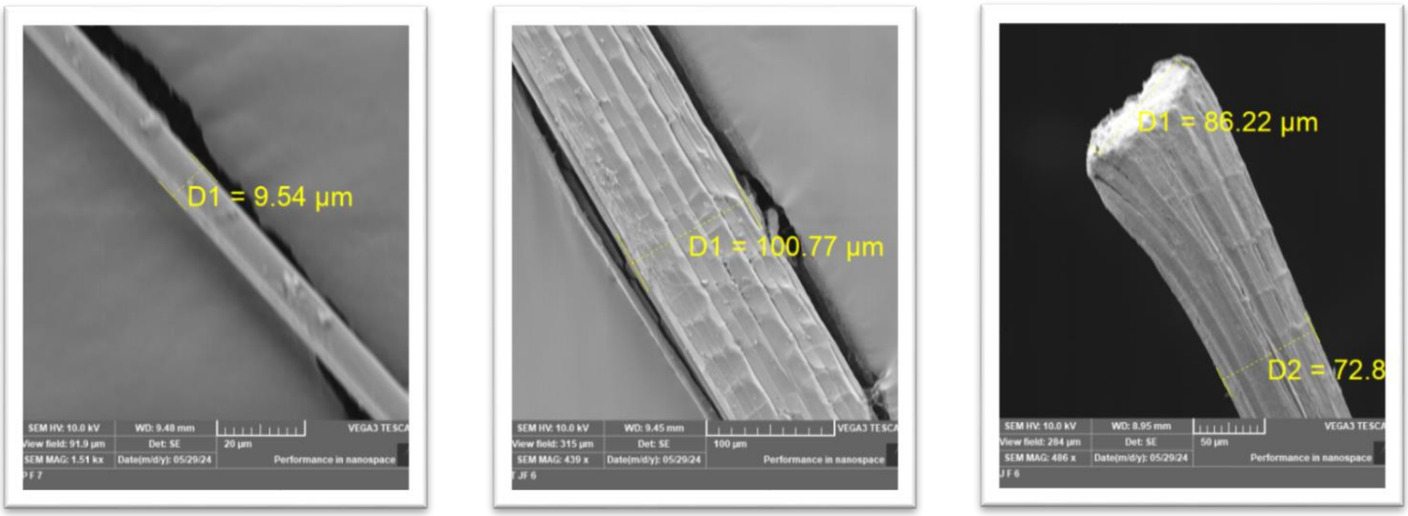
Similarly, the Fineness Modulus of the materials is listed in table below:

Materials	**Fineness Modulus**	**Specifications Used**
Coarse Sand (CS)	2.93	ASTM C136
Sylhet Sand (SS)	2.76	ASTM C136
Medium Sand (MS)	2.42	ASTM C136
Fine Sand (FS)	2.14	ASTM C136
Brick Dust (BD)	2.33	ASTM C136
Ladle Furnace Slag (LFS)	2.78	ASTM C136
Construction Waste (CW)	2.21	ASTM C136

Table 2: Fineness Modulus Test Result of Materials

3.2.3 Diameter Test of Fibers

For the diameter test of fibers, we examined untreated jute, treated jute and polypropylene fiber using a Scanning Electron Microscope (SEM). Scanning Electron Microscopy (SEM) examines material surfaces at high magnifications using a focused beam of electrons. This interaction produces signals that create detailed images of the surface's structure and composition. SEM is essential in science and engineering for analyzing material properties and behavior. The diameters of the fibers are illustrated in the figure. Here D1 indicates the diameter of fibers.



Diameter of Polypropylene Fiber

Diameter of Untreated Jute Fiber

Diameter of Treated Jute Fiber

Figure 5: Diameter of Jute and Polypropylene Fiber

3.3 Details of Specimens, Cases Investigated and Mix Design

3.3.1 Details of Specimens

The concrete block specimen prepared for this study has dimensions of 100 mm in width, 70 mm in height and 240 mm in length. The production process involves using a mixture machine to combine the raw materials, followed by a compressor machine that applies approximately 16 MPa of compressive pressure to shape the blocks. Subsequently, the blocks undergo a vibration process to ensure proper compaction. After the vibration process, the blocks are carefully removed from the mold and placed in an open area for drying. They are allowed to dry naturally in open air, a process that can take several days depending on the ambient temperature and humidity. During this time, the blocks continue to cure and gain strength as the hydration of the cement progresses. Once it is fully dried and solid, it is ready for further use and testing.

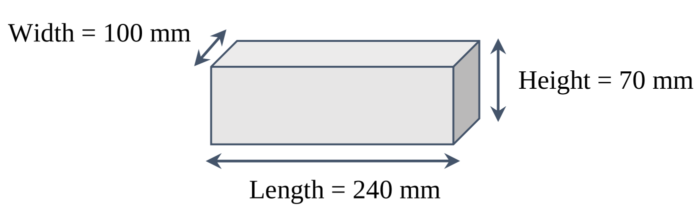
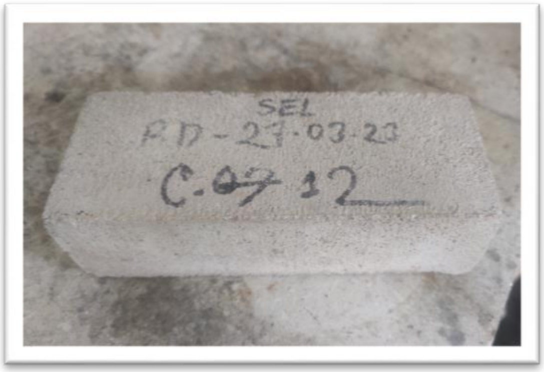


Figure 6: Unit Concrete Block Model



Concrete Block

Mixture Machine

Compressor Machine

Fresh Concrete Blocks

Figure 7: Concrete Block Preparation Process

For a new test procedure that will be used in our experiment, we developed an additional specimen type consisting of a 6-unit concrete block with mortar joints of 5 inches (approximately 127 mm) between each block. The total length of the large sized specimen is 1500 mm. Two struts were placed at the ends of the specimen to support the comparator for measuring length as well as length changes. The figure below provides a detailed illustration of the specimen, showing the arrangement of the concrete blocks, the mortar joints and the positioning of the struts. This setup is critical for achieving reliable and repeatable measurements, which are essential for evaluating the performance and behavior of the concrete block assembly under test conditions.

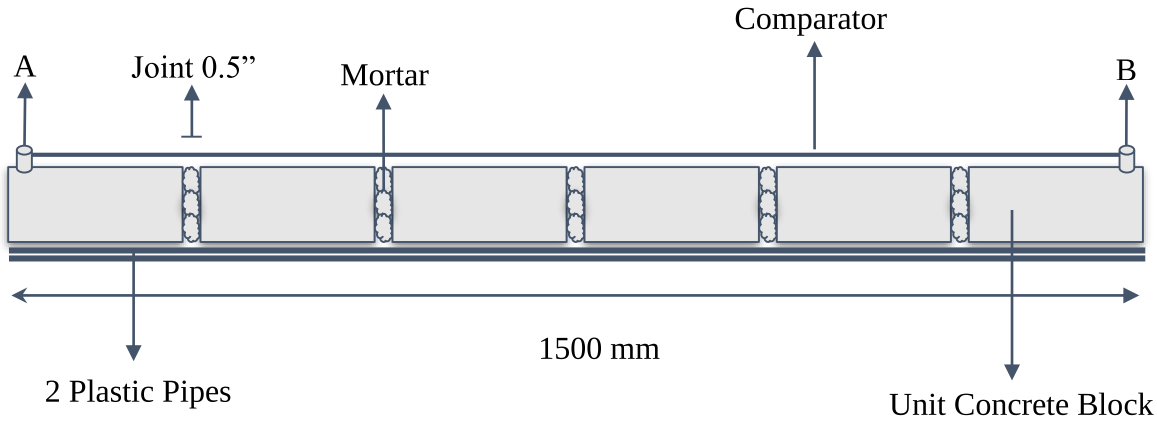


Figure 8: Large Sized Specimen Model

3.3.2 Cases Investigated

The study includes 14 cases of unit concrete blocks with varying percentages of by-products and fine aggregates. We used two different water-to-cement ratios: 0.30 and 0.25. In addition to these cases, the study also includes 10 cases incorporating different fiber percentages by the total concrete block volume that use the first case of the previous 14 cases. Specifically, we evaluated two fiber percentages: 0.3% and 0.4%. These cases involved both jute and polypropylene fibers, with jute fibers being tested at three different lengths (10 mm, 15 mm and 20 mm), while polypropylene fibers were tested at a single length of 10 mm. This approach aims to evaluate the impact of varying fiber types, lengths and percentages on the mechanical properties and overall performance of the concrete blocks.

