Utilization Of Waste Plastic and Fly Ash to Enhance Mechanical Properties of Rigid Pavements

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Abstract - Surface transportation is a primary mode of travel across regions, and rigid pavements made from concrete are commonly used in roadway construction. Concrete is composed of basic natural materials, but due to their limited availability, the need to find alternative materials has become crucial. Fly ash, a byproduct of coal combustion, is being explored as a partial replacement for cement. Waste plastic, a growing environmental concern due to its non-biodegradability, can be an effective substitute for fine aggregates in concrete. This study investigates the combined impact of waste plastic and fly ash on the mechanical properties of rigid pavement concrete. Experimental results indicate that waste plastic can replace fine aggregate in concrete without significantly compromising performance. Additionally, the strength loss due to the plastic content can be mitigated by using 10% fly ash as a partial substitute for Portland Pozzolana Cement (PPC).

Key Words: Waste plastic, Fly ash, Compressive strength, Rigid pavement

1.INTRODUCTION

Transportation is crucial to the economic, social, and cultural advancement of society. The most prevalent mode of transportation is surface transport, including roadways and railways. Roadways are widely used by people across the world and consist of rigid and flexible pavements. Rigid pavements, made from concrete, are known for their durability and require minimal maintenance compared to flexible pavements.

The increasing demand for roadways necessitates the use of concrete, which is typically made from natural materials such as cement, aggregates, and water. As these resources are finite, their overuse poses environmental concerns. The exploration of alternative materials like fly ash, a byproduct of coal combustion in thermal power plants, and waste plastics, which are non-biodegradable, can help conserve resources and manage environmental waste.

Fly ash is produced during coal combustion in power plants and requires significant land and water for disposal. The increasing volume of fly ash presents a disposal challenge, and finding ways to utilize it in construction could alleviate this problem. On the other hand, the massive use of plastic in daily life has led to an environmental crisis, with plastic waste accumulating in landfills and ecosystems. Given its low cost and widespread availability, plastic waste has been considered as a potential alternative for fine aggregates in concrete.

This study explores the combined use of fly ash and waste plastic in rigid pavements as a partial replacement for cement and fine aggregates, respectively, to enhance both material sustainability and waste management.

2. Literature Review

Ismail et al. [2007] studied the efficiency of reusing waste plastic in production of concrete and concluded that reusing waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost of materials and solve some of the solid waste problems posed by plastics.

Frigione [2010] investigated and found that the WPET concretes display similar workability, characteristics, compressive strength and splitting tensile strength slightly lower that the reference concrete and a moderately higher ductility.

Sultana et al. [2012] investigated the potential use of waste plastic as a modifier for asphalt concrete and cement concrete pavement. The results showed the better values for asphalt concrete .This is eco-friendly process.

Harison et al. [2013] investigated PPC cement replacement by fly ash in the range of 0 to 60 % by weight of PPC at water cement ratio 0.48 for M-25 mix. Concrete mixtures were produced, tested and compared in terms of compressive strength and reported that compressive strength comparable upto 20% replacement .level at 28 days.

Kumar et al. [2014] reported that the workability is reduced with increase in dose of polythene and the compressive strength is increased on inclusion of waste polythene in concrete at all edges up to 0.75% and thereafter it starts decreasing.

Harison et al. [2014] reported that up to 30% replacement of PPC by fly ash strength is almost equal to referral concrete after 56 day. PPC gained strength after the 56 day curing because of slow hydration process.

Chaudhary et al. [2014] reported a study on the use of waste without plasticizer. Compressive strength and split tensile strength of concrete with plastic waste as aggregate and observed a good strength gain.

Singh et al. [2015] investigated that PPC can be replaced up to 20%by fly ash without compromising compressive strength of concrete.

Ariyamuthu et.al [2015] concluded that adding of shredded waste plastics with 0.25% of weight of cement leads to improvement in both compressive and split tensile strength.

Soni et al. [2015] reported that by addition of fly ash and ponded as partial replacement of PPC and fine aggregate respectively, improved compressive strength can be achieved as compared to referral conventional concrete both in tap water as well as in chloride environment at all the ages.

Srivastava et al. [2015] reported that the workability was considerably decreased with increase in dose of waste polythene, however, both compressive and flexural strength considerably increased with addition of waste polythene.

