Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

Evaluating the Mechanical Properties of Concrete and Bituminous Asphalt with Addition of Waste Plastic

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***Abstract*— The one of the most important inventions of the 20th century was plastic. In recent years, plastic usage has increased significantly over the globe, which has also increased the amount of garbage made from plastic. Today's contemporary society faces a major environmental challenge from plastic trash. Plastic recycling is a potential solution. Since plastic is an organic hydrocarbon-based material, it may be burned or employed in other high-temperature processes due to its high calorific value. However, burning plastics causes a number of harmful compounds, including dioxins, one of the most dangerous substances, to be released into the air. After processing, plastic trash may potentially be utilized to create new plastic-based goods. There is already an assessment of the use of waste plastic (WP) in the manufacturing of cement, mortar, and concrete. The glossy plastic Multi-layered Plastics (MLPs), which are used to package chips, cookies, mouthwash, tobacco products, and ready-to-eat food items, are becoming into a serious hazard to the ecology. This study uses M30 grade concrete to conduct an experimental investigation into the effects of single-layer and multi-layered waste plastic waste on the compressive strength, flexural strength and workability of concrete. Single-layer and multilayer waste plastics, in the form of shreds, are incorporated in concrete at rates of 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.75%, and 1.00%, respectively, by weight of cement. The density of concrete increases when waste plastic is used in multilayer construction, but the density of concrete decreases when waste plastic is used in single layer construction. However, it starts to decline once 0.4% of waste plastic is added. When it comes to single-layer plastic trash, the compressive strength continues to decline, but when it comes to multilayer plastic waste, it increases for the first 0.3% before continuing to decline. In both situations, the flexural strength decreased compared to the reference concrete. The Marshall Stability Test was also conducted in this study using single- and multi-layer waste plastics to substitute bitumen at 7% by weight of bitumen content in bituminous mix. In comparison to multi-layer plastic waste with bituminous mix and bituminous mix without waste plastic, the value for Marshall Stability was higher in the case of single layer waste plastic with bituminous mix.**

***Keywords*—Waste plastic, Multilayer Plastic, Bituminous Asphalt, Compressive Strength, Flexural Strength.**

I. INTRODUCTION

Currently, 360 million tons of plastic are produced worldwide. The average person uses 45 kg of plastic each year worldwide. A large number of plastics are thrown away after a brief lifespan which generates enormous trash accumulation and serious environmental issues. Every year, about 3% of plastic waste finds its way into the ocean, endangering both the ecosystem and species. One major environmental issue is the safe disposal of discarded plastic. Plastic is a non-biodegradable substance that can persist for up to 4,000 years. If it is disposed of in landfills, it can contaminate the construction fill, clog drains and drainage channels, cause illness and death in grazing animals, and return to the environment through air and water erosion. Additionally, dumping on open ground will lead to the wasteful use of scarce land resources. Using these materials for road construction will greatly minimize land pollution and the problem of disposing of waste plastic.

II. RESEARCH SIGNIFICANCE

Investigation is carried out for mechanical characteristics for concrete mix having waste plastic single layer and multilayer waste plastic aggregate as partial replacement by weight with cement employed with different percentages (0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.75% and 1%) for compressive and flexural strength test are investigated. The Marshall Stability Test was also conducted in this study using single- and multi-layer waste plastics to substitute bitumen at 7% by weight of bitumen content in bituminous mix. Eventually, mechanical characteristics were studied for 7day, 14day and 28days concrete curing age. Study will draw attention to utilization of waste plastic in construction application for the sustainability of the construction industry with addition of waste plastic single and multilayer to enhance the strength of concrete.

III. MATERIALS

(A) Polythene Bags Used in Daily Life

The polyethylene or polypropylene plastic bag, which was initially used in the 1960s, is viewed as a representation of the consumer culture. Each year, over 600 billion plastic bags are produced worldwide; an average European consumes roughly 500 of them. They typically only get used once, which is in sharp contrast to how long they last. Particularly thin plastic bags pose a significant ecological issue. However, the massive usage of plastic also creates a number of issues. The plastic is easily disposed away in vast quantities. Plastic waste that is incorrectly disposed of pollutes our ecosystem for decades or even centuries because conventional plastic is not biodegradable.