Table 3: Cases using By-Products

		Percentage of Aggregates							
Cases	**W/C**	**CS %**	**SS %**	**MS %**	**FS %**	**BD %**	**WCF %**	**LFS %**	**CW %**
C50S30M20	0.3	50	30	20	0	0	0	0	0
C50S30M20 – LW	0.25	50	30	20	0	0	0	0	0
C50S30M20 - LC	0.3	50	30	20	0	0	0	0	0

C50S20M20F10	0.3	50	20	20	10	0	0	0	0
C40S20M20F20	0.3	40	20	20	20	0	0	0	0
C50S20M15F10B5	0.3	50	20	15	10	5	0	0	0
C50S20M10F10B5W5	0.3	50	20	10	10	5	5	0	0
C40S20M10F10B10W10	0.3	40	20	10	10	10	10	0	0
C30S20M20F20B10	0.3	30	20	20	20	10	0	0	0
C40S20M10B10CW20	0.3	40	20	10	0	10	0	0	20
C40S20M30L10	0.3	40	20	30	0	0	0	10	0
C50F45B5	0.3	50	0	0	45	5	0	0	0
C50F40B10	0.3	50	0	0	40	10	0	0	0
C50F35B15	0.3	50	0	0	35	15	0	0	0

Table 4: Cases using Jute Fiber

For Jute Fiber % and Length		
Cases	**%**	**Length (mm)**
CC-C50S30M20	0	-
TJ0.3%-L10	0.3	10
TJ0.3%-L15	0.3	15
TJ0.3%-L20	0.3	20
TJ0.4%-L10	0.4	10
TJ0.4%-L15	0.4	15
TJ0.4%-L20	0.4	20
RJ0.4%-L20	0.4	20

Table 5: Cases using Polypropylene Fiber

For Polypropylene Fiber % and Length		
Cases	**%**	**Length (mm)**
PP0.3%-L10	0.3	10
PP0.4%-L10	0.4	10

The legends for the case names are given below:

C – Coarse Sand, S – Sylhet Sand, M – Medium Sand, F – Fine Sand, B – Brick Dust, L – LFS, CW – Construction Waste, W – WCF, LW – Less Water, LC – Less Cement, 40 – 40 % Aggregate, C50S30M20 – Coarse Sand 30% Sylhet Sand 30% Medium Sand 20%

CC – Control Case, TJ – Treated Jute Fiber, RJ – Raw (Untreated) Jute Fiber, PP – Polypropylene Fiber

3.3.3 Mix Design for Concrete Blocks

The mix design for all the cases is detailed in table below:

Table 6: Mix Design using By-Products

Cases	C (kg/m³)	W/C	W (kg/m³)	Aggregate (kg/m³)	CS (kg/m³)	SS (kg/m³)	MS (kg/m³)	FS (kg/m³)	BD (kg/m³)	WCF (kg/m³)	LFS (kg/m³)	CW (kg/m³)
C50S30M20	205	0.3	61	1361	636	382	241	0	0	0	0	0
C50S30M20 – LW	205	0.25	51	1433	670	402	254	0	0	0	0	0
C50S30M20 - LC	191	0.3	57	1423	665	399	252	0	0	0	0	0
C50S20M20F10	205	0.3	61	1361	636	254	241	115	0	0	0	0
C40S20M20F20	205	0.3	61	1361	509	254	241	230	0	0	0	0
C50S20M15F10B5	205	0.3	61	1361	636	254	181	115	58	0	0	0
C50S20M10F10B5W5	205	0.3	61	1361	636	254	120	115	58	60	0	0
C40S20M10F10B10W10	205	0.3	61	1361	509	254	120	115	115	121	0	0
C30S20M20F20B10	218	0.3	66	1299	364	243	230	220	110	0	0	0
C40S20M10B10CW20	205	0.3	61	1361	509	254	120	0	115	0	0	230
C40S20M30L10	205	0.3	61	1361	509	254	361	0	0	0	136	0
C50F45B5	205	0.3	61	1361	636	0	0	518	58	0	0	0
C50F40B10	205	0.3	61	1361	636	0	0	461	115	0	0	0
C50F35B15	205	0.3	61	1361	636	0	0	403	173	0	0	0

Table 7: Mix Design using Jute Fibers

Cases	C (kg/m³)	W/C	W (kg/m³)	Aggregate (kg/m³)	CS (kg/m³)	SS (kg/m³)	MS (kg/m³)	Jute %	Jute (kg/m³)
CC-C50S30M20	205	0.3	61	1361	636	382	241	0	0
TJ0.3%-L10 TJ0.3%-L15 TJ0.3%-L20	205	0.3	61	1353	632	379	239	0.3	3.95
TJ0.4%-L10 TJ0.4%-L15 TJ0.4%-L20 RJ0.4%-L20	205	0.3	61	1350	631	379	239	0.4	5.26

Table 8: Mix Design using Polypropylene Fibers

Cases	C (kg/m³)	W/C	W (kg/m³)	Aggregate (kg/m³)	CS (kg/m³)	SS (kg/m³)	MS (kg/m³)	Polypropylene %	Polypropylene (kg/m³)
PP0.3%-L10	205	0.3	61	1353	632	379	239	0.3	3.95
PP0.4%-L10	205	0.3	61	1350	631	379	239	0.4	5.26

3.4 Method of Evaluations

For our thesis work, we conducted a series of tests on concrete block specimen to evaluate their different mechanical and durability properties:

1. Compressive Strength Test:

The compressive strength of the concrete blocks was determined in accordance with ASTM C 109, the standard test method for hydraulic cement mortars. Each specimen was tested three times to ensure accuracy and reliability. The values from these tests were averaged to obtain a single representative result for each specimen. This process accounts for minor variations or inconsistencies in individual results, providing a more precise assessment of the compressive strength. This figure illustrates the process in detail.

Figure 9: Compressive Strength Test

2. Modulus of Rupture Test:

The flexural strength of the concrete blocks was measured in accordance with ASTM C67/C67M-21, the standard test method for sampling and testing brick and structural clay tile. This test was conducted using a 3-point loading system, which is designed to evaluate the blocks' resistance to bending forces.

In this procedure, the following steps were undertaken:

1. **Test Setup:** The blocks were placed on two supports with a known span length between them. A loading nose was positioned at the midpoint of the span to apply a load.
2. **Loading Procedure:** The load was gradually applied at the midpoint of the block until failure occurred. The 3-point loading system ensures that the maximum bending moment is applied at the center of the block.
3. **Data Collection:** The maximum load at failure was recorded for each block. This load was then used to calculate the flexural strength, also known as the modulus of rupture.

This figure below illustrates the process in detail.

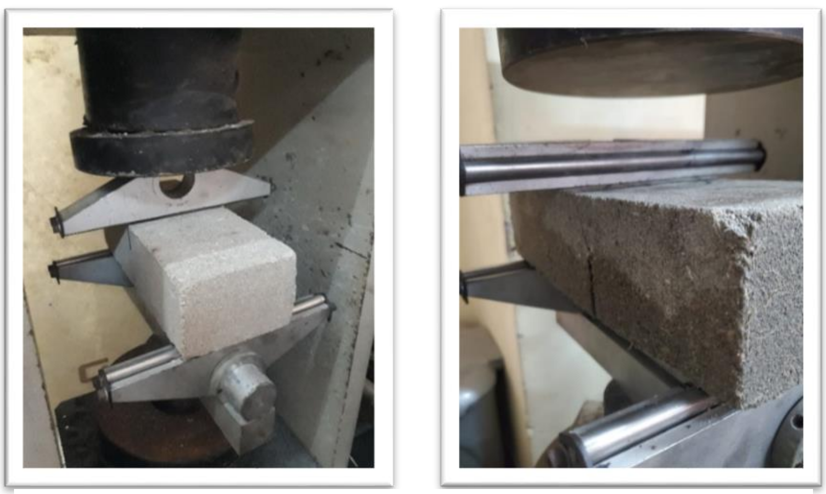


Figure 10: Modulus of Rupture Test

3. Permeable Voids and Boiling Water Absorption Test (ASTM C 642):

We evaluated the porosity and absorption capacity of the concrete blocks to understand their resistance to moisture ingress, which is vital for durability. This involved preparing and drying samples to a constant weight, then immersing them in water to measure absorbed volume and weight increase. The results were analyzed to determine porosity and absorption capacity, providing insights into the blocks' long-term performance in various environmental conditions.

4. Linear Drying Shrinkage Test:

i) Individual Specimen:

The linear drying shrinkage test, conducted according to ASTM C 426-99 for individual specimens, evaluates how much a concrete block contracts as it dries. Here's a detailed explanation of the procedure:

Preparation of Specimens: Concrete block specimens are initially brought to a state of Saturated Surface Dry (SSD), ensuring they are uniformly moist throughout without free surface water.

Measurement of Dimensions: The initial length of the specimens is measured in the SSD condition, providing a baseline measurement.

Drying Procedure: Specimens are then placed in an oven set at a specified temperature (typically around 50-60°C) to accelerate drying. The drying process continues until the specimens reach an Oven Dry (OD) state, where all moisture has been removed.

Final Measurements: Once dried to OD, the length of the specimens is measured again. The difference between the initial length (SSD) and the final length (OD) represents the linear drying shrinkage of the specimen.

Calculation: The linear drying shrinkage is calculated using the formula:

$$\text{Linear Drying Shrinkage} = (\text{Initial Length (SSD)} - \text{Final Length (OD)} / \text{Initial Length (SSD)}) \times 100\%$$

This calculation yields the percentage change in length due to drying, indicating the amount of shrinkage the concrete block experiences. The figures illustrate the process:

SSD Condition of Blocks

Oven Drying of Blocks

Oven Dry Weight | *Reference Bar -Zero Check* | *Linear Shrinkage Measurement*

Figure 11: Linear Drying Shrinkage Test of Individual Specimen

ii) Large Sized Specimen (New Test Procedure):

We developed and applied a new procedure to measure linear drying shrinkage in larger concrete block specimens. By using this refined procedure for larger specimens, we aimed to achieve more accurate and reliable measurements of linear drying shrinkage. This enhanced accuracy is crucial for assessing the dimensional stability of larger concrete block specimens, ensuring they meet performance standards and durability requirements in construction applications.

