Production of Light Weight Concrete Blocks Using Waste Styrofoam

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Certification

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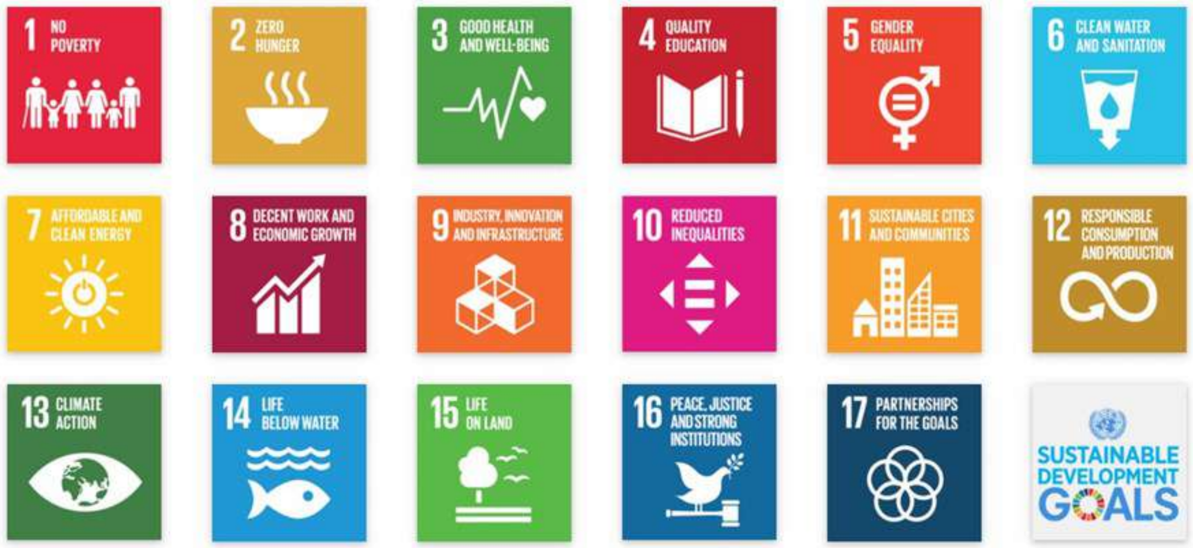
Production of Light Weight Concrete Blocks Using Waste Styrofoam

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	**Description of SDG**	**SDG No**	**Description of SDG**
SDG 1	No Poverty	**SDG 9**	**Industry, Innovation, and Infrastructure**
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	**SDG 11**	**Sustainable Cities and Communities**
SDG 4	Quality Education	**SDG 12**	**Responsible Consumption and Production**
SDG 5	Gender Equality	**SDG 13**	**Climate Change**
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	**Decent Work and Economic Growth**	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals



Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	**Depth of analysis required**	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	**Depth of knowledge required**	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	**Extent of applicable codes**	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	**Consequences**	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	**Range of resources**	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	**Level of interaction**	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	**Innovation**	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	**Consequences to society and the environment**	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

Lightweight concrete plays an important role in high-rise buildings. The weight of structural elements of such structures increases the design loads and ultimately increases the cost of construction. Therefore, it is mandatory to reduce the weight of structures. Aggregates occupy a major portion of the concrete volume. Therefore, reducing the weight of aggregate ultimately reduces the weight of concrete. Apart from this, a huge amount of energy is required for heating and cooling buildings. For this purpose, it is suggested that insulated building components would result in less heating and cooling system. Waste Styrofoam is a lightweight material and is being disposed of in large amounts. The accumulation of waste Styrofoam as a landfill is a serious threat to the environment. Therefore, this study attempts to utilize waste Styrofoam as a partial replacement of aggregate to produce lightweight concrete. Concrete blocks were produced by replacing coarse aggregate at a dosage of 25%, 50%, and 75% by volume of coarse aggregate. The blocks were investigated for physical, mechanical, and thermal insulation properties. The results of the study suggest that replacing 50% of coarse aggregate can result in a lightweight concrete block with acceptable physical, mechanical, and thermal insulation properties.

Keywords: Concrete; Lightweight; thermal insulation; mechanical properties; physical properties.

Undertaking

I certify that the project **Production of Light Weight Concrete Blocks Using Waste Styrofoam** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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Chapter 1

1.1 Introduction

Since the 1950s, expanded polystyrene (EPS), a lightweight polymer, has been utilized in engineering applications. EPS, also known as expanded polystyrene, is a rigid cellular plastic that was first developed in Germany in 1950 (Abd, Dhamya Gh, & Maan Hattem, 2016). Since 1958, it has been a part of packaging solutions. Although it contains 98% air, the remaining portion is composed of small, spherical EPS beads, which are only composed of carbon and hydrogen (Ali, Ezzat H.A. Fahmy , Mohamed N. AbouZeid, & Yoursy B.I. Shaheen, 2020). It is unable to absorb water due to its closed cell structure. It is impact resistant and possesses the qualities of thermal and sound insulation. Foam made of polystyrene does not biodegrade. These include less self-weight in structures, lighter weights during construction, and higher thermal resistance.

The prevailing consensus is that lightweight concrete is defined as having a density of no more than 1800 kg/m3 (AõÈtcin, 2000). The utilization of leftover Styrofoam as a partial substitute for conventional aggregates in the manufacture of lightweight concrete has garnered significant interest in recent times owing to its possible advantages for the environment and economy. Reducing the quantity of waste transported to landfills and the need for natural resources can be achieved by substituting waste Styrofoam, a non-biodegradable substance that occupies a lot of space in landfills, for coarse aggregates in concrete (Elkordi & B.A. Herki, 2018). In addition to having better thermal insulation qualities, lightweight concrete made from leftover Styrofoam is perfect for use in structures where energy economy is a top concern. Furthermore, incorporating leftover Styrofoam into concrete may reduce the material's overall weight, which will make installation and transportation simpler and more affordable. Nevertheless, there are several drawbacks to making lightweight concrete from leftover Styrofoam, such as possible decreases in durability and compressive strength. To guarantee that the final product satisfies the necessary requirements for strength and durability, it is crucial to carefully assess its qualities and modify the mix's proportions as needed (Fernando & M.T.R. Jayasinghe, 2017). All things considered, there are a number of advantages to be gained from producing lightweight concrete from leftover Styrofoam, including decreased waste, increased energy efficiency, and cheaper production costs.