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(B) Multi-Layer Plastic Used in Food Packing

The shelf life of food is largely determined by the packaging used in the food sector. It offers protection while handling, transporting, and displaying food, as well as aids in maintaining food safety. The container has the power to either encourage or inhibit the flow of gases and vapors between the environment and the food. The term permeant is referred for gas or vapors. Reducing the amount of certain permeants in a product prolongs its shelf life by lowering microbial growth, chemical and biological degradation, and alterations to the food's color, flavor, texture, and odor. The usage of plastic packaging has significantly increased in recent decades. Following a thorough life cycle study, plastics often prove to be more ecologically friendly than traditional packaging materials due to their flexibility, low density, processability, and adaptability. Over the past few decades, the global use of plastics has grown exponentially, closing the gap with the consumption of steel and paper. The greatest amount of time between a food's manufacturing and final usage or consumption is known as its shelf life. Any chemical, biological, or physical alteration to foods shortens this period of time. These modifications may affect how the consumer perceives foods in terms of their sensory qualities, their nutritional worth, or their safety, thus posing a risk to the consumer.

(C) Concrete

It is a substance used in building and is formed of cement, sand, fine and coarse aggregates. Due to the fact that this combination becomes harder over time, it is typically employed in construction. Portland cement, which is used for concrete, is the most widely used form of cement. This concrete is used to create a variety of items during the construction of buildings and roadways, including slabs, beams, columns, foundations, and other components of rigid, load-bearing pavements. Regular concrete grades like M15, M20, M25 and M30 are often utilized.

(D) Bituminous Asphalt

A graded mixture of aggregate, filler, and bitumen. It is used to construct operational surfaces such as runways, taxiways, aprons, and road pavements to guarantee efficient traffic flow. It is the topmost layer of the crust. According to several laboratory or cylinder tests, mixed design concrete completes the mixing ratio because of its compressive strength. This process is sometimes referred to as blending design. The purpose of these tests is to identify the best mix of locally available materials to achieve the necessary strength in compliance with the structural design. A blended design makes effective use of ingredients.

TABLE I: PHYSICAL PROPERTIES OF CEMENT.

S. No.	Characteristics	Units	Results Obtained	Value Specified
1	Fineness (Specific Surface)	Cm^2/gm	3000	3500
2	Soundness (expansion by Le-Chatelier test)	mm	1.2	10 (max.)
3	Specific Gravity	gm/cm^3	3.15	--
4	Normal Consistency of Cement (% of cement by weight)	%	29	30
5	Setting Time			
	(i) Initial	minutes	135	30 (min.)
	(ii) Final	minutes	225	600 (max.)

TABLE II: PHYSICAL PROPERTIES OF FINE AGGREGATE.

S. No	Characteristics	Result Obtained (%)
1	Specific Gravity	2.62
2	Fineness Modulus	2.86
3	Water absorption %	1.8
4	Bulk density (loose) Kg/m3	1680
5	Free Surface Water	--
6	Zone	II

TABLE III: PHYSICAL PROPERTIES OF COARSE AGGREGATE

S. No	Characteristics	Result Obtained	
		20mm	10mm
1	Specific Gravity	2.67	2.62
2	Water absorption %	0.48%	0.56%
3	Free Surface Water	--	--
4	Aggregate Impact Value	10.49%	11.61%
5	Flakiness Index	6.8%	10.00%
6	Elongation Index	17.6%	20.8%

TABLE IV: WASTE PLASTIC AND ITS SOURCE

Waste Plastic	Origin
Low Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Polyethylene Teryphthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit, wafer packets, microwave trays for readymade meal etc.,
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc.
Polyvinyl Chloride (PVC)	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc.

Published by :
http://www.ijert.org

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Figure 1: Waste Plastic Single Layer