Guendouz et al. [2016] concluded that reusing waste plastic in sand concrete gives a positive approach to reduce the cost of materials and solve some environmental problems.

3.METHODOLOGY

3.MATERIALS AND METHODS

3.1.Materials

3.1.1.Cement

For this study, Portland Pozzolana Cement (PPC) from Reliance brand, sourced from a single batch, was employed throughout the investigation. The properties of the cement are as follows:

- Fineness: 3.34%
- Normal Consistency: 30%
- Initial Setting Time: 90 minutes
- Final Setting Time: 200 minutes

3.1.2.FineAggregate

The fine aggregate used in this study was natural river sand, specifically 'Jamuna' sand. Sieve analysis was conducted, revealing the following properties for the fine aggregate:

- Fineness Modulus: 2.8
- Specific Gravity: 2.73
- Water Absorption: 1.4%

3.1.3.CoarseAggregate

Crushed stone aggregates from Bharatpur, with nominal sizes of 20mm and 12.5mm, were used in this study. The properties of the coarse aggregates are:

- For 20mm size:
  - Fineness Modulus: 7.43
  - Specific Gravity: 2.64
  - Water Absorption: 0.61%
- For 12.5mm size:
  - Fineness Modulus: 6.76
  - Specific Gravity: 2.71
  - Water Absorption: 0.51%

3.1.4.PlasticWaste

Shredded PVC pipes were utilized as plastic waste in this research. The properties of the plastic waste are as follows:

- Fineness Modulus: 2.0
- Specific Gravity: 1.54
- Water Absorption: 0.28%

Figure 1: Plastic Waste

3.1.5.FlyAsh

Fly ash used in this study was sourced from the NTPC Bara Shankargadh Thermal Power Plant, located in Allahabad, Uttar Pradesh.

Figure 2: Fly Ash

3.1.6.Superplasticizer

A superplasticizer from Sicca Company was used at a consistent dosage of 0.4% by weight of cement to improve workability.

Figure 3: Plastic Waste

3.2.Methods

For the experimental work, M25 grade concrete was chosen. The concrete mix was prepared with a proportion of 1:1.8:3.2, with a water-cement ratio of 0.44. The concrete specimens were tested for density, workability in the fresh state, and compressive and flexural strength in the hardened state after 7 and 28 days of moist curing.

4.RESULT AND DISCUSSION

4.1 Properties of Fresh Concrete

4.1.1. Density

Density refers to the ratio of mass to volume in an object, essentially indicating how much matter is contained within a given volume. An object with less matter for the same volume will have a lower density. The density values of fresh concrete at various replacement levels are presented in Table 1.

Table 1: Slump Values and Density of Concrete

S.NO.	W/C	% Replacement of Plastic Waste	% Replacement of Fly Ash	Slump Value (mm)	Density (kg/m^3)
1.	0.44	0	0	131	2499.667
2.	0.44	2	0	125	2459.667
3.	0.44	4	0	101	2419.667
4.	0.44	6	0	81	2342.333
5.	0.44	8	0	53	2264.239
6.	0.44	10	0	15	2175.629
7.	0.44	0	10	129	2501
8.	0.44	2	10	122	2479.5
9.	0.44	4	10	96	2463
10.	0.44	6	10	69	2413.27
11.	0.44	8	10	46	2335.855
12.	0.44	10	10	13	2242.49