1.2 Statement of the problem

Currently, millions of tons of garbage made of polystyrene and Styrofoam are produced worldwide, polluting the environment. More stringent national and international environmental rules have increased the cost of disposing of polystyrene (Gawale, Shubham Mishra, & Harshal Sambare, 2016). Furthermore, construction work is problematic since typical concrete blocks are heavy and difficult to manage. Furthermore, the heat-conductive nature of these blocks leads to temperature fluctuations and discomfort within buildings. To improve waste management, support environmental sustainability, and increase the use and thermal performance of concrete blocks, it is imperative to solve these issues.

1.3 Goals/Aims & Objectives

The aim of the project is to use waste Styrofoam to produce lightweight concrete blocks.

The following objectives have been set for the study.

1. To investigate the physical and mechanical characteristics of Styrofoam-made concrete blocks.

2. To examine the thermal insulation properties of Styrofoam-made lightweight concrete blocks.

1.4 Scope of the Study

The purpose of the study is to assess several important characteristics of concrete building blocks. We will examine the mechanical properties, particularly the compressive strength, in order to evaluate the blocks' structural integrity. We will also look at their thermal insulation qualities at the same time to see how well they can impede heat transfer. Furthermore, in order to assess the structural appropriateness of the blocks, we will weigh each unit volume of the blocks when they are fully dry by measuring their dry density. Finally, to determine their resistance to water infiltration, we shall evaluate their water permeability. Together, these evaluations of the mechanical, thermal, physical, and water-resistant qualities of the concrete blocks will provide a comprehensive picture of their performance and appropriateness for a range of building uses.

1.4 Significance of the Study

This study solves the urgent problem of Styrofoam waste, which is important in addressing environmental sustainability (Gunavel, S. Aishwarya, & K. Indhumathi, 2020). This waste material may be recycled into lightweight concrete blocks, which reduces environmental impact and provides a sustainable waste management solution, according to the study. Furthermore, these blocks' enhanced insulating qualities boost energy efficiency, lowering carbon emissions and encouraging sustainability in the building sector. By minimizing heat transfer and temperature swings, the Styrofoam in the concrete blocks serves as thermal insulation, improving thermal comfort inside structures. This feature improves a building's energy efficiency even more, which lowers energy use and improves residents' thermal comfort (K., Krishna Rao Akula, & Mahesh V., Experimental investigation on lightweight concrete by replacing the coarse aggregate with coconut shell and expanded polystyene beads and using polypropylene fiber, 2020). By using lighter, more manageable blocks, the project also improves building efficiency, resulting in higher output and lower labor costs. Utilizing leftover Styrofoam also offers cost-effectiveness because it may reduce the requirement for additional structural support and transportation expenses.

By combining leftover Styrofoam into lightweight concrete blocks, this study addresses multiple Sustainable Development Goals (SDGs) of the United Nations and provides a sustainable solution. It encourages responsible consumption and production (SDG 12), lowers carbon emissions (SDG 13), and improves energy efficiency in urban living settings (SDG 11). The creative strategy streamlines building procedures to promote decent labor and economic growth (SDG 8), while also aligning with industry, innovation, and infrastructure goals (SDG 9). This research provides a comprehensive answer to the environmental and economic challenges and is an excellent example of a holistic approach to sustainability, aligning with many SDGs.

Chapter 2 Literature Review

One of the most popular building materials in the world is concrete. Here is a quick rundown of how concrete is used in the building sector:

Applications in Structure: Concrete is widely utilized in airports, subways, bridges, tunnels, buildings, and for columns, beams, slabs, walls, and other structural elements (K., Krishna Rao Akula, & Mahesh V., Experimental investigation on lightweight concrete by replacing the coarse aggregate with coconut shell and expanded polystyene beads and using polypropylene fiber, 2020). It offers the longevity and high compressive strength required for various structural applications. Concrete that has been reinforced can be utilized for slabs, beams, and other components that are subjected to tensile forces.

Roads: Concrete is used to build curbs, sidewalks, streets, and other features. It offers the durability to resist weathering effects and the strength required to handle vehicle traffic (Kanchanapiya & Pawadee Methacanon, 2019). Airports and ports employ pavement made of reinforced concrete.

Pre-cast Components: Using certain molds, a manufacturer precasts concrete elements such as walls, beams, columns, and slabs, which are subsequently brought to the construction site. Better quality control and speedier construction are made possible by this. Precast concrete is often employed in tall buildings and bridges.

Architectural Elements: For aesthetically pleasing purposes in buildings, concrete is molded into a variety of architectural shapes and patterns. These consist of ornamental features, cladding, facades, etc. It is possible to manufacture thin concrete pieces thanks to glass fiber reinforced concrete (Kulkarni & Prof.G.N.Shete, 2022).

Dams: Because of its thermal mass, impermeability, and long-term strength growth, mass concrete is employed in the construction of dams. It offers the stability required for holding onto water (Kanchanapiya & Pawadee Methacanon, 2019).

Tanks and Silos: Large liquid and dry storage facilities, including water tanks, oil tanks, silos, etc., can be built with reinforced concrete.

Pipelines: Concrete pipes are widely utilized in irrigation, sewage, and water supply purposes. They offer durability, strength, and impermeability.

Coastal Structures: Jetties, docks, and ports are built using reinforced concrete. It offers the necessary toughness in corrosive maritime conditions (Naik & F.ASCE, 2020).

In conclusion, because of its strength, durability, impermeability, fire resistance, and ease of construction, concrete is a flexible building material that can be utilized to create nearly any kind of structure. It may be molded into any shape and utilized for a wide range of purposes with reinforcement.

Furthermore, the following are some important statistics and facts on the usage of concrete in the construction sector:

Concrete construction stats

Globally, concrete is the most often utilized building material. Approximately 40 million cubic meters of concrete were utilized globally in 1900. In 1997, this grew to around 6.4 billion cubic meters, or more than one cubic meter per person year (Nadh & K. Muthumani, 2017).

In the 20th century, there has been a sharp increase in the use of cement, a vital component of concrete. In 1900, the world produced about 10 million tonnes of cement; by 1998, that amount had increased to 1.6 billion tonnes (Maghfouri, Mohammad Saberian, & Rajeev Roychand, 2022). Concrete is the material we use the most on the world, second only to water. We use almost 30 billion tonnes of concrete annually worldwide.

The gross national product per capita and cement consumption per capita are directly correlated, suggesting that rising living standards and infrastructural requirements are what fuel the need for concrete (Mwero & Vane Onchaga, 2020). In industrialized nations, however, consumption reaches saturation.