Figure 2: Multilayer Plastic

Advisory related to use of waste plastic in construction and maintenance of PMGSY roads under Swacchata Hi Sewa (SHS)
This makes reference to the Honorable Prime Minister's Independence day address from August 15, 2019, which discussed handling of plastic trash. The management of plastic waste would be the focus of this year's SHS, according to the government. The 2019 Plastic waste free campaign is being observed by the government from September 11 to October 27, 2019. The programme aims to speed up the management of plastic garbage in villages, urban local bodies, and public spaces including schools, hospitals, mandies, and houses of worship. In this regard, the secretary of rural development of the Government of India has already written to the Chief Secretaries of the states via D.O. letter No. L-12046/03/2019-SAGY dated September 3, 2019, in order to raise awareness of the use of single-use plastic among both the rural and urban population.
As part of the Pradhan Mantri Gram SadakYojana (PMGSY) , the Ministry of Rural Development has been tasked with, among other things, using the plastic garbage gathered throughout the campaign for road development. Many States have contributed significantly to the PMGSY program's effort to build rural roads using recycled plastic as an environmentally acceptable method. More than 13,000 km of roads have already been built nationwide as part of the PMGSY using waste plastic. These roads have also been proven to have excellent performance.
According to studies, waste plastics have a tremendous potential for application in bituminous construction since their inclusion in tiny amounts 6 to 8 percent by weight of bitumen—helps to significantly improve the material. Improved lifetime and pavement performance are made possible by the concrete stability, strength, fatigue life, stronger resistance to deformation, higher resistance to water-induced damages, and other desired features. Thus, in addition to being economically advantageous, the use of waste plastic in road building aids in the creation of green roads. In OGPC, using waste plastic alone to reduce construction costs results in savings of between Rs. 10,000 and 25,000 per kilometer, depending on bitumen and waste plastic prices.

2.1 Plastic Waste Roads in Punjab
According to IRC SP:98:2013 standards, the overall length of Premix Carpet installed in Punjab by utilising single-layer plastic waste is 1131.85 km, and the total length by using multilayer plastic is 325.64 km, although there is no code for the use of multilayer plastic.

IV. TESTING PROGRAME

Specimens were tested as per IS1199:1959 for cube for compressive strength and beams for flexural strength after 7, 14 and 28days of curing age.

TABLE V: MIX DESCRIPTION

Mix Designation	**%age of Waste Plastic**
M1	Concrete Mix with 0% waste plastic.
WP1	Concrete + 0.1% waste Plastic single layer
WP2	Concrete + 0.2% waste Plastic single layer
WP3	Concrete + 0.3% waste Plastic single layer
WP4	Concrete + 0.4% waste Plastic single layer
WP5	Concrete + 0.5% waste Plastic single layer
WP6	Concrete + 0.75% waste Plastic single layer
WP7	Concrete + 1.00% waste Plastic single layer

Mix designation	**% of waste plastic**
MLP1	Concrete + 0.1% Multilayer waste Plastic
MLP2	Concrete + 0.2% Multilayer waste Plastic
MLP3	Concrete + 0.3% Multilayer waste Plastic
MLP4	Concrete + 0.4% Multilayer waste Plastic
MLP5	Concrete + 0.5% Multilayer waste Plastic
MLP6	Concrete + 0.75% Multilayer waste Plastic
MLP7	Concrete + 1.00% Multilayer waste Plastic

Mix designation	**% of waste plastic**
BM	Bitumen VG-10 without plastic waste
BM1	Bitumen VG-10 + @ 7% Waste plastic replacing bitumen
BM2	Bitumen VG-10 + @ 7% Multilayer Waste plastic replacing bitumen

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 11, November 2024

Figure 3: Specimens

V. RESULTS AND DISCUSSIONS

The results for different tests for different mixes are given as under:

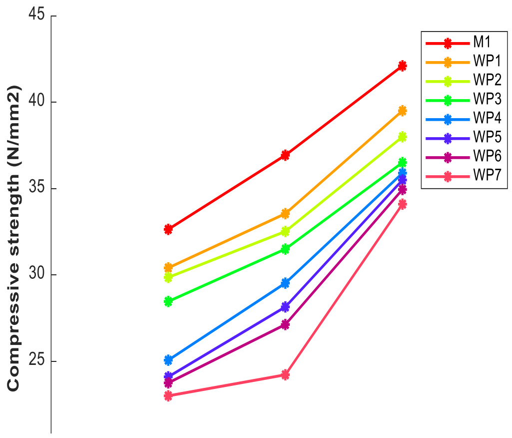

Figure 5: Comparison of compressive strength for single layer plastic waste mix after 7, 14 and 28 days of curing