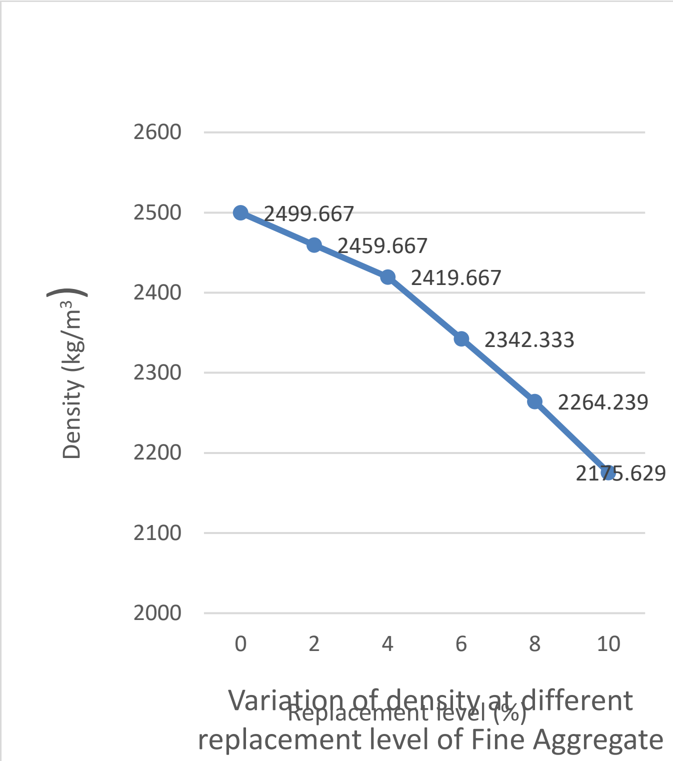

Figure 4 Variation of density at different replacement level

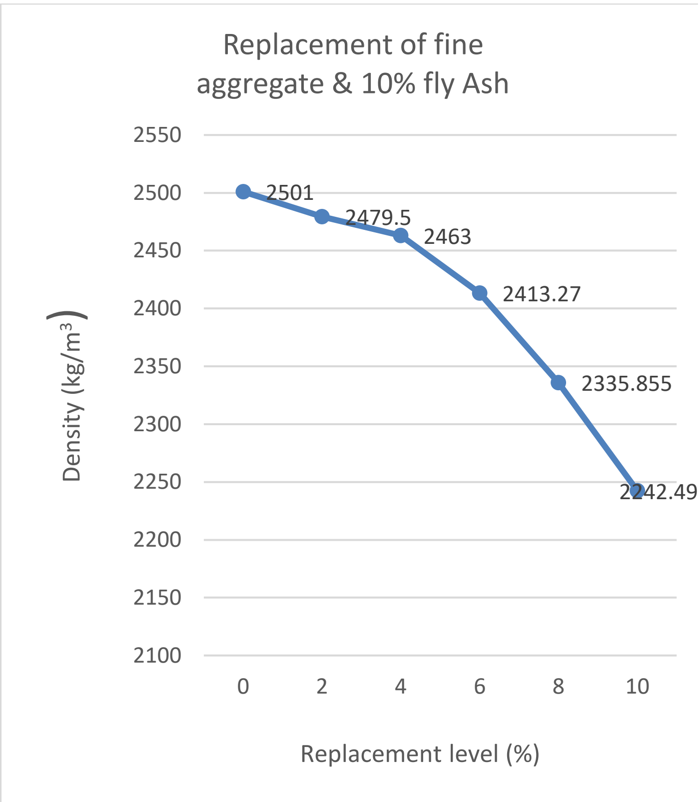

Figure 5 Variation of density at different replacement level & 10% fly ash

The results of workability in terms of slump are shown in table. The same results are shown in figure in graphical form for observation of various pattern