The density of regular weight concrete is about 2400 kg/m3. The density of lightweight concrete ranges from 800 to 1800 kg/m3 (P & Sowmya S M, 2018). When use this method instead of regular weight concrete, structural dead loads can be decreased.

Numerous constructions, such as homes, roads, floating maritime structures, cladding panels, and insulating elements, have been built using expanded polystyrene (EPS) concrete. Typically, its density is between 800 and 1800 kg/m3 (Rahman, M. Akter, & H. S. Sarker, 2023).

Around 2.5 million tonnes were produced annually in Western Europe and 2.3 million tonnes in the USA, accounting for approximately 14 million tonnes of total EPS production in the early 2000s. Much of it is disposed of in landfills.

An estimated 300,000 tonnes of EPS waste—enough to fill 15,000 Olympic swimming pools—go to landfills annually in the UK (Sandanayake & Yanni Bouras, 2020). This demonstrates how EPS may be recycled into lightweight concretes.

In conclusion, infrastructure requirements and development have caused a significant increase in the use of concrete during the past century. When compared to standard concrete, lightweight concretes made of waste materials like EPS provide potential savings in terms of both building costs and environmental impact (Ali, Ezzat H.A. Fahmy , Mohamed N. AbouZeid, & Yoursy B.I. Shaheen, 2020).

Applications and importance of concrete in the construction industry:

Versatility: Concrete is perfect for a wide range of construction applications, including buildings, bridges, roads, dams, tunnels, sidewalks, walls, and so on. It may be poured into any shape or form. On the spot, it may be shaped into any shape (Tang, Y. Lo, & A. Nadeem, 2008).

Strength: Compared to other building materials, concrete has a significantly higher compressive strength. It can tolerate strong forces and loads because of this. Concrete constructions that are properly engineered are incredibly resilient and long-lasting (Sulong, Siti Aisyah Syaerah Mustapa, & , Muhammad Khairi Abdul Rashid, 2018).

Affordability: When compared to other building materials like steel, concrete is comparatively less expensive. Cement, aggregates, and water are easily obtained ingredients. It can be produced locally. It is therefore cost-effective for building on a broad scale (Sabaa & Rasiah Sri Ravindraraja, 1997).

Durability: Concrete structures have a design life of more than 100 years, making them incredibly robust. Concrete that is properly constructed is less prone to rust, rot, or decay, which simplifies maintenance (Van & Tho Vu Dinh,, 2018).

Sustainability: Heat is slowly absorbed and radiated by concrete due to its high thermal mass. Building energy costs are decreased as a result. It also makes use of fly ash and other industrial wastes. Its sustainability is being improved by production methods.

Aesthetics: There are numerous ways to tint and texture concrete. Concrete that is decorative and architectural is becoming increasingly common in infrastructure and modern buildings.

Simple construction: When compared to other materials, concrete construction is comparatively quick and straightforward. The availability of ready-mix concrete has expedited the procedure even more. Concrete may be poured in any shape thanks to formwork.

In conclusion, concrete is affordable, sustainable, robust, long-lasting, and fireproof. Because of these qualities, it is the preferred material for many uses in contemporary infrastructure and building (Gawale, Shubham Mishra, & Harshal Sambare, 2016). Megastructures can now be erected thanks to concrete, which has also completely changed our built environment.

Drawback of heavy concrete:

Greater dead load: Structural self-weight from heavy concrete necessitates larger structural elements. Costs go up as a result (Elkordi & B.A. Herki, 2018).

Seismic vulnerability: Larger inertia forces during earthquakes due to heavier mass result in more seismic damage (K., Krishna Rao Akula, & Mahesh V., Experimental investigation on lightweight concrete by replacing the coarse aggregate with coconut shell and expanded polystyene beads and using polypropylene fiber, 2020).

Transport and construction challenges: It is challenging to move, hoist, and install heavy concrete components, necessitating the use of heavy lifting equipment.

Thermal insulation: Because regular concrete has a higher thermal conductivity, it provides less insulation and raises building energy expenses (Nadh & K. Muthumani, 2017).

Acoustic insulation: Regular concrete offers less noise insulation and acoustic damping because of its larger density.

Cracking risk: Normal concrete's increased bulk and rigidity cause higher loads and, when restrained early on, cracking (Sabaa & Rasiah Sri Ravindraraja, 1997).

Sustainability: When using regular concrete to create a given construction volume, more raw materials like cement and aggregates are used.

Limitations in large spans: Bridges, floors, and other structures needing additional support have limited spans due to heavy self-weight (Tang, Y. Lo, & A. Nadeem, 2008).

Durability concerns: Because of its controlled shrinkage, denser regular concrete is more vulnerable to freeze-thaw damage and cracking.

Architectural forms are limited by heavy concrete, which restricts the shapes, textures, and thin elements that can be created.

Slower construction: Heavy concrete takes longer to place, compact, and finish, which slows down building (K., Krishna Rao Akula, & Mahesh V., Experimental investigation on lightweight concrete by replacing the coarse aggregate with coconut shell and expanded polystyene beads and using polypropylene fiber, 2020).

In conclusion, lightweight concrete seeks to address the structural, seismic, insulating, durable, fast-track, and sustainable issues presented by regular concrete's higher density and weight.

Lightweight concrete:

The density of lightweight concrete is 600–1800 kg/m3, whereas conventional concrete has a density of 2200–2600 kg/m3 (Naik & F.ASCE, 2020). Use of lightweight aggregates such as expanded clay, shale, and slate results in a lower density. Lightweight aggregates produce a more porous concrete matrix. yields improved fire resistance and thermal insulation at the expense of reduced strength and rigidity. Common uses include floors, roofs, and bridges where it's crucial to minimize dead load. Because lightweight aggregates have special qualities, careful mix design, manufacture, and placement are necessary. compromises strength and insulation compared to regular concrete, but still achieves structural requirements while reducing weight (Sandanayake & Yanni Bouras, 2020).

Origin of lightweight concrete:

To lower the dead load of structures: Concrete constructions such as buildings and bridges can have their self-weight considerably decreased by using lightweight concrete. Longer spans, thinner sections, smaller structural parts, such as foundations and columns, and total cost savings are made possible by this (Abd, Dhamya Gh, & Maan Hattem, 2016).

To increase thermal insulation: Because lightweight concrete has more porosity and air void content than regular weight concrete, it usually has lower thermal conductivity. Building thermal comfort and energy efficiency both increase as a result (Gunavel, S. Aishwarya, & K. Indhumathi, 2020).