Measurement Procedure:

- **Initial Measurements:** The initial length of each specimen was measured in the SSD condition before exposure to the varying environmental conditions.
- **Drying Process:** Specimens were then subjected to the specified temperature and humidity conditions in controlled environmental chambers. These conditions were maintained for 48 hours for each exposure condition
- **Final Measurements:** After 48 hours, the final length of each specimen was measured.

Then the linear drying shrinkage was calculated using the same formula as for the individual specimens.

Here is the setup for linear drying shrinkage test setup for large sized specimen:

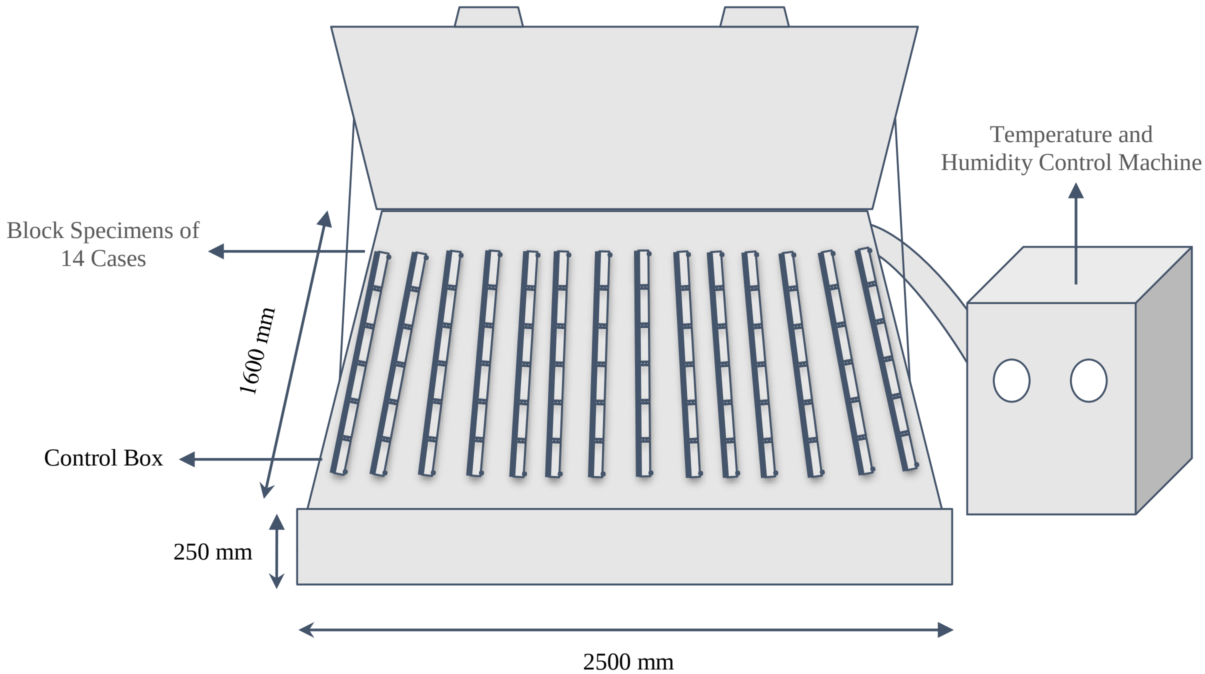


Figure 12: Drying Shrinkage Test Setup Model for Large Sized Specimen

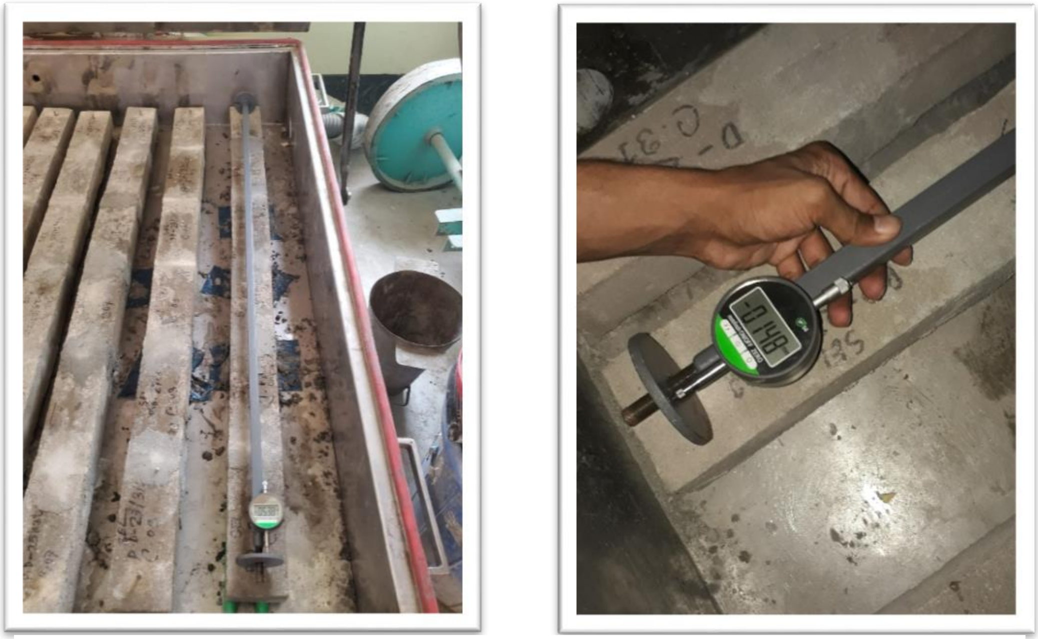


Figure 13: Drying Shrinkage Measurement of Large Sized Specimens

These tests collectively provided comprehensive data on the mechanical strength, durability and dimensional stability of the concrete blocks, crucial for our thesis research.

3.5 Exposure Conditions

To assess the drying shrinkage of large-sized specimens incorporating both by-products and fibers, we conducted a new test method under varying temperature and humidity conditions. These conditions were chosen to simulate a wide range of environmental scenarios that the specimens might encounter in real-world applications. The exposure conditions were categorized based on three different temperatures and three corresponding humidity levels at each temperature, resulting in a total of nine distinct exposure scenarios. The detailed description of these conditions is as follows:

Temperature and Humidity Conditions:

1. At 20°C:

- Specimens were exposed to a relative humidity of 100%.
- Specimens were exposed to a relative humidity of 80%.
- Specimens were exposed to a relative humidity of 60%.

2. At 30°C:

- Specimens were exposed to a relative humidity of 100%.
- Specimens were exposed to a relative humidity of 80%.
- Specimens were exposed to a relative humidity of 60%.

3. At 40°C:

- Specimens were exposed to a relative humidity of 100%.
- Specimens were exposed to a relative humidity of 80%.
- Specimens were exposed to a relative humidity of 60%.

Total Exposure Cases:

These combinations of temperature and humidity levels produced nine different exposure cases, each designed to observe the effects of varying environmental conditions on the drying shrinkage behavior of the specimens. The cases are summarized as follows:

1. Case 1: 20°C and 100% RH
2. Case 2: 20°C and 80% RH
3. Case 3: 20°C and 60% RH
4. Case 4: 30°C and 100% RH
5. Case 5: 30°C and 80% RH
6. Case 6: 30°C and 60% RH
7. Case 7: 40°C and 100% RH
8. Case 8: 40°C and 80% RH
9. Case 9: 40°C and 60% RH

This systematic variation in environmental conditions allowed for a comprehensive analysis of the drying shrinkage behavior under different temperature and humidity scenarios. The insights gained from these tests are crucial for understanding the performance and durability of the materials in diverse environmental conditions, ultimately guiding the development of more resilient construction materials.

Chapter 4: Results and Analysis

4.1 Linear Drying Shrinkage Test Results

4.1.1 For Individual Specimens

Table 9: Drying Shrinkage Test Results (Blocks using By-Products)

Cases	Difference with reference bar (SSD) mm	Difference with reference bar (Dry) mm	Change in linear dimension ΔL mm	Linear Drying Shrinkage S %
C50S30M20	6.463	6.384	0.079	0.0326
C50S30M20 – LW	5.154	5.046	0.108	0.0445
C50S30M20 - LC	8.011	7.935	0.076	0.0313
C50S20M20F10	5.764	5.698	0.066	0.0271
C40S20M20F20	3.955	3.886	0.069	0.0286
C50S20M15F10B5	7.327	7.279	0.048	0.0198
C50S20M10F10B5W5	11.278	11.238	0.04	0.0165
C40S20M10F10B10W10	9.855	9.799	0.056	0.0231
C30S20M20F20B10	10.358	10.323	0.035	0.0144
C40S20M10B10CW20	4.023	3.968	0.055	0.0227
C40S20M30L10	4.963	4.902	0.061	0.0252
C50F45B5	7.523	7.444	0.079	0.0326
C50F40B10	9.587	9.512	0.075	0.0310
C50F35B15	7.421	7.338	0.083	0.0342

C – Coarse Sand, S – Sylhet Sand, M – Medium Sand, F – Fine Sand, B – Brick Dust, L – Ladle Furnace Slag
CW – Construction Waste, W – WCF, LW – Less Water, LC – Less Cement, XX – XX % Aggregate
LDS – Linear Drying Shrinkage

Graph 1: Linear Drying Shrinkage % vs Cases (Blocks using By-Products)