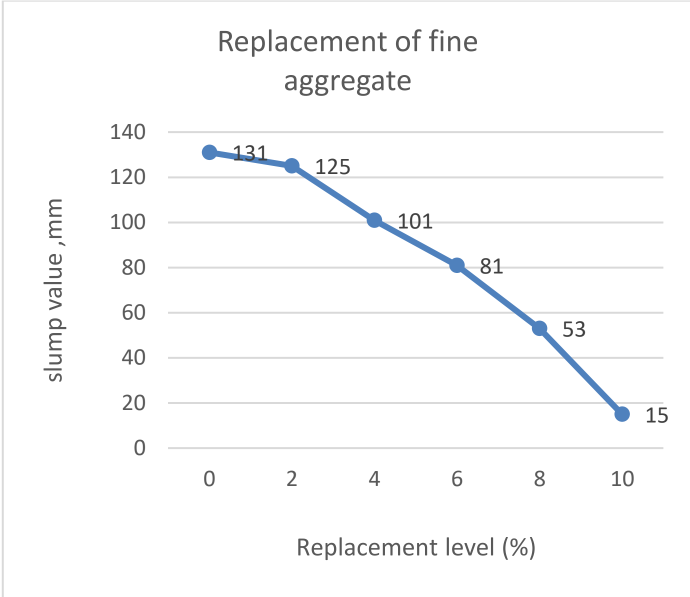

Figure 6 Variation of slump at different replacement level

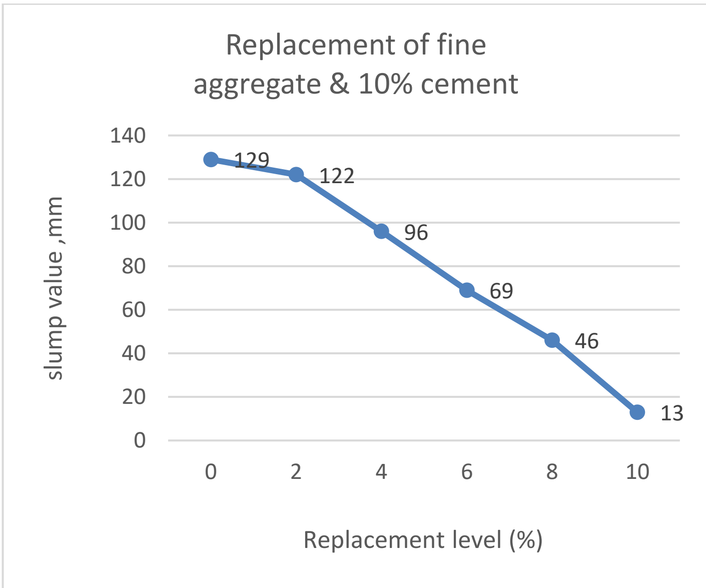

Figure 7 Variation of slump at different replacement level & 10% fly ash

It was observed that workability decreased as the replacement level increased. Beyond an 8% replacement level, the workability became significantly low, rendering the concrete mix unworkable. This reduction in workability can be attributed to the higher volume of waste plastic compared to sand for the same weight, due to the lower specific gravity of waste plastic. As the volume of fine aggregate increases, more water is required for surface lubrication, leading to a reduction in the net available water and, consequently, decreased workability.

4.2 Properties of Concrete in Hardened State

4.2.1 Compressive Strength

Compressive strength of concrete is the most common test for judging the ability of the concrete to withstand the load as well as the quality of the hardened concrete.

Table 2 Compressive strength of concrete

S. NO.	W/c	Cube Designation	Replacement of Plastic Waste	Replacement of Fly Ash	Compressive strength (N/mm^2)	
					7 days	28 days
1.	0.44	A1	0	0	23.2	35.0667
2.	0.44	A2	2	0	21.2	34.8667
3.	0.44	A3	4	0	19.667	32.4667
4.	0.44	A4	6	0	15.333	29.8
5.	0.44	A5	8	0	13	22.733
6.	0.44	A6	10	0	12.2	17.33
7.	0.44	AF1	0	10	22.667	35.933
8.	0.44	AF2	2	10	20.53	34.93
9.	0.44	AF3	4	10	19.533	32.667
10.	0.44	AF4	6	10	14.133	30.133
11.	0.44	AF5	8	10	12.733	23.4
12.	0.44	AF6	10	10	11.666	18.13

28 days curing, it is evident from table that compressive strength was decreased with increase in replacement level of fine aggregate. The decrease in compressive strength is the range of 2.29 -51.52% for replacement level of 2 to 10%

28 days curing, it is observed from table that compressive strength was increased 2.41% with replacement of 10% ppc cement with fly ash. The decrease in compressive strength is the range of 0.38 -48.29% for replacement level of plastic waste 2 to 10 % & 10% flies ash.

4.2.2 Flexural Strength

Flexural strength is defined as a materials ability to resist deformation under load. It is also known as modulus of rupture, bend strength, or fracture strength.

Observed data of specimens after 28 days for flexure strength is given below in table and figure.

Table 3 Flexural Strength of Concrete

S. NO.	W/C	Cube Designation	Replacement of Plastic Waste	Replacement of Fly Ash	Flexural Strength (N/mm^2) 28 days
1.	0.44	C1	0	0	7
2.	0.44	C2	2	0	7.2
3.	0.44	C3	4	0	7
4.	0.44	C4	6	0	5.6
5.	0.44	CF1	0	10	7.4
6.	0.44	CF2	2	10	7.6
7.	0.44	CF3	4	10	7.2
8.	0.44	CF4	6	10	5.2

For improvement in flexural strength of fresh concrete we replaced 10% of Portland pozzolana cement (PPC) with fly ash and observe that flexural strength of concrete increased 5.4% of 0.44 w/c.

The compressive strength of concrete made with plastic waste and fly ash is given in table. Same results are shown in graphical form for observation of various pattern.