To lessen structural damage from earthquakes: Lightweight concrete constructions' smaller bulk causes them to experience less inertia forces during seismic events. In regions that are prone to earthquakes, this is extremely crucial (Nadh & K. Muthumani, 2017).

To make construction and transportation easier: Lightweight concrete's reduced weight makes construction and transportation simpler. Installing and lifting prefabricated lightweight concrete components is simple (Patidar, Mayur Singi, & Abhijeet Bhawsar, 2019).

To offer sound-absorbing material: Better acoustical insulation is produced by lightweight concrete's porous nature, which scatters sound waves and lowers sound transmission.

To create customized concretes: Lightweight aggregates enable the creation of concretes that are specifically suited for uses such as sound barriers, marine concrete, and concrete blocks (P & Sowmya S M, 2018).

In conclusion, the development of lightweight concrete technology as an alternative to traditional concrete was driven by the need for lower self-weight, improved insulating qualities, ease of building, and specialized applications. This development was further facilitated by the availability of appropriate lightweight aggregates.

Waste materials that have been used in lightweight concrete:

A pozzolanic byproduct of the palm oil industry is palm oil fuel ash increases the lightweight concrete's durability and strength.

Crushed coconut shells can be used to partially replace coarse aggregates, which lowers density.

Bottom Ash: Concrete produced from coal-fired thermal plants has a stronger strength and a lower density.

Perlite: For extremely light-weight concrete, expanded perlite is utilized as an aggregate. provides effective insulation against heat (Gunavel, S. Aishwarya, & K. Indhumathi, 2020).

Vermiculite: When utilized as a lightweight aggregate, exfoliated vermiculite exhibits good fire resistance.

Tire shreds: Rubber shreds from used tires decrease density and increase resilience.

Glass Cullet: Crushed glass scrap can take the place of several natural aggregates. enhances strength (Abd, Dhamya Gh, & Maan Hattem, 2016).

In conclusion, employing these waste byproducts as substitute lightweight aggregates during the concrete production process can lead to sustainable construction.

Non-biodegradable waste:

These types of waste do not decompose naturally; it endures undamaged for millennia or centuries. Styrofoam, plastics, synthetics, metals, and e-waste are a few examples. Builds up quickly since it doesn't break down; difficult to get rid of (Elkordi & B.A. Herki, 2018).

Impact of non-biodegradable waste:

Heavy metals and hazardous compounds that contaminate soil and water can be released by non-biodegradable garbage. This damages aquatic life and renders the water hazardous to consume. Methane and other greenhouse gasses are released during the breakdown of non-biodegradable garbage. Climate change is exacerbated by methane. In towns and the natural world, non-biodegradable trash accumulates (Nadh & K. Muthumani, 2017). Ecosystems are harmed by this disruption. Animals that ingest plastic or become entangled in it suffer injuries. Waste that is not biodegradable takes hundreds of years to break down. Micro plastics are small fragments of plastic. Through ecosystems, these micro plastics disperse. Heavy elements including lead and mercury are included in e-waste. These metals are dangerous to human health and the environment because they can seep into the environment. Toxins enter the air when plastic and electronic debris are burned. It is detrimental to human health. It is crucial to recycle and properly dispose of non-biodegradable garbage. This lessens damage (Maghfouri, Mohammad Saberian, & Rajeev Roychand, 2022).

Styrofoam (EPS)

Lightweight materials like Styrofoam (EPS) have been employed in engineering applications at least since the 1950s. The stiff cellular plastic known as Styrofoam, or EPS, was first created in Germany in 1950. Since 1958, it has been a part of packaging solutions. The remaining portion is composed of tiny, spherical EPS beads, which are only composed of carbon and hydrogen. It is composed of 98% air (Maghfouri, Mohammad Saberian, & Rajeev Roychand, 2022). It is unable to absorb water due to its closed cell structure. It is impact resistant and possesses qualities of thermal and sound insulation. Foam made of Styrofoam is not biodegradable (Patidar, Mayur Singi, & Abhijeet Bhawsar, 2019).

Why Styrofoam acts as a non-biodegradable waste?

Styrofoam's chemical structure is extremely stable and impervious to deterioration. Microorganisms capable of degrading the polymer chains of Styrofoam are rare (Elkordi & B.A. Herki, 2018). Styrofoam fragmentation produces nano plastics and microplastics that do not break down. Since Styrofoam doesn't break down biologically, it accumulates over time. Styrofoam is thought to take hundreds to thousands of years to biodegrade (Kulkarni & Prof.G.N.Shete, 2022).

Here are some key statistics on Styrofoam waste worldwide:

The annual manufacturing of Styrofoam is more than 14 million tons worldwide. An estimated 25 billion Styrofoam cups are thrown away annually in the United States alone. Each year, Americans discard around 25 million Styrofoam cups, or 82 cups per person. Eighty percent of Styrofoam is thought to wind up in landfills. The majority of the leftover 20% ends up in rivers. Approximately 30% of garbage volume worldwide is composed of Styrofoam (Sabaa & Rasiah Sri Ravindraraja, 1997). Nowadays, less than 1% of Styrofoam is recycled because of challenges with processing and collection. The annual expense of cleaning up the US coast due to Styrofoam debris is estimated to be close to $1 billion. In the US, the annual expense of cleaning up foam from highways is estimated to be $300 million. Because Styrofoam is resistant to biodegradation, it can linger in landfills for hundreds of years (Sandanayake & Yanni Bouras, 2020).

Impacts of Styrofoam (EPS):

Emissions of greenhouse gases are produced during the raw material production and EPS manufacturing processes, which both demand significant energy inputs. While less so than material manufacture, transporting lightweight EPS might burn fuel and increase air pollution during its use phase. Due to a lack of infrastructure, EPS frequently ends up in landfills rather than being recycled when its useful life is over. It occupies landfill space and is extremely persistent. Over time, additives added to EPS, like as flame retardants like HBCD, may seep out and accumulate in the environment and in living things (Gunavel, S. Aishwarya, & K. Indhumathi, 2020). Marine life can consume the micro and nano plastics that are readily broken down from EPS. EPS recycling technologies, the use of substitute materials, and product redesigns to reduce EPS consumption are among suggested remedies (Worrell, Lynn Price, & Nathan Martin, 2001).