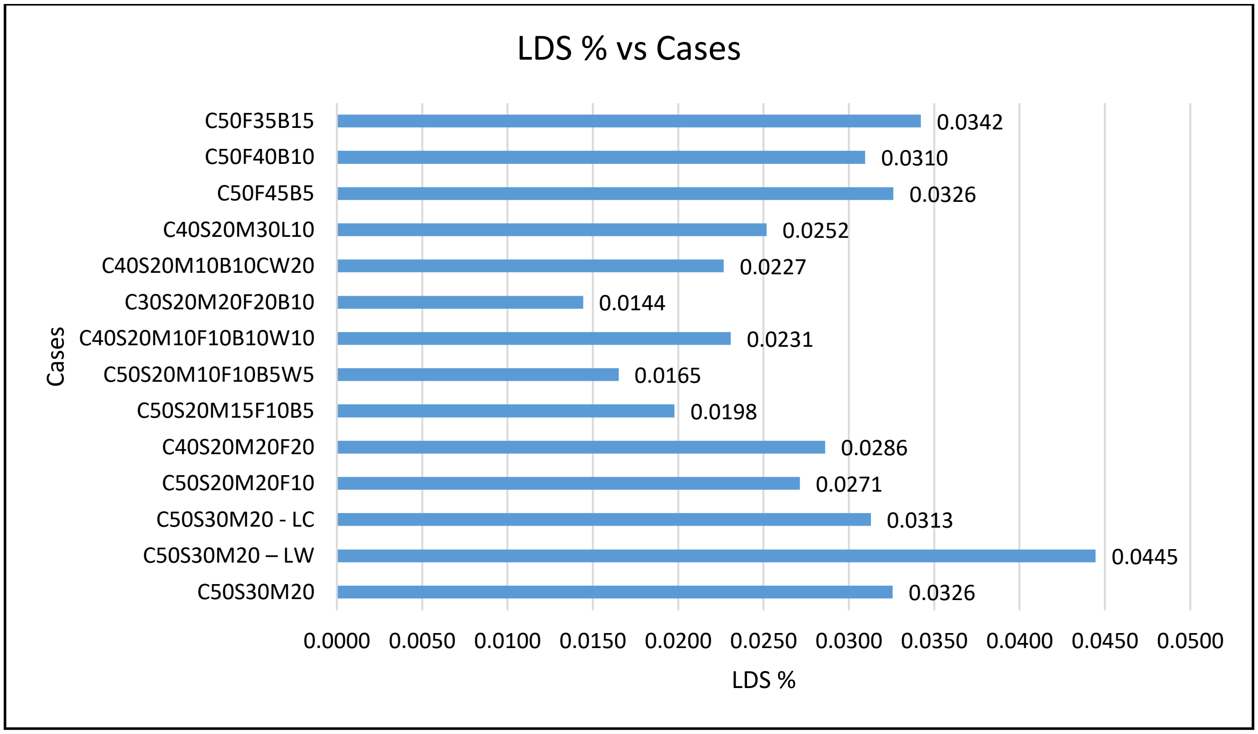
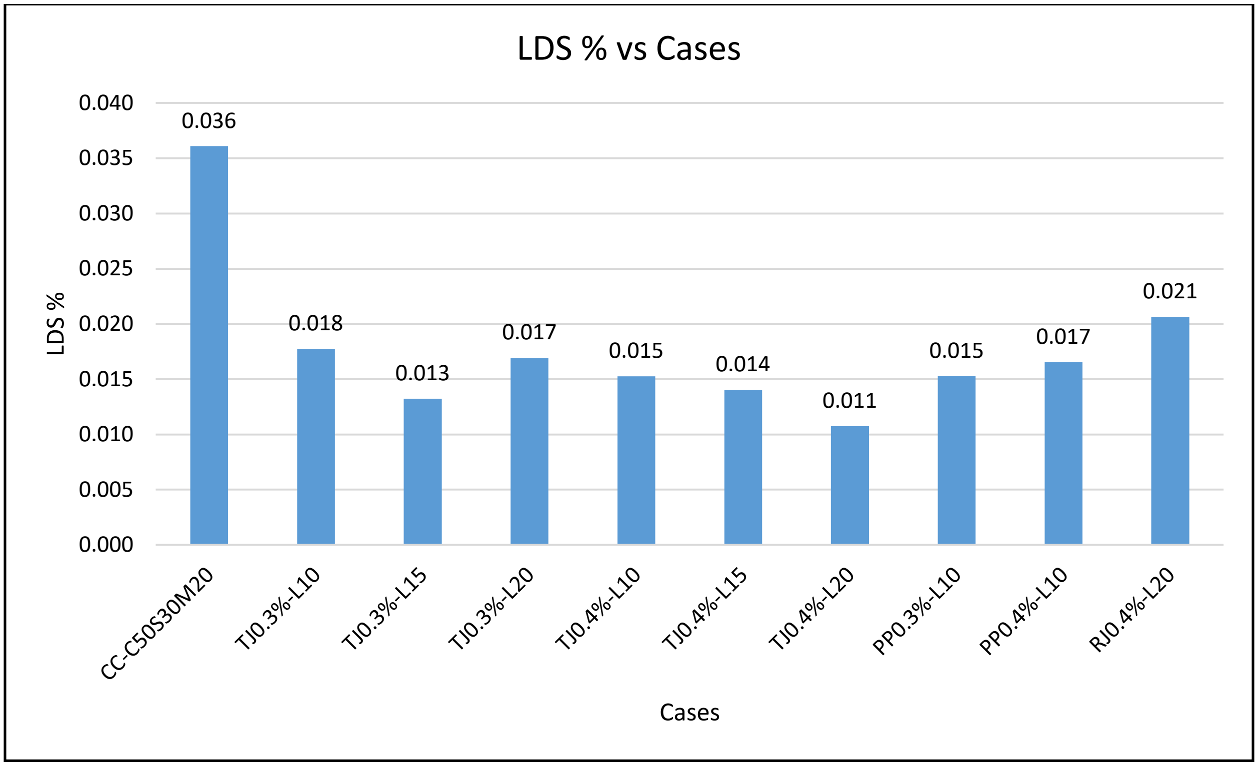


Table 10: Drying Shrinkage Test Results (Blocks using Fibers)

Cases	**Difference with reference bar (SSD) mm**	**Difference with reference bar (Dry) mm**	**Change in linear dimension ΔL mm**	**Linear Drying Shrinkage S %**	**% Reduction from CC**
CC-C50S30M20	3.052	2.965	0.087	0.036	0.00
TJ0.3%-L10	1.462	1.419	0.043	0.018	50.85
TJ0.3%-L15	-2.849	-2.881	0.032	0.013	63.37
TJ0.3%-L20	-0.702	-0.743	0.041	0.017	53.13
TJ0.4%-L10	0.788	0.751	0.037	0.015	57.71
TJ0.4%-L15	0.328	0.294	0.034	0.014	61.13
TJ0.4%-L20	2.354	2.328	0.026	0.011	70.24
PP0.3%-L10	2.456	2.419	0.037	0.015	57.65
PP0.4%-L10	1.269	1.229	0.04	0.017	54.21
RJ0.4%-L20	4.822	4.772	0.05	0.021	42.84

CC – Control Case, TJ – Treated Jute Fiber, RJ – Raw (Untreated) Jute Fiber, PP – Polypropylene Fiber

Graph 2: Linear Drying Shrinkage % vs Cases (Blocks using Fibers)



The observations indicate that adding brick dust helps to prevent drying shrinkage. Conversely, a low water-to-cement ratio promotes drying shrinkage. Using less cement also reduces drying shrinkage. Additionally, not utilizing Sylhet Sand and Medium Sand can cause further drying shrinkage. For the cases using fiber, the control case (CC) has the highest LDS at 0.036%. Treated jute fiber (TJ) and raw jute fiber (RJ) both reduce LDS, with values ranging from 0.011% to 0.021% depending on fiber length and percentage. Polypropylene fiber (PP) also lowers LDS, with values around 0.015% to 0.017%. Overall, adding fibers generally decreases LDS compared to the control, with the specific impact varying based on fiber type, length and percentage used.

