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SELECTION OF SUITABLE PLASTIC WASTE MATERIAL AS AN ADDITIVE IN CEMENT CONCRETE

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ABSTRACT

This study investigates the selection and addition of plastic waste materials as additives in cement concrete in order to improve the mechanical properties of cement concrete. This study examines the possibility of using plastic waste, such as used plastic bottles, bags, and other plastic waste material in cement concrete, in light of the increasing demand for sustainable construction methods and the rising concern about plastic waste pollution. The study uses a thorough methodology that includes plastic waste material selection by TOPSIS method.

The outcomes of this study contribute to sustainable construction practices, waste reduction efforts, and the realization of environmentally friendly and economically viable concrete solutions for the construction industry by using selected plastic waste as an additive.

Keywords: Plastic Waste, TOPSIS, Analysis.

I. INTRODUCTION

In an era defined by environmental consciousness and the pursuit of sustainable solutions, the construction industry stands at the crossroads of innovation and responsibility. The construction industry plays a pivotal role in the global economy due to the increasing need for housing and infrastructure. The demand for cost-effective, durable, and environmentally friendly building materials has never been more pressing. In response to this challenge, exploring alternative materials has become a focal point of research. This research paper focuses on the selection of suitable plastic waste materials by using TOPSIS and incorporating that plastic waste in cement concrete to make it cost-effective and eco-friendly.

Plastic waste, a global predicament, poses a dual challenge. On one hand, it contributes significantly to environmental pollution when inadequately managed, and on the other, it represents a valuable resource that can be repurposed to address sustainability concerns in construction. Plastic waste is one of the major solid wastes that is being generated in huge amounts globally and poses numerous threats to the environment. The rapid increase in population and urbanization has caused plastic waste generation, which is unavoidable, as most of the items are related to Plastic or by-products of plastic. Plastic pollution is one of the main environmental issues that affects our environment.

Plastic waste, particularly single-use plastics, has become a global environmental crisis. With an estimated 8.3 billion metric tons of plastic produced to date, the majority of plastic waste ends up in landfills or polluting natural ecosystems. These materials can take centuries to decompose, exacerbating environmental problems and negatively affecting human health and wildlife.

Plastic takes years to break down and can pose a major threat to natural ecosystems. Because of the quick rise in the usage of PET bottles, solid waste issue remains elevated. it's far-famed that a protracted-time (over 100-years) is required towards the degradation of the left-over PET bottles within nature.Silva et al., (2005)

II. METHODOLOGY

This study is concerned with plastic waste and its selection. The selection of suitable plastic waste is done with the help of TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) a multi-criteria decision analysis method. In this research, the literature was reviewed and from the literature, it was found that there are various waste materials, plastic is one of the major contributors of waste generation. Various plastic types were identified. Such as Low-Density Polyethylene (LDPE), Polyethylene Terephthalate (PET), Polyvinyl

Chloride (PVC), and High-Density Polyethylene (HDPE). After identifying the different types of plastic, their characteristics along with the amount of production were studied.

A decision-making tool was utilized and interviews were performed with the concerned field experts with the help of a structured questionnaire survey. After analyzing the responses, the ranking of plastic waste material was finalized.