Lightweight concrete using waste Styrofoam:

The utilization of leftover Styrofoam as a partial substitute for conventional aggregates in the manufacture of lightweight concrete has garnered significant interest in recent times owing to its possible advantages for the environment and economy. When used in place of coarse aggregates in concrete, waste Styrofoam—a non-biodegradable substance that occupies a lot of landfill space—can cut down on the quantity of waste dumped in landfills and lower the demand on natural resources. In addition to having better thermal insulation qualities, lightweight concrete made from leftover Styrofoam is perfect for use in structures where energy economy is a top concern (Abd, Dhamya Gh, & Maan Hattem, 2016). Furthermore, incorporating leftover Styrofoam into concrete may reduce the material's overall weight, which will make installation and transportation simpler and more affordable.

Nevertheless, there are several drawbacks to making lightweight concrete from leftover Styrofoam, such as possible decreases in durability and compressive strength. Because of this, it's critical to carefully assess the final material's qualities and modify the mix's proportions as needed to guarantee that it satisfies the necessary requirements for strength and durability (Rosca, 2020).

Overall, there could be a number of advantages to producing lightweight concrete from leftover Styrofoam, such as decreased waste, increased energy efficiency, and cheaper production costs (Gawale, Shubham Mishra, & Harshal Sambare, 2016).

Chapter 3 SUSTAINABLE DEVOLOPMENT GOALS (SDGs)

The aim of our research work covers the following SDG’s.

SDG 9: Infrastructure, Industry, and Innovation:

Objectives: Develop innovative solutions, encourage equitable and sustainable industrialization, and construct robust infrastructure.

Relation to Lightweight Concrete Blocks: Using leftover Styrofoam, lightweight concrete blocks are produced, which is a creative way to sustainable industry. By utilizing cutting-edge materials and production techniques, it promotes innovation in the building sector and builds durable infrastructure. The context of Pakistan is that the country is facing obstacles in the development of its infrastructure. One way to solve these concerns is to use new construction materials, such as lightweight concrete blocks, to create more robust and sustainable infrastructure. This will also help to reduce costs associated with building materials.

(SDG 11): Sustainable Cities and Communities:

The objective is to create inclusive, secure, resilient, and sustainable cities and human settlements.

Relation to Lightweight Concrete Blocks: Because they are environmentally benign, lightweight concrete blocks support resilient and sustainable building techniques. In line with the objective of developing livable and ecologically friendly communities, they can aid in the construction of safer and more sustainable buildings.

Pakistan's Context: Housing and infrastructural issues are brought on by Pakistan's fast urbanization. In order to address the issues associated with urban development, the use of lightweight concrete blocks can be crucial in the construction of sustainable structures.

SDG 12: Ethical Production and Consumption

Assure sustainable patterns of production and consumption.

Link to Lightweight Concrete Blocks: By repurposing discarded Styrofoam, the manufacture of lightweight concrete blocks demonstrates responsible consumerism.

By lessening the environmental effect of using conventional building materials, it encourages sustainable production practices.

Pakistan's Context: Pakistan faces challenges related to waste management. Construction projects that include waste materials, such as Styrofoam, promote responsible consumption and solve environmental issues associated with trash disposal.

Climate Action (SDG 13):

Objective: Immediately tackle climate change and its effects.

Relation to Lightweight Concrete Blocks: Recycled materials, such as leftover Styrofoam, are used in the production of lightweight concrete blocks, which can help reduce carbon emissions in the building sector. This lessens the environmental impact of using traditional building materials, which is in line with climate action aims.

Pakistan's Context: The country suffers from extreme weather events and other climate-related problems. Resilience against the effects of climate change can be enhanced by using climate-friendly construction techniques.

Chapter 4 Methodology

1. INTRODUCTION

This chapter's goal is to explain the process of creating discarded Styrofoam models (cubes and cylinders) and the outcomes that can be gained from them. Various shaped molds, waste Styrofoam, cement, coarse and fine aggregates, and testing equipment (compressive testing machine, high speed finishing machine, 2000-watt coil heater, weight balance, permeability machine) are collected in order to create the models (Gawale, Shubham Mishra, & Harshal Sambare, 2016). This project was completed in the Department of Civil Engineering Khuzdar's concrete laboratory.

2. Material and source

The material use for this experiment are:

1. Portland cement
2. Coarse aggregate
3. Fine aggregate
4. Water
5. Waste Styrofoam

Cement

The type of cement utilized in this study is regular Portland cement with a specific gravity of 3.15, marketed as Falcon Cement. Ordinary Portland cement was chosen for this investigation primarily because it is the most widely used type of cement and works well for normal concrete construction where sulphate contamination of the soil or groundwater is not a concern. The cement was bought from Waseem Cement Agency and Iron Dealer.

Coarse aggregate

The coarse aggregate used in the experiment was passed from sieves no 12.5mm retained on the sieves no 2.36mm were obtained from Khuzdar crush plant. The sieve analysis of coarse aggregate was carried out in accordance with ASTM C33-03.

Table ***Error! No text of specified style in document.****-1 Coarse aggregate Sieve Analysis Results*

Sieve size(mm)	Retain %
12.5	100
9.5	88
4.75	10
2.36	2.5

Table ***Error! No text of specified style in document.****-2 Physical Properties of Aggregate*

S/N	Test Description	Test Method	Results	Specification Required
1	Los Angeles Abrasion, %	ASTM C131	19%	<30%
2	Aggregate Impact Value, %	ASTMD256	18%	<30%
3	Aggregate crushing Value test, %	ASTM D2940	24.26%	<30%
4	Specific Gravity Test	ASTM D127	2.69	2 - 3
5	Water absorption Test	ASTM C127	2.061	2 - 3

Fine aggregate

The fine aggregate used were river sand with a maximum size of 2mm, free from all organic substance and it was obtained from Khuzdar city. The sieve analysis was carried out in accordance with ASTM C136/C136M-14 sand.

Water

In addition to mixing concrete, regular tap water from the concrete lab has been used for other experimentation tasks like equipment washing and specimen curing. In our experiment, we employed a 50% water to cement ratio.

Styrofoam

Waste Styrofoam was collected from the waste bins of the market. The Styrofoam was washed and dried. Then it was processed to reduce its size in workshop of the university.

3. Batching, Mix Design, Transporting and Curing

Batching

Batching is the procedure of measurement of cement, coarse aggregate, fine aggregate, and water for operation of concrete making.