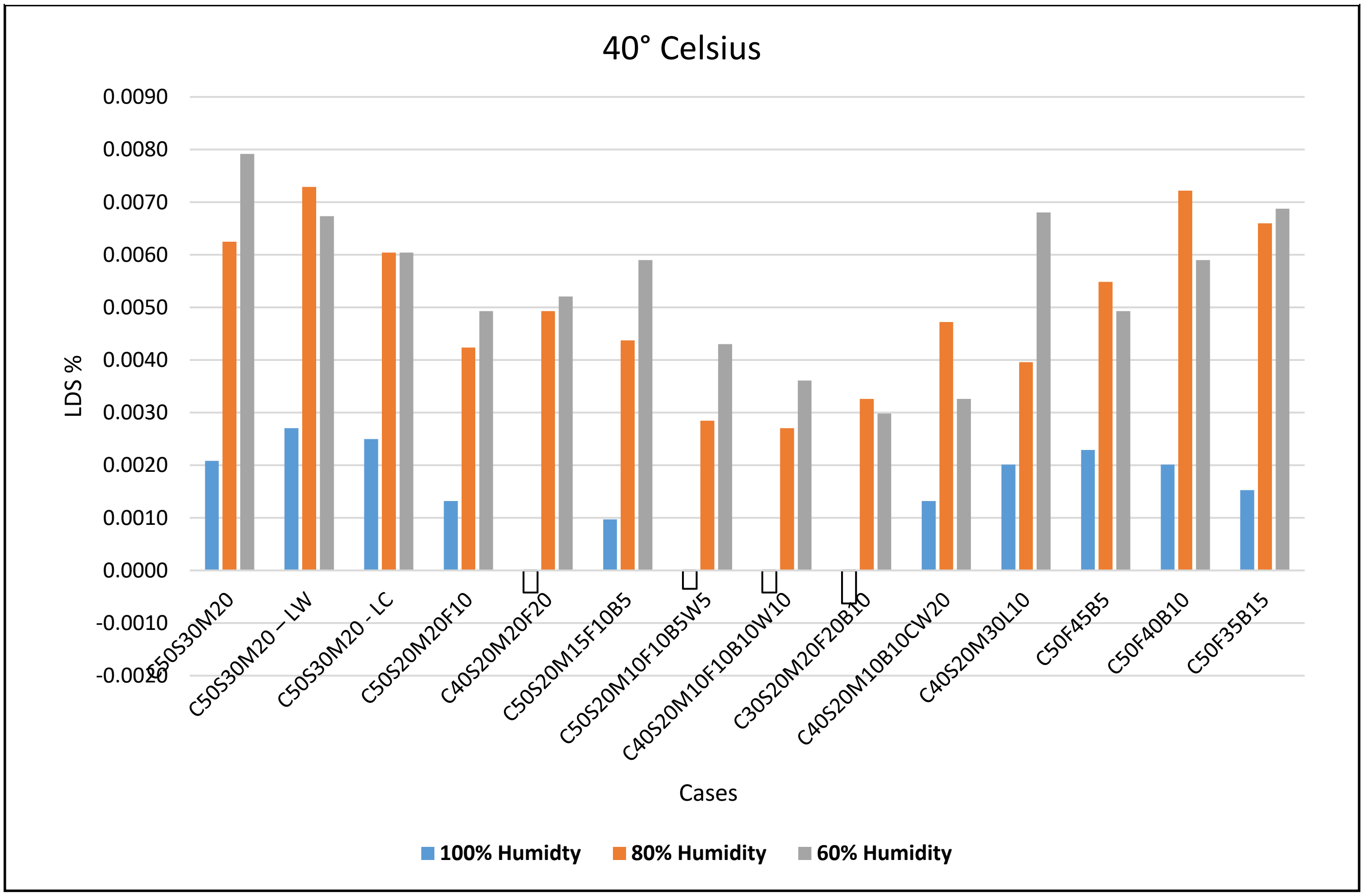
4.1.2 For Large Sized Specimens

The graphs below represent the comparison among the conditions for three different temperatures (20°C, 30°C, 40°C) and humidity conditions (60%,80%,100%).

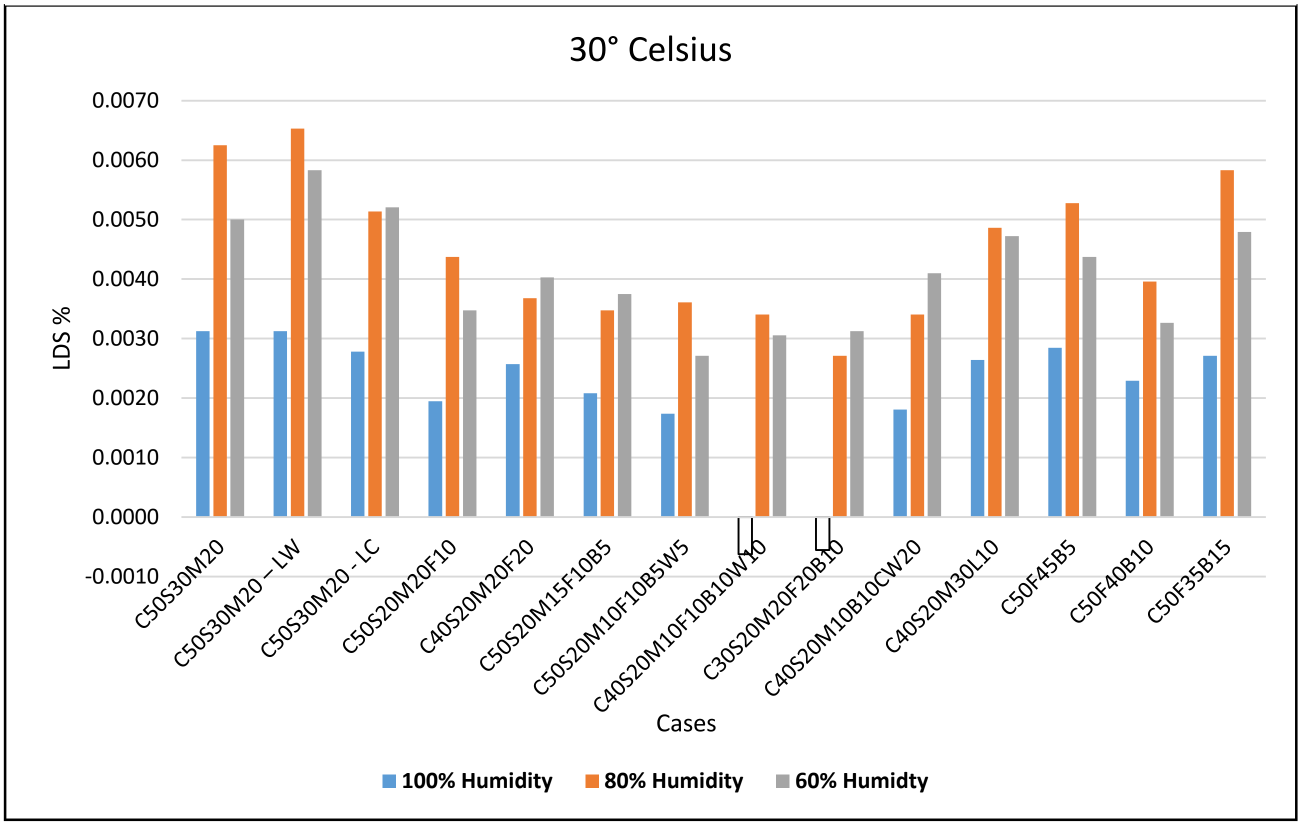
For Blocks using By-Products

(3 humidity conditions for a same temperature)

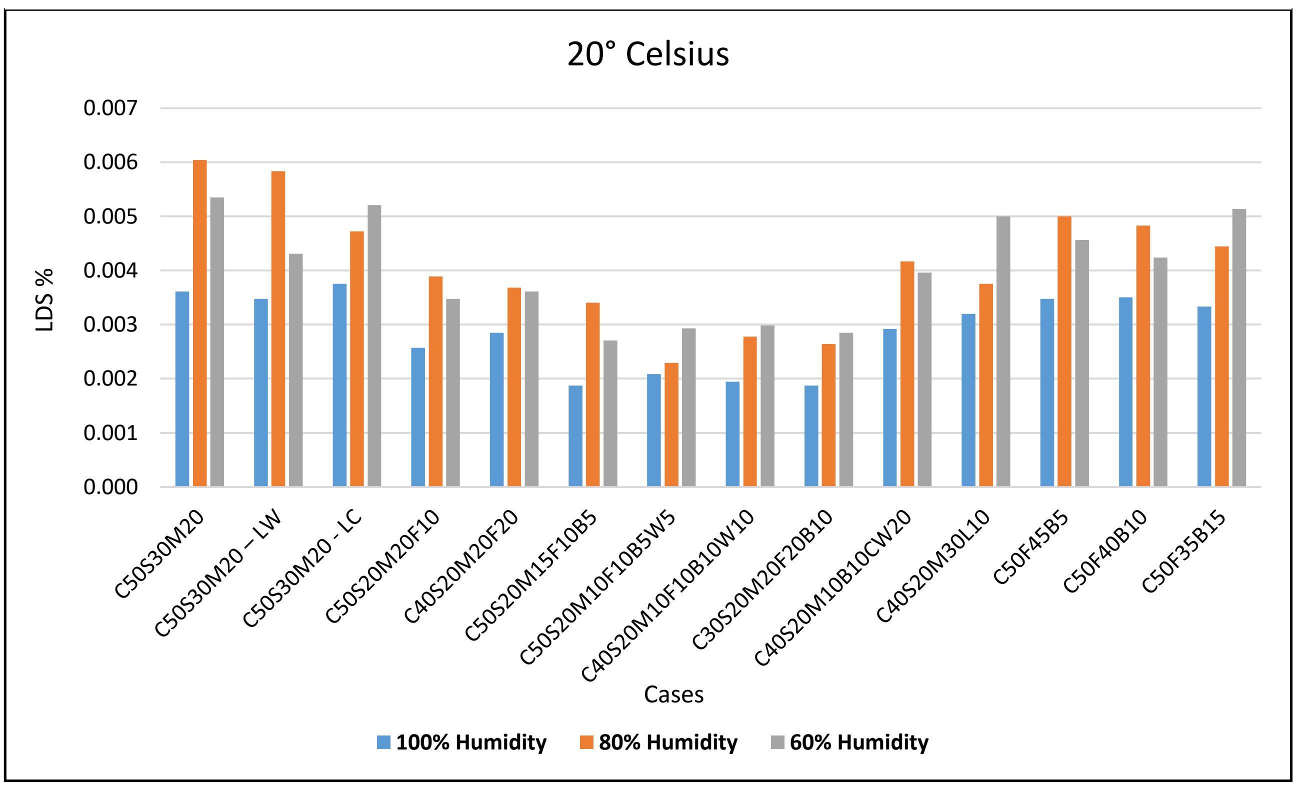
Graph 3: Dying Shrinkage vs Cases for Large Sized Specimen at 40° C