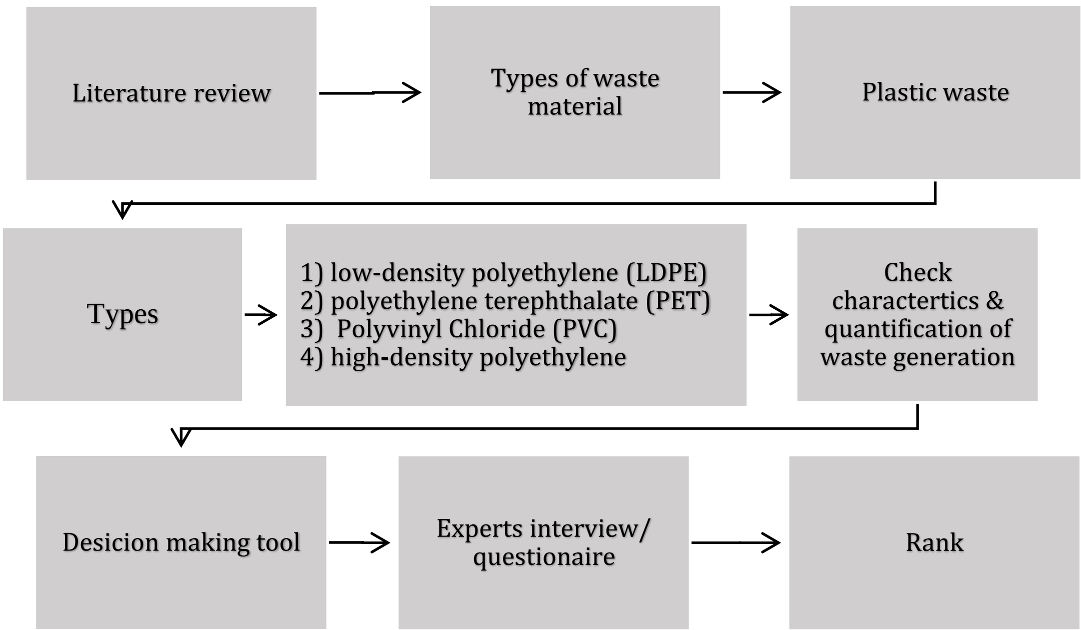

Figure 1: Systematic research process

Table 1: Characteristics of different plastic materials.

Plastic Type	Plastic production globally per year (million tons)	Uses	Time for the decomposition of plastic	Compressive strength (MPA)	Tensile strength MPA
Polyethylene terephthalae (PET)	33*	packaging foods and beverages, soft drinks, juices & water bottles	Up to 450 years *****	80 ***	80 ***
High-density polyethylene (HDPE)	52*	Wire, cable insulation & toys	100 years *****	20 ***	28 ***
Low-density polyethylene (LDPE)	64 *	packaging film & grocery bags	Up to 20 years *****	-	10 ****
Polyvinyl Chloride (PVC)	30 *	pipes, medical devices, wire & cable insulation	450 years	31.3 ******	35 ******

- *(Geyer et al., 2017)
- ** (Maesindo, 2020)

- *** (Mittal et al., 2023)
- **** (Technologies, 2021)
- ***** (earthling co, 2021)
- ****** (Unar et al., 2010)

Data Collection

The data collection process for this research involves a systematic and comprehensive approach to gather essential information related to the selection of suitable plastic waste materials. The first phase of data collection revolves around the characteristics of various plastic waste materials. From the literature, it was found that there is a diverse range of plastic types which are commonly found in waste streams.

Structured Questionnaire Survey was comprised of 4 parts, and each part's description is given as under:

Part 1: Demographical information of each respondent was gathered, such as organization type, level of experience and designation.

Part 2: It contains the importance of plastic waste material to be use in the cement concrete. A five-point Likert scale was designed to get the responses where 1 represents not important, and 5 indicates the most important. This part helped in computing the ranking of criteria using a descriptive analysis approach.

Part 3: This section contains the selection of suitable type of plastic waste. This was designed on the basis of a scale of rating for qualitative criterion in TOPSIS method, which is a nine-point Likert scale where 1 represents not important, and 9 shows the extreme side of importance. Moreover, the intermediate values between the two adjacent judgments, such as 2, 4, 6, 8, were also provided for flexibility in judgments.

Part 4: This section involves the selection of the most suitable type of plastic to be used in the concrete with respect to the characteristics of concrete based on the listed criteria. The listed criteria were ranked based on characteristics such as Tensile strength, compressive strength, amount of production, decomposition period, and economy individually. The rating scale for the criterion in the TOPSIS method was developed on a similar nine-point Likert scale.