Method of batching

a. Batching of cement

Cement is always measured by weight. Mostly it is used in term of bags. 1 bag of cement weighs 50 kg and has a volume of 35 liters. Cement should not be batched by volume because its weight per unit volume varies according to the way the container is filled. In our research work we used the electronic weighing machine for batching cement available in the material testing lab at civil engineering department.

b. Batching of aggregate

A Gauge box is used for batching of fine and coarse aggregate the box should not be shallow it should be completely filled with aggregate. The top of the material should be stuck off level with a straight edge.

Weight batching

In weight batching the ingredient are measured by weight. Generally, weight batching is the practice for construction where highly concrete is required weight batching is much more accurate than volume batching. Different types of weight batching are available. The particular type to be used depends on the nature of the job.

In our research work we used the electronic weighing machine available in MT LAB at civil engineering department for batching. The calculation is as under.

Table ***Error! No text of specified style in document.****-3 For Mix Proportions*

Material	ST0	ST25	ST50	ST75
Cement	144 kg/m^3	144 kg/m^3	144 kg/m^3	144 kg/m^3
Sand	456 kg/m^3	456kg/m^3	456kg/m^3	456kg/m^3
Aggregate	960 kg/m^3	730kg/m^3	440kg/m^3	215kg/m^3
Water	2600 ml	2600 ml	2600 ml	2600 ml
Styrofoam	0 ml	5000 ml	10,000 ml	15,000 ml

For partition walls, 1:3:6 design mix concrete is far more frequently used. The examples are cast using regular Portland cement, but all of the concrete mixture is formed using natural sand, which has a minimum aggregate size of 2.36 mm, and a maximum size of 9.5 mm. Fine aggregate (river sand) must be washed in order to eliminate clay. We used portable, clean water to mix the concrete and mortar. Waste Styrofoam was mixed into this concrete at volumes of aggregate of 25%, 50%, and 75%, respectively. Two types of concrete cast were available: a standard one and a non-traditional one that includes Styrofoam. Weight balancing was utilized to batch the concrete in order to create a homogenous mixture. Standard steel molds were used to cast the concrete into cubes measuring 150 mm by 150 mm by 150 mm and cylinders measuring 150 mm by 300 mm in height. For a proper compacting, three layers of concrete were poured at each stage, and a vibrator was also be utilized. Once the concrete has been compacted, any excess was pushed off at the top of the mold and finished with a trowel. The specimen was cured for 28 days and then demolds after 24 hours. Universal testing equipment was used to test the prepared specimen in accordance with ACI standards.

4. PREPARATION OF SPECIMENS

The specimens were ready as follows.

Thirty-six concrete specimens were cast for tests on permeability, heat, and compressive strength. In the laboratory of the civil engineering department, cement, fine aggregate, coarse aggregate, and Styrofoam were manually mixed completely to achieve a consistent hue in a dry state. Water was added and properly mixed to create a concrete that was workable. After filling the cylinder measuring 2 inches by 6 inches and the cubes measuring 6 inches by 6 inches by 6 inches, three layers were compacted by hand. A vibrator was used to ensure correct compaction after the third layer was completed. A trowel was used to polish the surface of the specimens.

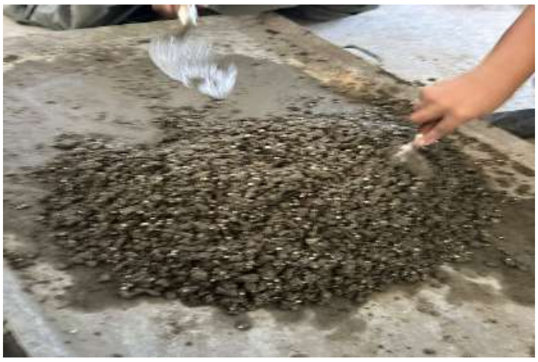

Figure ***Error! No text of specified style in document.****-1 Mixture ready for casting*

1. CURING OF SPECIMENS

Curing involves removing the concrete cube from the mold and promoting the hydration of cement in concrete. In order for quality concrete, the placing of an appropriate mix must be followed by curing in suitable environment during the early stage. The curing process used for the purpose of this project is by placing the concrete cubes in hydration tank full of water to the brim, so as to keep the concrete cube at a constant saturated condition during the testing period. Basically, curing helps to maximize cracking, to reduce permeability and in turn increase the durability of concrete. The concrete cubes were removed from the mold after 24 hours of casting and transferred to the water tank for a period of 28 days.

Figure ***Error! No text of specified style in document.****-2 Curing of specimens*

5. TESTING OF SPECIMENS

The following test was done for the concrete.

a) Slump test

b) Dry density test

c) Compressive strength of cube

d) Thermal test of cubes

e) Permeability test of cylinder

1. SLUMP TEST

The concrete slump test is a straightforward and widely used method for estimating the right amount of each ingredient to add to concrete in order to achieve the desired consistency and workability. The slump cone test is a straightforward and popular method for figuring out if fresh concrete is workable. The vertical settlement, or slump, of the specimen during the test needs to be measured and reported in millimeters of subsidence. In the material lab for civil engineering at BUET Khuzdar, the slump test was conducted in accordance with ASTM C143. The slump test mold is shaped like a frustum of a cone, standing 300 mm tall, 200 mm in diameter at the base, and featuring a 100 mm opening at the top. Timing rod: 60cm in length, 15mm in diameter.

2. Dry Density TEST

A number of dry density experiments were carried out to evaluate the effect of Styrofoam integration on the density of lightweight concrete blocks. Styrofoam was added to the concrete mixture at different replacement percentages of coarse aggregate—25%, 50%, and 75%, to be exact. One important way to determine the mass of the concrete blocks per unit volume is to conduct a dry density test. For comparison, the control cubes—which were devoid of Styrofoam—served as the standard. Every concrete batch was carefully mixed in accordance with the specified ratios, guaranteeing consistency among the samples. Using established protocols, the cubes were put through a dry density test after the curing time. The complete investigation of the impact of Styrofoam content on the total density of the lightweight concrete blocks was made possible by the test findings. The data analysis that follows will help to clarify the connection between the amount of Styrofoam replacement and the final dry density, offering important information on the viability and optimization of producing lightweight concrete from waste Styrofoam.

3. COMPRESSIVE TEST

According to ASTM we use compressive testing machine to determine the compressive strength of the samples. The cubes have dimensions (6*6*6 inches). After fixing the cube, the load is gradually applied. The machine gives us a load at which the cube fails in unit tons. Compressive strength was calculated as

Compressive strength = Load/Area

The finished cubes have a smooth finish and this is done by ourselves. Tests for various models made in various ratio was done by using the machine in the lab.