Graph 4: Dying Shrinkage vs Cases for Large Sized Specimen at 30° C



Graph 5: Dying Shrinkage vs Cases for Large Sized Specimen at 20° C



The analysis describes that

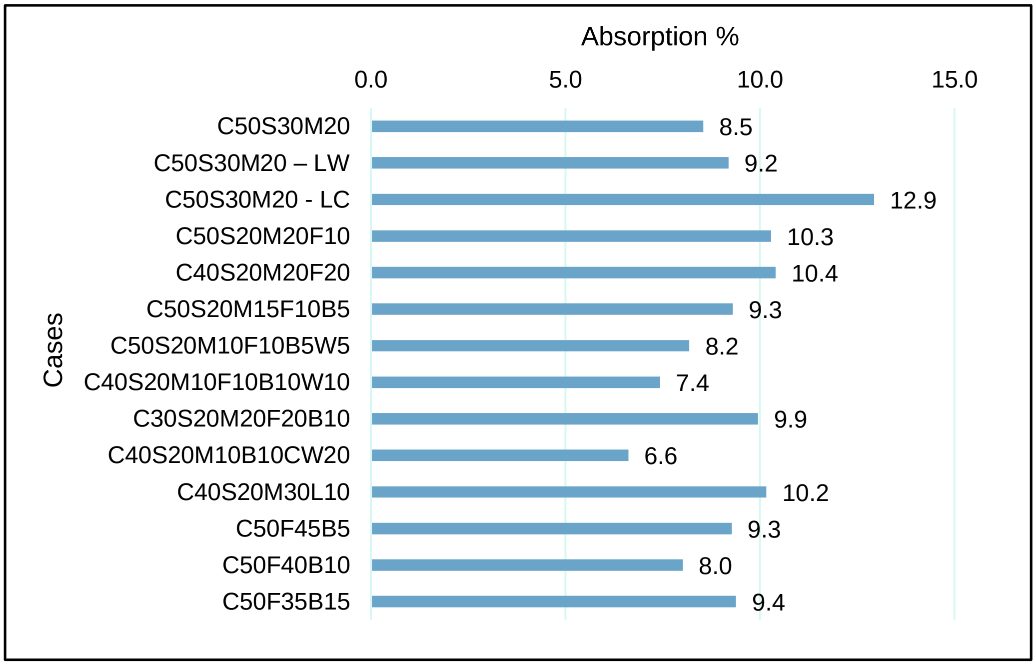
- The highest drying shrinkage occurs in high temperatures and low humidity because water evaporates more quickly in these conditions.
- At low temperatures and high humidity evaporation occurs more slowly and drying shrinkage is observed minimal.
- Drying shrinkage is highly reduced when brick dust and WCF are used optimally.

4.2 Absorption Capacity % Test Result

Table 11: Absorption % Test Results

Cases	Absorption Capacity %
C50S30M20	8.5
C50S30M20 – LW	9.2
C50S30M20 - LC	12.9
C50S20M20F10	10.3
C40S20M20F20	10.4
C50S20M15F10B5	9.3
C50S20M10F10B5W5	8.2
C40S20M10F10B10W10	7.4
C30S20M20F20B10	9.9
C40S20M10B10CW20	6.6
C40S20M30L10	10.2
C50F45B5	9.3
C50F40B10	8.0
C50F35B15	9.4

Graph 6: Absorption % vs Cases

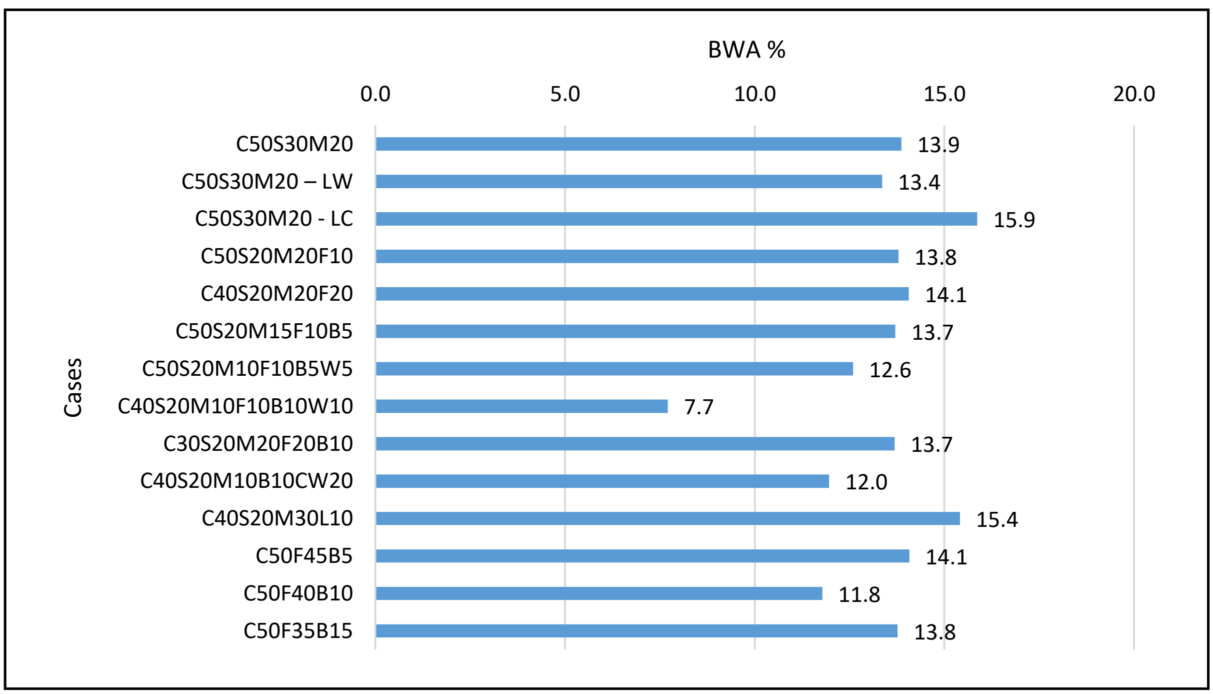


4.3 Boiling Water Absorption (BWA) % Test

Table 12: Boiling Water Absorption (BWA) % Test Results

Cases	Boiling Water Absorption %
C50S30M20	13.9
C50S30M20 – LW	13.4
C50S30M20 - LC	15.9
C50S20M20F10	13.8
C40S20M20F20	14.1
C50S20M15F10B5	13.7
C50S20M10F10B5W5	12.6
C40S20M10F10B10W10	7.7
C30S20M20F20B10	13.7
C40S20M10B10CW20	12.0
C40S20M30L10	15.4
C50F45B5	14.1
C50F40B10	11.8
C50F35B15	13.8

Graph 7: BWA % vs Cases



4.4 Modulus of Rupture Test

Table 13: Modulus of Rupture Test Results (Concrete Block using By-Products)

Cases	Modulus of Rupture (MPa)
C50S30M20	1.61
C50S30M20 – LW	1.51
C50S30M20 - LC	1.49
C50S20M20F10	1.56
C40S20M20F20	1.82
C50S20M15F10B5	2.28
C50S20M10F10B5W5	2.14
C40S20M10F10B10W10	2.23
C30S20M20F20B10	2.33
C40S20M10B10CW20	2.35
C40S20M30L10	2.56
C50F45B5	2.09
C50F40B10	2.49
C50F35B15	2.90