Weightage of characteristics of Plastic material

The relative Importance Index (RII) approach was used to determine the weightage of each characteristic involved by using Equation as shown below. The five-point Likert scale was used in the questionnaire design from 1 (not important) to 5 (very important).Ramli et al., (2021)

The RII is calculated as:

$$\mathbf{RII} = \frac{\sum \mathbf{W}}{\mathbf{N \times T}}$$

Where:

W is response on Likert scale

T is highest value on the scale

N is sum of respondents.

TOPSIS

The Technique for Order of Preference by Similarity to Ideal Solution TOPSIS is a multi-criteria decision analysis method. It compares a set of alternatives based on a pre-specified criterion. Numerous multi-criteria problem applications have successfully used the TOPSIS method, which has gained widespread acceptance. Due to its ubiquity and variety of problem-solving abilities, TOPSIS, according to (Khoso & Yusof, 2020), is the method that is most generally used and accepted. Furthermore, TOPSIS is one of the innovative applications in this field because it is highly restricted in PDM-related issues. In TOPSIS techniques, the following key steps are taken:

Step 1: Criteria weight determination.

Selection criteria are weighted using the designed relative scale

Step 2: Normalization

A normalization process is followed to find the final weightages of each criteria over each alternative, This changes the current judgmental matrix to a non-scaled matrix.

$$\overline{X_{ij}} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}}}$$

Step 3: Calculate weighted Normalized Matrix

$$V_{ij} = \overline{X_{ij}} \times W_j$$

Step 4: Determine the best and the worst alternative for each criterion.

$$V_+ = \mathrm{Max}_{i=1}^{M} X_{ij}$$

$$V_- = \mathrm{Min}_{i=1}^{M} X_{ij}$$

Step 5: Calculate the Euclidean distance between the target alternative and the best/worst alternative.

$$S_I^+ = \{\sum_{J=1}^{M} (V_{ij} - V_J^+)^2\}^{0.5}$$

$$S_I^- = \{\sum_{J=1}^{M} (V_{ij} - V_J^-)^2\}^{0.5}$$

Step 5: Calculate Performance Score

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

Step 7: Ranking the choice.

Rank alternatives according to the TOPSIS score by descending order.

III. RESULTS AND DISCUSSION

Influential factors affecting selection of Plastic waste

The most influential factors were categorized into five classifications such as factors related to Compressive strength, Tensile Strength, Decomposition time, Amount of waste Generated, Economy of plastic waste material. The collected responses were analyzed using RII values.

The ranking of the most influential factors was computed using the respective RII values