4. THERMAL TEST

In the thermal testing setup for lightweight concrete blocks made from waste Styrofoam, a heater is positioned 6 inches away from the concrete block having a coil of 2000watt. The objective is to measure the heat transfer characteristics of the block's surface at different depths. The procedure involves activating the heater to impart heat to the block, and after a specified duration, typically 10 minutes, 20 minutes and 30 minutes’ temperature readings are recorded at various depths: at the surface, 2 inches, 4 inches, and 6 inches into the block. By calculating the temperature differentials between these points, the rate of heat flow through the lightweight concrete block can be determined. This comprehensive testing methodology allows for a thorough understanding of the material's thermal performance and aids in evaluating its suitability for various applications, particularly in terms of insulation efficiency and energy conservation.

Chapter 5 Results and Discussion

Introduction

In this chapter we will study different results and discussion which are observed in the models which we have made and these models have a different ratio of Styrofoam. After 28 days of curing, we tested the lightweight concrete's slump test, Dry density test, compressive strength, Thermal test, water permeability, to ascertain its mechanical, physical, and thermal insulating qualities.

i. RESULT OF SLUMP TEST

To determine the fresh qualities (i.e., workability) of concrete, a slump test is conducted. Next, a workability test is conducted using both plain and Styrofoam-containing concrete at a mix design ratio of 1:3:6 and 0.50 percent water cement ratio.

Table 5-4 Result of slump test

s.no	Mix type	Percentage of Styrofoam	Slump value (mm)	Degree of workability
1	ST0	0%	12.7mm	Very low
2	ST25	25%	25.4mm	Low
3	ST50	50%	38.1mm	Low
4	ST75	75%	50.8mm	Medium

The findings of the slump test offer important information on the feasibility of various concrete mixtures. The slump value of the base mix devoid of Styrofoam (ST0) is measured at 12.7 mm, providing a benchmark. The slump value clearly climbs to 24.5 mm as the Styrofoam content reaches 25% (ST25), showing enhanced workability. 50% Styrofoam (ST50) shows a continued increase in the slump value, continuing this trend, while 75% Styrofoam (ST75) reaches its highest recorded value. The increase in slump values is ascribed to the use of Styrofoam, which improves workability while retaining a constant water-to-cement (w/c) ratio of 0.50%. Styrofoam's air-entraining qualities and light weight probably encourage more flow and plasticity in the concrete mixture, raising the slump values in every sample. These findings imply that adding

Styrofoam to concrete not only lowers its density but also improves its workability, which makes it more appropriate for use in construction. From the Figure 1 above, the slump increased with an increase in the percentage of EPS introduced into the mix with the 75% replacement having the highest slump. From these observations, it implies that workability of concrete mix increased on addition of polystyrene. This can be attributed to the smooth and round surface of the EPS beads which in turn acted as ball bearings making it easier for them to move around in the mix easily. The increase in workability however does not mean increase in strength as the EPS has low specific gravity as compared to coarse aggregates but it implies that the mix is easy to place.

ii. DRY DENSITY TEST

The dry density test results are displayed below after 28 days of curing.

Table 5-5 Results of dry density

Mix type	Sample 1	Sample 2	Sample 3	average
ST0	2377 Kg/m^3	2289 Kg/m^3	2349 Kg/m^3	2338 Kg/m^3
ST25	2040 Kg/m^3	2000 Kg/m^3	2043 Kg/m^3	2028 Kg/m^3
ST50	1751 Kg/m^3	1748 Kg/m^3	1785 Kg/m^3	1761 Kg/m^3
ST75	1365 Kg/m^3	1357 Kg/m^3	1371Kg/m^3	1364 Kg/m^3

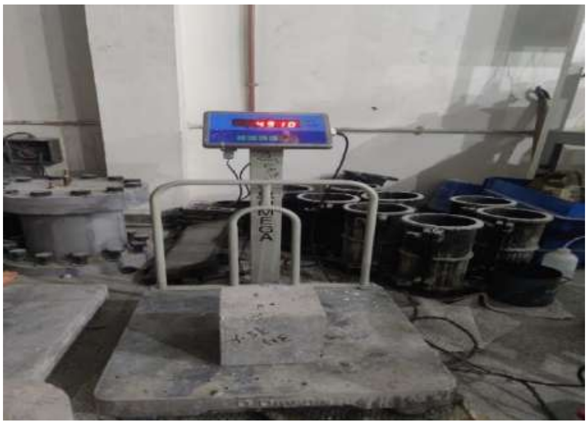

Figure 5-3 Dry density test

Discussion of dry density results

As observed from above table, there is a decrease in the density of the concrete with increase in percentage of EPS beads in the mix. This is because of the low specific gravity of the EPS beads, as compared to that of the coarse aggregates. As compared to the control mix, the voids introduced with the increase in the percentage of EPS are high which also reduces the density of the concrete. Cubes with 25%, 50%, and 75% Styrofoam replacement were tested in the dry density test against a control cube that had no Styrofoam. The results show that adding Styrofoam causes the density to drop. At 50% and 75% Styrofoam. the graph shows a noticeably lower dry density, indicating lightweight characteristics. The impact of Styrofoam on lowering concrete density is discussed here, with particular attention paid to the 50% and 75% replacement level.

iii. Result of Compressive strength test

The compressive strength test results are displayed below after 28 days of curing.

Table 5-6 Results of Compressive Strength

Mix Type	Curing Duration	Compressive Strength (psi)	Average Compressive strength (psi)	Average Compressive strength (Mpa)
ST0	28 Days	4049.4	3837.8	26.5
		3363.7		
		4100.4		
ST25	28 Days	2748	22733.7	18.9
		2595.1		
		2891.1		
ST50	28 Days	1826.6	1675.5	11.6
		1450.4		
		1750.2		
ST75	28 Days	1101	1055.4	7.3
		1060.8		
		1004.5		