4.3 Workability

Workability is defined as the property of freshly mixed concrete or mortar which determines the ease and homogeneity with it can be mixed, place, compacted and finished.

5. CONCLUSION

- The density of fresh concrete was observed to decrease (by 1.62–13%) as the replacement level of materials increased.
- The workability of concrete containing waste plastic was found to decrease with higher replacement levels.
- The compressive strength of concrete incorporating waste plastic also decreased as the replacement level increased.
- The reduction in compressive strength when using waste plastic can be partially mitigated by replacing up to 10% of the cement with fly ash.

REFERENCES

[1] Ariyamuthu, A., & Varadarajan, R. (2015). "Experimental study on the effects of shredded waste plastics in rigid pavements." International Journal of Emerging Technology and Advanced Engineering (IJETAE), 5(2), February 2015. ISSN 2250-2459. Retrieved from www.ijetae.co

[2] Chaudhary, M., Srivastava, V., & Agarwal, V.C. (2014). "Effect of waste low-density polyethylene on the mechanical properties of concrete." Journal of Academia and Industrial Research (JAIR), 3(3), August 2014, pp. 123-126.

[3] Frigione, M. (2010). "Recycling of PET bottles as fine aggregates in concrete." Waste Management, 30(2010), 1101-1106. Elsevier Ltd. Retrieved from www.elsevier.com/locate/wasman

[4] Guendouz, M., Debieb, F., Boukendakdji, O., Kadri, E.H., Bentchikou, M., & Soualhi, H. (2016). "Use of plastic waste in sand concrete." Journal of Materials and Environmental Science, 7(2), 382-389. ISSN: 2028-2508 CODEN: JMESCN

[5] Harison, A., Srivastava, V., & Gupta, C.B. (2013). "Fly ash as a supplementary cementitious material in Portland pozzolana cement concrete." International Journal of Engineering Trends and Technology (IJETT), 6(3), December 2013. ISSN 2231-5381. Retrieved from www.ijettjournal.org

[6] Harison, A., Srivastava, V., & Herbert, A. (2014). "Effect of fly ash on the compressive strength of Portland pozzolana cement concrete." Journal of Academia and Industrial Research (JAIR), 2(8), January 2014. ISSN 2278-5213.

[7] Ismail, Z.Z., & Al-Hashmi, E.A. (2008). "Use of waste plastic in concrete mixture as aggregate replacement." Waste Management, 28(2008), 2041-2047. Elsevier Ltd. Retrieved from www.elsevier.com/locate/wasman

[8] Kumar, A., Srivastava, V., & Kumar, R. (2014). "Effect of waste polythene on the compressive strength of concrete." Journal of Academia and Industrial Research (JAIR), 3(3), August 2014. ISSN 2278-5213.

[9] Ahmad, M.S. (2014). "Strength of fly ash mixed with waste sludge." International Journal of Civil Engineering and Technology (IJCIET), 5(2), pp. 25–32.

[10] Singh, V.K., Srivastava, V., Agrawal, V.C., & Harison, A. (2015). "Effect of fly ash as partial replacement of cement in PPC concrete." International Journal of Innovative Research in Science, Engineering, and Technology, 4(7), July 2015. ISSN 2319-8753

[11] Afroz, S.K., & Prasad, K.S.B. (2012). "Utilization of waste plastic as a strength modifier in the surface course of flexible and rigid pavement." International Journal of Engineering Research and Applications (IJERA), 2(4), July-August 2012, pp. 1185-1191. ISSN 2248-9622. Retrieved from www.ijera.com

[12] Soni, A., Srivastava, A., & Agrawal, V.C. (2015). "Effects of chloride environment on PPC concrete made using fly ash and pond ash." Journal of Multidisciplinary Engineering Science and Technology (JMEST), 2(8), August 2015. ISSN 3159-0040

[13] Penmetsa, S.R., Kesiraju, A., & Varma, A.D. (2015). "Productive re-use of municipal plastic waste to improve temperature resistance and reduce rainwater infiltration in flexible pavements." International Journal of Civil Engineering and Technology (IJCIET), 6(3), pp. 01–09.

[14] Srivastava, V., Chaudhary, M., & Kumar, A. (2015). "Waste polythene in concrete – An attempt towards its disposal." International Journal of Engineering Research and Technology (IJERT), ISSN 2278-0181.