Graph 8: Modulus of Rupture vs Cases

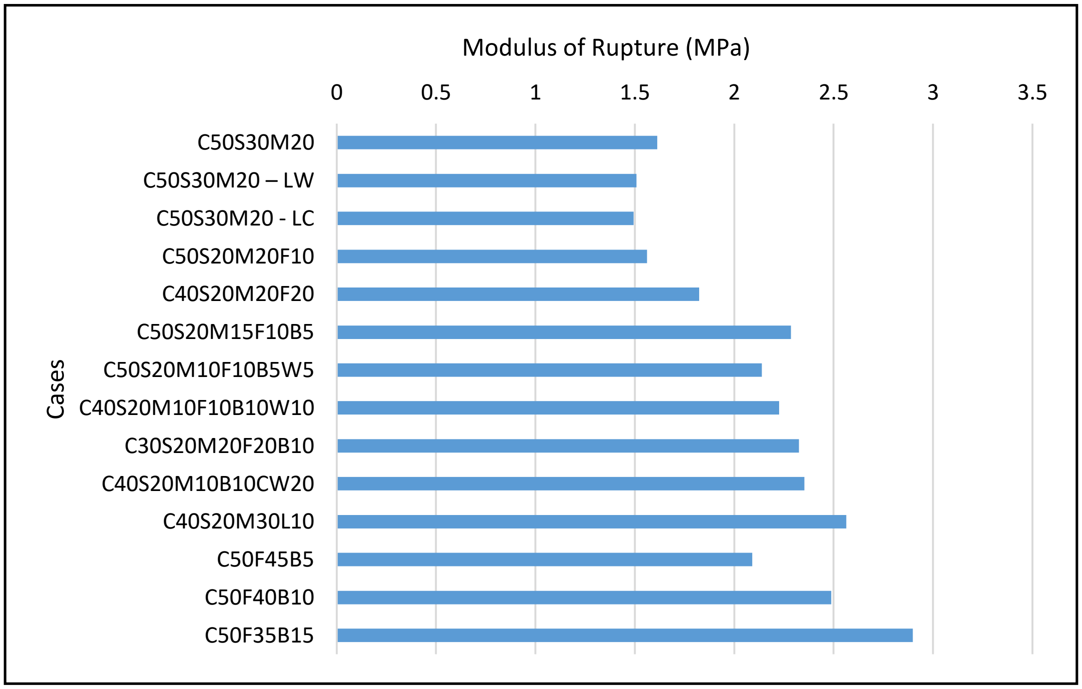
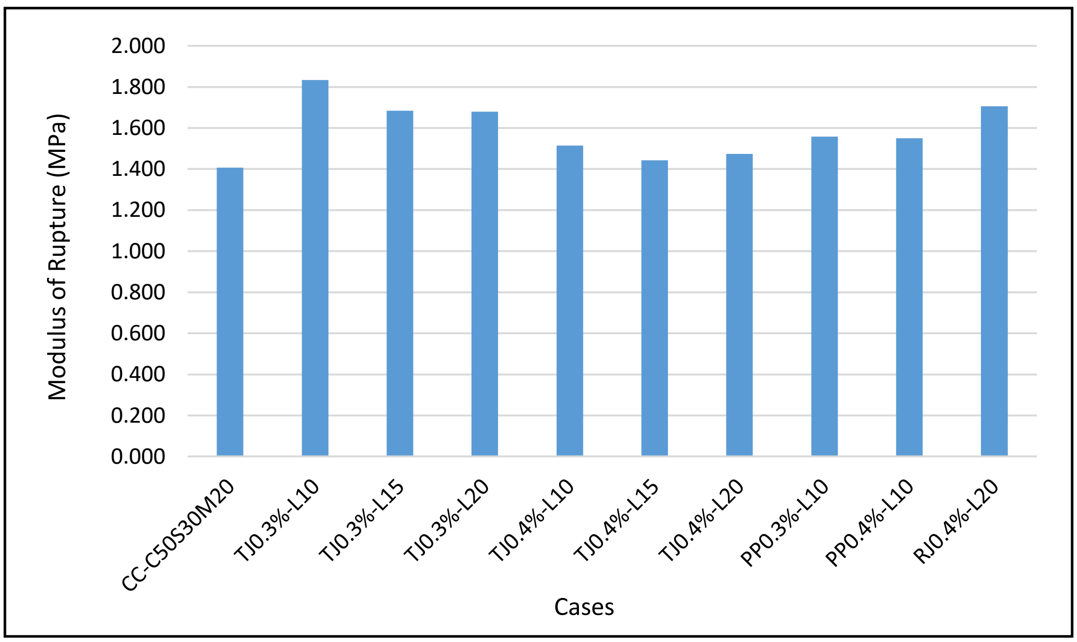


Table 14: Modulus of Rupture Test Results (Concrete Block using Fibers)

Cases	Modulus of Rupture (MPa)
CC-C50S30M20	1.406
TJ0.3%-L10	1.835
TJ0.3%-L15	1.683
TJ0.3%-L20	1.680
TJ0.4%-L10	1.515
TJ0.4%-L15	1.442
TJ0.4%-L20	1.474
PP0.3%-L10	1.559
PP0.4%-L10	1.550
RJ0.4%-L20	1.706

Graph 9: Modulus of Rupture vs Cases (Blocks using Fibers)



The results conclude that

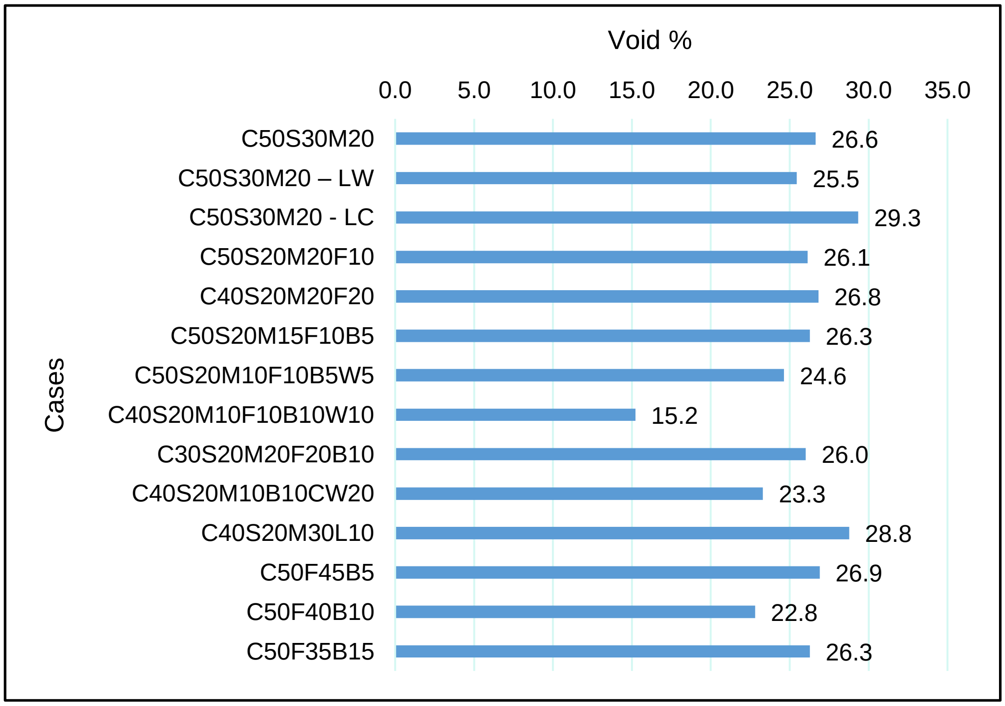
- Incorporating 15% brick dust enhances the modulus of rupture.
- The use of both brick dust and WCF together significantly increases values compared to samples made without these by-products.
- Incorporation of Fibers increases modulus of rupture.

4.5 Void % Test

Table 15: Void % Test Results

Cases	Void %
C50S30M20	26.6
C50S30M20 – LW	25.5
C50S30M20 - LC	29.3
C50S20M20F10	26.1
C40S20M20F20	26.8
C50S20M15F10B5	26.3
C50S20M10F10B5W5	24.6
C40S20M10F10B10W10	15.2
C30S20M20F20B10	26.0
C40S20M10B10CW20	23.3
C40S20M30L10	28.8
C50F45B5	26.9
C50F40B10	22.8
C50F35B15	26.3

Graph 10: Void % vs Cases



4.6 Compressive Strength Test

Table 16: Compressive Strength Test Results (Blocks using By-Products)

Cases	Compressive Strength (psi)
C50S30M20	1499.78
C50S30M20 – LW	1473.77
C50S30M20 - LC	1513.78
C50S20M20F10	1354.54
C40S20M20F20	1313.35
C50S20M15F10B5	1784.96
C50S20M10F10B5W5	1686.62
C40S20M10F10B10W10	1917.20
C30S20M20F20B10	1421.35
C40S20M10B10CW20	1778.15
C40S20M30L10	1494.66
C50F45B5	1957.01
C50F40B10	2202.57
C50F35B15	2009.83

Graph 11: Compressive Strength vs Cases (Blocks using By-Products)