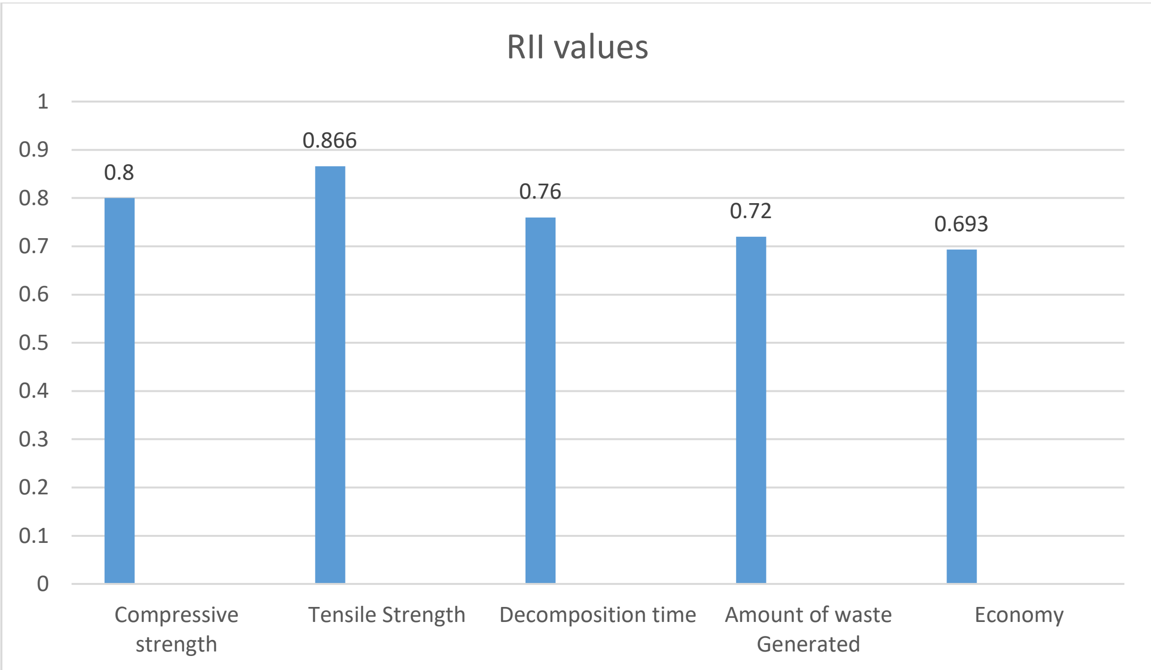

Figure 2: Top significant factors affecting selection of selection of plastic waste

Tensile strength in the characteristics of plastic waste is extremely important (having RII value 0.866), second and third top-most important factors in the characteristics of plastic waste selection are 'compressive strength' and "decomposition time" (having RII value as 0.8 and 0.76, respectively). Hence the least considerable factors in the selection of plastic waste are "amount of waste generation" and economy" (having RII value as 0.72 and 0.693, respectively).

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Decision preferences using TOPSIS analysis

The mean weights of each criterion were initially determined. The mean weights of each criterion were initially determined. MS Excel was utilized to compute the mean weightages of selection criteria for each characteristics of plastic waste. The weightages are calculated on a nine-point qualitative scale, as demonstrated in Table 2.

Table 2: normalized matrix

	Decomposition period	compressive strength	Tensile Strength	amount of waste generation	economy
PET	0.656174933	0.658937502	0.702935499	0.580979821	0.62404817
HDPE	0.428223344	0.450006099	0.439631201	0.490865675	0.483107787
PVC	0.45020439	0.441970275	0.395351799	0.490865675	0.439929519
LDPE	0.428223344	0.409826983	0.395351799	0.424928495	0.428523939

A normalized judgement matrix is later computed from the already computed weights (Step 1). The weight normalized matrix was found following Step 2, the analysis is illustrated in Table 3. Later, PIS and NIS solutions were determined (Table 4) followed by a distance of alternative from positive-ideal solution (S_i^+), and distance of alternative from negative-ideal solution (S_i^-). The relative closeness to each ideal solution for each alternative was computed by applying a term Pi which is equal to the (S_i^-) divided by the sum of the(S_i^-) and (S_i^+) distance to the PIS and NIS.

Based on the relative closeness to the ideal solution, the plastic waste are ranked in descending order as; PET, HDPE, PVC, LDPE, as shown in Figure 3. This ranking is based on the assumption that there is no significant difference among the selection criteria, and all these criteria are treated equally.

Table 3: Weighted Normalization of matrix

	Decomposition period	compressive strength	Tensile Strength	amount of waste generation	economy
PET	0.498692949	0.527150001	0.60452453	0.418305471	0.430593237
HDPE	0.325449741	0.360004879	0.378082833	0.353423286	0.333344373
PVC	0.342155336	0.35357622	0.340002548	0.353423286	0.303551368
LDPE	0.325449741	0.327861586	0.340002548	0.305948516	0.295681518

Table 4: Calculate the ideal best and ideal worst value

	MAXIMUM	MINIMUM	MINIMUM	MAXIMUM	MINIMUM
V-	0.498692949	0.327861586	0.340002548	0.418305471	0.295681518
	MINIMUM	MAXIMUM	MAXIMUM	MINIMUM	MAXIMUM
V+	0.325449741	0.527150001	0.60452453	0.305948516	0.430593237