The table showed that how the amount of waste Styrofoam substituted for coarse aggregate affected the compressive strength of the concrete, providing important information about the structural effects of using waste Styrofoam. The table showed that there is a discernible trend toward a decrease in compressive strength as the amount of styrofoam increases. A moderate drop in compressive strength is seen in the specimens that have 25% styrofoam replacement, suggesting a certain level of compatibility between styrofoam and the concrete matrix. But as the replacement level hits 50%, there is a more noticeable decrease, and at 75% styrofoam replacement, the compressive strength reaches its lowest point. The Increase in the amount of the beads also increased the voids in the mix due to their rounded surfaces which as compared to coarse aggregates are angular and thus offer more interlocking. The reduced interlocking reduced the strength. This result implies that although styrofoam can help make concrete lighter, there is a point at which the structural integrity is jeopardized. The scenario involving the replacement of 75% of the Styrofoam with diminishing compressive strength calls for careful attention because it emphasizes the necessity of designing lightweight concrete blocks in a way that balances weight reduction with sufficient load-bearing capacity. To find the ideal styrofoam composition that strikes the right balance between weight reduction and structural performance, more research and optimization could be needed. It was noted that upon loading of the specimens partially replaced with EPS, they underwent reduction in height and had a compressibility attribute to them as opposed to the control sample which cracked and spalled suddenly upon reaching the failure load. This is because the EPS beads are 98% air and thus, they result in compressibility of the concrete. The different variations in compressive strength imply that the concrete can be used to make special concrete blocks such as sound and thermal insulation blocks for percentages resulting in compressive strength above 5N/mm2 according to BS 5628: Part 1:1992.

*Figure 5-**Error! No text of specified style in document.**-4 Compressive test*

iv. Thermal test

The water thermal test results are displayed below after 28 days of curing

Table 5-7 Results of thermal test

Mix Type	Time (mint)	Distance (inch)	Heat Transfer (J/sec)
ST0	10	0 – 6	7.153973121
	20		9.067815617
	30		10.49733008
ST25	10	0 - 6	4.503576346
	20		6.324136547
	30		6.958009243
ST50	10	0 - 6	3.685358387
	20		4.561240795
	30		5.488123952
ST75	10	0 - 6	2.091104956
	20		2.605682538
	30		2.982522667

Discussion of thermal test results

The findings of the thermal testing provided interesting new information on the properties of heat transport in lightweight concrete blocks with different amounts of Styrofoam. A clear pattern appeared when the surface, 2 inch, 4 inch, and 6 inch temperature readings for the control samples and the samples with 25%, 50%, and 75% Styrofoam content are analyzed. The rate of heat transfer is seen to decrease with increasing depth, demonstrating the insulating efficiency of the block. Moreover, a strong pattern emerges from the comparison of various Styrofoam content percentages. The 0% Styrofoam component has the fastest rate of heat transfer, followed by 25%, 50%, and 75%. This suggests that the lightweight concrete block's ability to insulate against heat grows gradually as the amount of Styrofoam increases. By decreasing heat conductivity, the inclusion of Styrofoam creates air pockets in the material, improving its insulating qualities. The material's ability to reduce heat flow is demonstrated by the significant drop in heat transfer rate at 75% Styrofoam content, which makes it a viable option for applications requiring high-quality thermal insulation. This investigation shows how well Styrofoam can be included into lightweight concrete and offers insightful data for improving material composition in accordance with certain thermal performance criteria. However, we are interested in checking the rate of heat flow from the surface to the 6 inch in our results for each sample of ST0, ST25, ST50, and ST75 at different times of 10 minutes, 20 minutes, and 30 minutes.

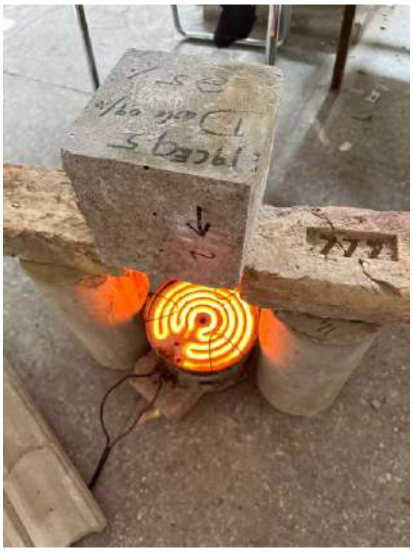

Figure 5-5 Thermal Test

v. WATER PERMEABILITY TEST

The water permeability test results are displayed below after 28 days of curing.

Table 5-8 Results of Water permeability test

Type of mix	Water permeability (m/sec)
ST0	6.9*10^-6
ST25	6.5*10^-6
ST50	5.9*10^-6
ST75	5.8*10^-6

Discussion of permeability results

The findings of the water permeability test show a clear pattern: at 0% Styrofoam, the permeability reached its maximum and then gradually drops. In particular, the permeability decreases at 25%, 50%, and 75% Styrofoam substitution, when it hits a minimum. This pattern highlights the contribution of Styrofoam to the decrease in water permeability, with the largest effect being shown at the 75% replacement threshold. Styrofoam has the potential to improve the water-resistant qualities of concrete, as seen by the decreasing permeability with larger Styrofoam percentages that point to an efficient barrier against water penetration.

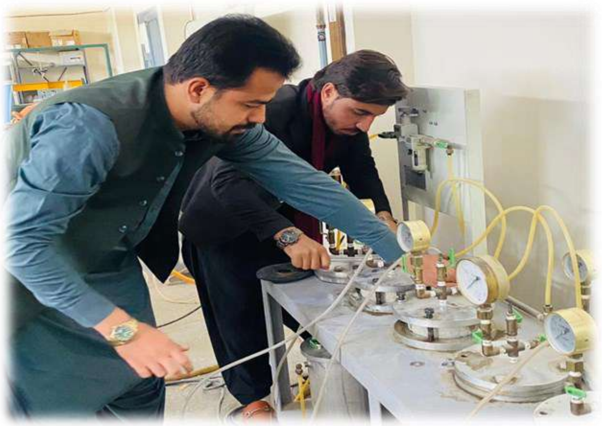

Figure 5-6 water permeability test

Chapter 6 Conclusion & Future Work

6.1 Conclusion:

our project is to provide clean and sound environment by using of waste material into a productive construction building material such as production of light weight concrete block, in this way we can achieve sustainable environment. The objectives of the project were to gain environmental sustainability by using non degradable waste to form a light weight concrete blocks as a result we can achieve environmental sustainability and as well as low cost and light weight concrete blocks. In chapter 4 we found that a blocks which is made from waste Styrofoam have all the mechanical properties that a conventional concrete blocks have.

6.2 Future work

The Following recommendation may be suggested for future works:

The research was done to find mechanical, physical and thermal insulation property of light weight concrete block. It is therefore recommended to do other studies for enhancing mechanical property (compressive strength) by adding different admixtures

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