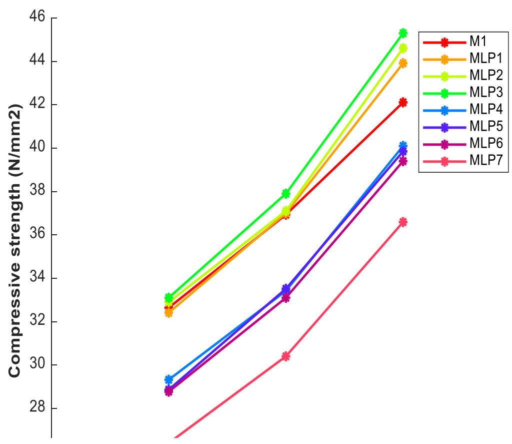

Figure 6: Comparison of compressive strength for Multi-layer plastic waste mix after 7, 14 and 28 days of curing

DISCUSSION

1. From the results it shows that up to 0.1% waste plastic there is less change in the compressive strength. however after 0.1% the compressive strength starts decreasing and with 1% waste plastic the decrease in compressive strength is 19% and the compressive strength starts decreasing rapidly after with 0.2% waste plastic single layer, whereas with addition of MLP waste there is increase in the compressive strength upto 0.3% and starts decreasing after that, and with 1% MLP waste the decrease in compressive strength is 13.1%.
2. Factors responsible for low compressive strength are the hydrophobic nature of plastic waste which can inhibits cements hydration reaction by restricting of water movement.

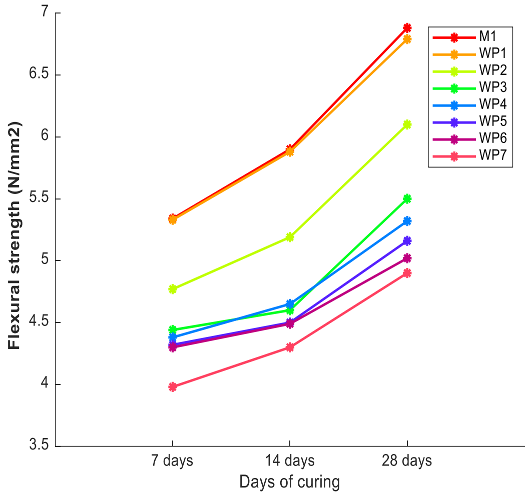

Figure 7: Comparison of flexural strength for single layer plastic waste mix after 7, 14 and 28 days of curing

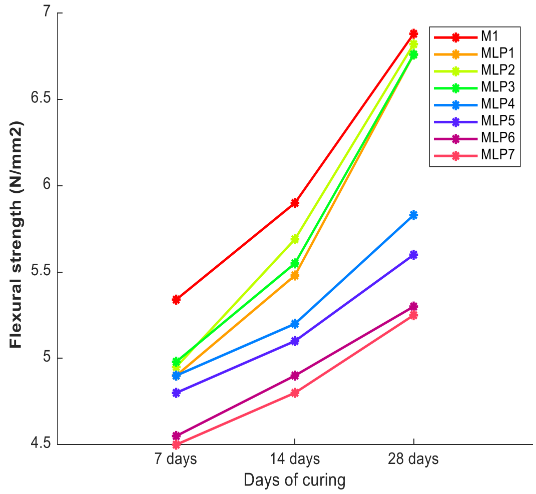

Figure 8: Comparison of flexural strength for Multi-layer plastic waste mix after 7, 14 and 28 days of curing

DISCUSSION

1. The flexural strength of waste plastic mix concrete is decreased with the increase of percentage of plastic waste in both cases but the decrease in flexural strength is more with waste plastic single layer as compared to multi layer waste plastic.
2. The decrease in flexural strength is very less with addition of 0.1% waste plastic single layer and after that starts decreasing rapidly and with 1% addition of waste plastic single layer, flexural strength decreases 28.7%.

CONCLUSIONS

This study has a positive impact on environment and the use of waste plastic in bitumen mix and concrete is eco-friendly.

1. Density of concrete with multi-layer waste plastic is more than the reference concrete upto 0.4% whereas in case of single layer waste plastic, with addition of 0.1%, there is negligible change but after that it starts decreasing. The density of concrete with multi-layer waste plastic is more than single layer waste plastic due to higher specific gravity and density of the multilayer waste plastic.
2. Compressive strength decreases by addition of waste plastic single layer and by addition of MLP waste up to 0.3% compressive strength increases, after that it starts decreasing.

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