Table 5: Performance Score

Plastic type	si+	si-	pi
PET	0.206488001	0.357616	2.089511
HDPE	0.301536945	0.195255	0.84279
PVC	0.344633579	0.171572	0.66941
LDPE	0.357615608	0.206488	0.78389

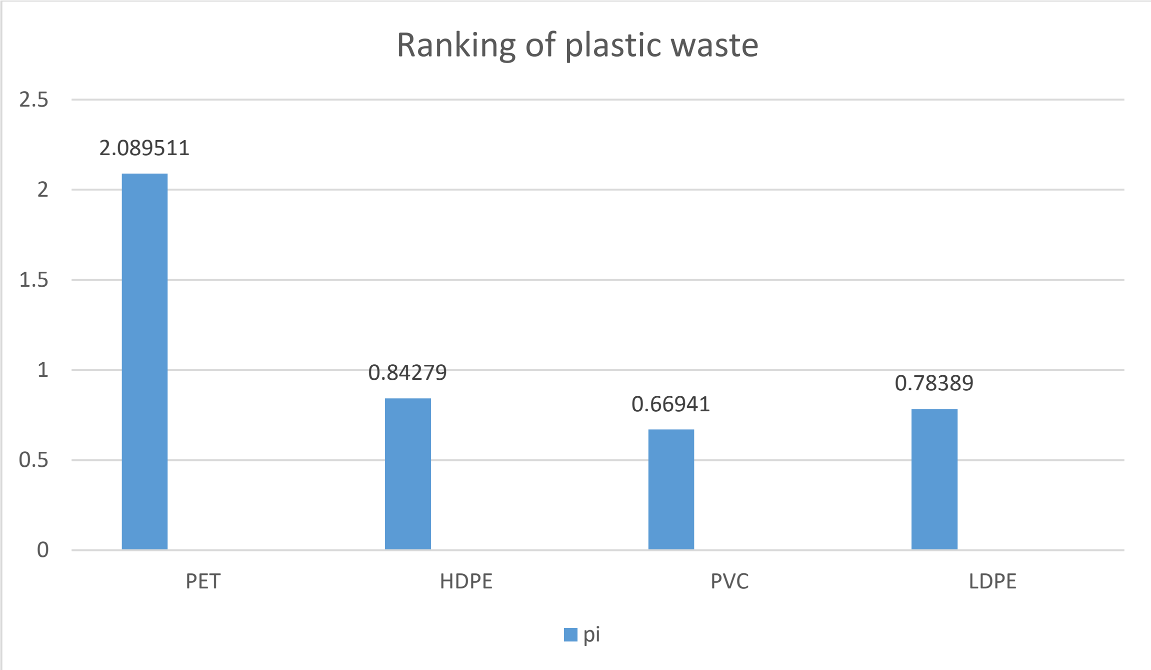

Figure 3. Ranking the choice

In the following research work, the TOPSIS analysis was carried out to calculate the Pi value of different types of plastic waste. The results shows that the PET plastic has pi value of 2.089511, hence it is ranked as 1st. Followed by HDPE LDPE and PVC. As mentioned in (Table 5). Hence PET plastic waste is selected to be use in the concrete.

IV. CONCLUSION

In the beginning, plastic waste was studied from the literature. It was found that there are several types of plastic that are discarded after a certain use and considered as waste. To improve the mechanical properties of concrete. It was decided to select a suitable plastic waste based on its characteristics.

To select a suitable plastic material, TOPSIS was used in order to select the best plastic.

For TOPSIS, it was required to collect data from the field experts through interviews and questionnaire surveys. The data was incorporated in TOPSIS analysis and calculations were done using MS Excel.

As per the study's findings, the most influential factors that affect the selection of suitable plastic waste are tensile strength and compressive strength, and the factors that affect the least are, decomposition time, amount of waste generation, and economy.

Based on research findings, this study concludes that the identified factors could affect the selection process of plastic waste.

The results showed that PET plastic waste was ranked as number one. Thus, PET plastic was selected as an additive in the Plastic-modified concrete.

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