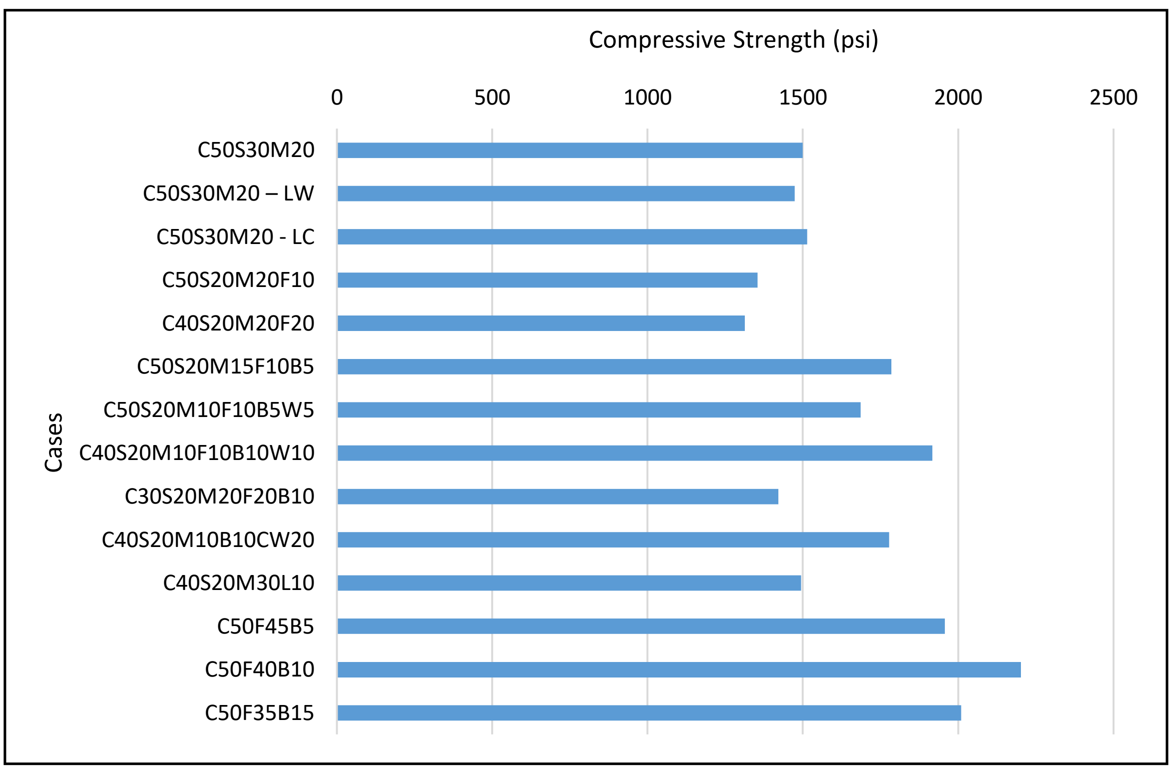
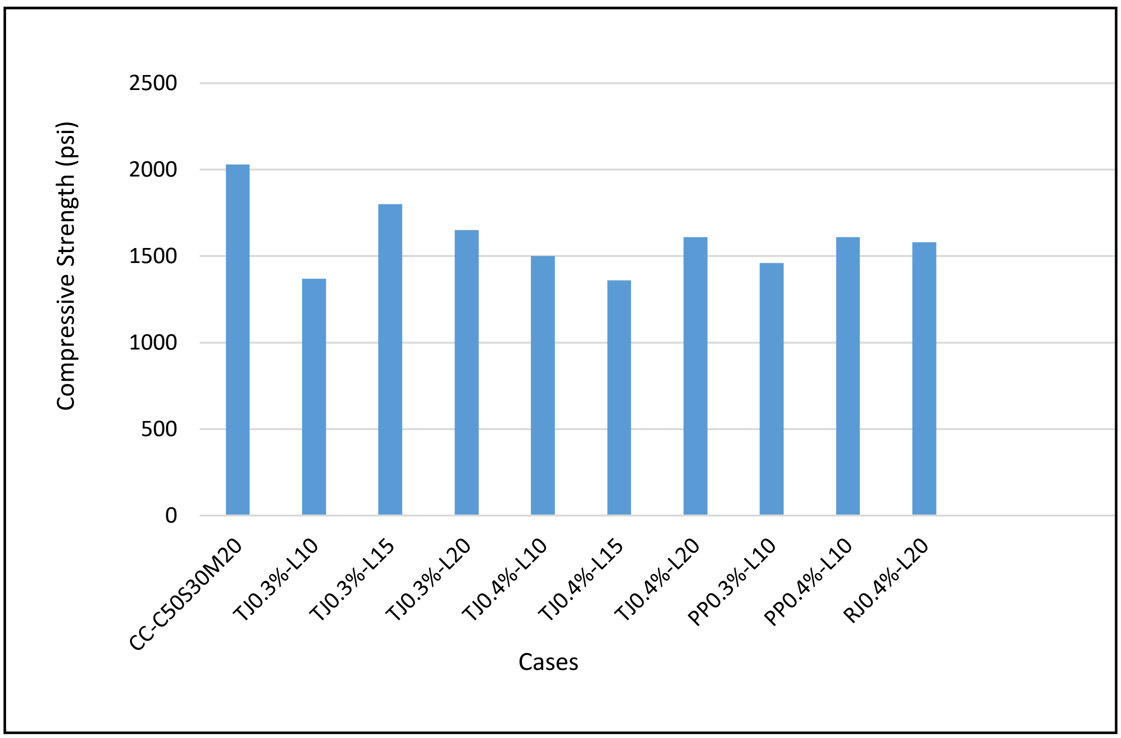


Table 17: Compressive Strength Test Results (Blocks using Fibers)

Cases	Compressive Strength (psi)
CC-C50S30M20	1620
TJ0.3%-L10	1340
TJ0.3%-L15	1370
TJ0.3%-L20	1430
TJ0.4%-L10	1560
TJ0.4%-L15	1290
TJ0.4%-L20	1480
PP0.3%-L10	1460
PP0.4%-L10	1640
RJ0.4%-L20	1630

Graph 12: Compressive Strength vs Cases (Blocks using Fibers)

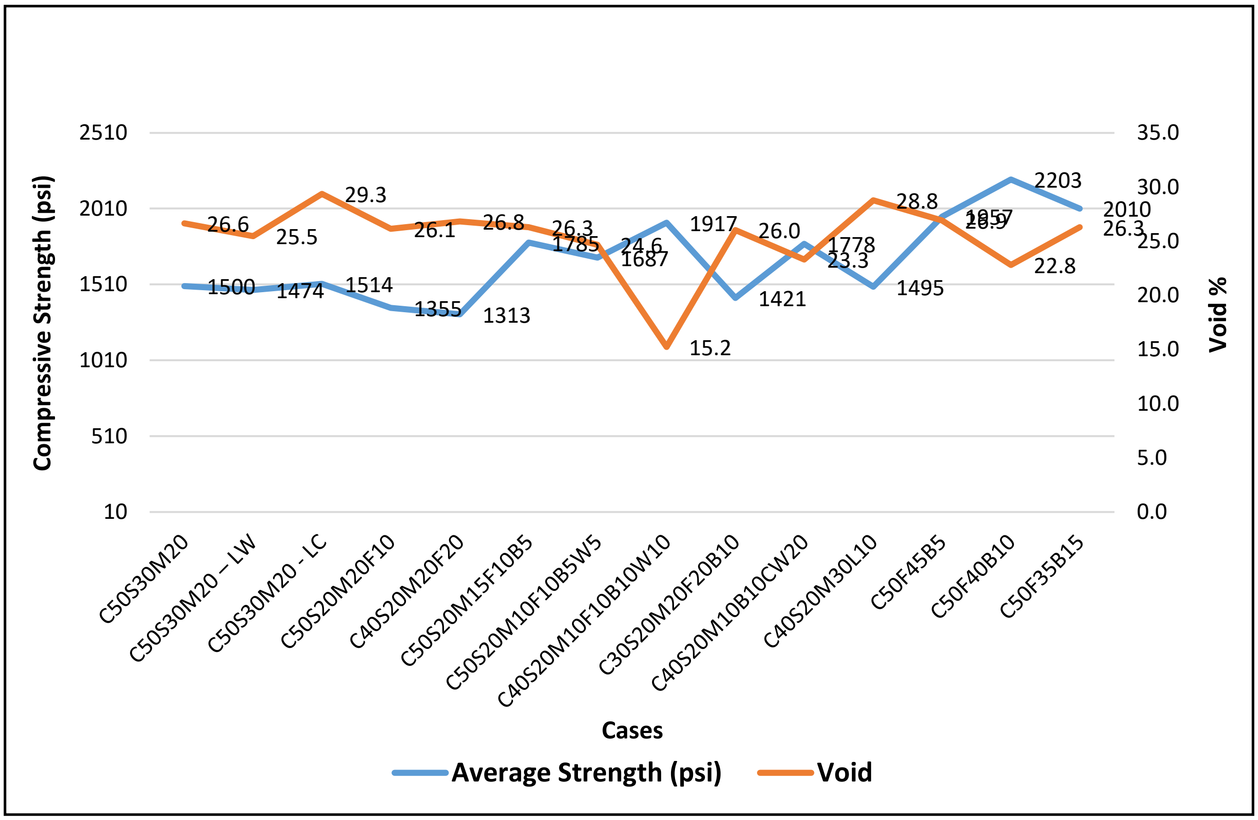


From the observation it may conclude that

- Adding brick dust increases the overall compressive strength of concrete blocks. On the other hand, not using by-products results in a relatively lower average strength.
- For our cases incorporation of jute and polypropylene fiber decreases compressive strength
- 0.3% dosage and 15 mm jute length shows higher value within the blocks with fibers.
- Untreated jute relatively reduces compressive strength.
- For the specimens using polypropylene fiber shows higher value than the same dosage and length of jute fiber.

4.7 Comparison between Compressive Strength (psi) and Void %

Graph 13: Compressive Strength vs Void % (Blocks using By-Products)



The analysis says that when percentage of void increases in concrete blocks, average strength decreases.

Chapter 5: Conclusion and Recommendation

5.1 General

The primary objective of this study was Controlling Drying Shrinkage of Concrete Blocks using By-Products (Construction Waste, Brick Dust, Waste Cement Fines, Ladle Furnace Slag, Recycled Block etc.) and controlling Drying Shrinkage of Concrete Blocks using Jute Fiber and Polypropylene Fiber.

This chapter describes the summary of the research findings based on the results and discussions in Chapter 4. Moreover, the conclusion and recommendations for this investigation are also mentioned in this chapter.

5.2 Conclusion

The following observation was found based on the analytical study –

- **Incorporation of both Brick Dust and WCF for individual specimen and large sized concrete blocks shows significant reduction in linear drying shrinkage.**
- **For individual specimen Inclusion of both Brick Dust and WCF shows significant rise in average strength.**
- **Inclusion of Jute and Polypropylene Fiber reduces average strength for our cases.**
- **Incorporation of 15 mm length jute with 0.3% dosage shows higher strength value for the cases where used jute fiber.**
- **The higher the temperature rises, the greater the drying shrinkage.**
- **Samples containing polypropylene fiber exhibit higher values compared to those with an equivalent dosage and length of jute fiber.**
- **At low temperature and high humidity drying shrinkage is observed least because the rate of moisture loss is reduced from the sample blocks.**

5.3 Recommendation

Our findings on the drying shrinkage of concrete blocks employing by-product materials, jute fiber and polypropylene fiber lead to several recommendations for further research and practical applications. First and foremost, fiber dispersion in the concrete mix needs to be enhanced. Implementing advanced mixing techniques or using chemical dispersants may result in more equal distribution, which improves structural performance. Furthermore, optimizing the curing conditions and transportation techniques is crucial to maintaining the blocks' integrity and limiting damage that could compromise their strength. Future study could explore the use of nanoparticles or hybrid fiber systems to improve the mechanical properties and durability of concrete blocks.

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