International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 12 - Issue 01 || January 2026 || PP. 11-20

Mechanical and Durability Performance of Concrete Incorporating Electronic Plastic Waste as Fine Aggregate: An Experimental Investigation with Predictive Modeling

Shady Omran[1], Samson Sisupalan[2]
[1]*Ph.D. Scholar, Department of Civil Engineering, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India*
[2]*Professor, Department of Civil Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India.*

Abstract: The rapid pace of urban expansion and population growth has led to an increased demand for concrete, resulting in the extensive depletion of natural aggregates such as sand. Simultaneously, the accumulation of electronic plastic waste (EPW) has become a critical environmental concern due to improper disposal practices and its non-biodegradable nature. This study investigates the feasibility of using EPW as a partial replacement for fine aggregates in concrete to address both resource depletion and waste management challenges. Five concrete mixes were prepared with EPW replacing sand at 0%, 5%, 10%, 15%, and 20% by weight. Mechanical properties—including compressive strength, splitting tensile strength, and flexural strength—were evaluated at 7 and 28 days of curing, along with durability characteristics such as water permeability and electrical resistivity. The results demonstrated a decline in mechanical properties with increasing EPW content, with the highest reductions recorded at the 20% replacement level. In contrast, durability improved with higher EPW percentages. The mix with 15% EPW showed the best improvement in water permeability (28.81%), while the 20% EPW mix achieved the highest increase in electrical resistance (250.76%) compared to the control mix. Additionally, machine learning models were used to predict mechanical performance, with Linear Regression (LR) outperforming Random Forest (RF) in terms of predictive accuracy. These findings suggest that incorporating up to 15% EPW as a sand replacement in concrete is a promising, sustainable approach that enhances durability while contributing to plastic waste reduction.

Keywords: Mechanical Properties, Electronic Plastic Waste, Machine Learning, Electrical Resistance.

1. Introduction

As the cornerstone of modern infrastructure, concrete dominates global construction, with yearly output exceeding 10 billion cubic meters—second only to water in total material usage [1–3]. Forecasts suggest this demand could nearly double by mid-century, reaching 18 billion metric tons annually [4], a trajectory fueled by expanding urban populations and the consequent need for large-scale development [5]. However, this reliance on conventional concrete poses significant ecological risks, particularly through the unsustainable extraction of natural aggregates, which threatens river systems and fragile habitats [6]. The engineering performance of concrete depends critically on its composition, with factors such as aggregate gradation, curing methods, and binder ratios playing decisive roles. Aggregates alone account for 65–80% of the material's volume, making their selection pivotal for achieving desired strength and longevity [7]. Sustainable mix design, therefore, demands rigorous optimization of these components to balance structural requirements with environmental stewardship. Meanwhile, the plastics industry faces a parallel crisis. Global plastic waste has surged from 359 million tons in 2018 to over 390 million tons in 2021 [8], and current disposal trajectories suggest an alarming escalation to 684 million tons by 2050 [9]. This exponential growth underscores the urgent need for innovative waste valorization strategies, particularly in sectors like construction where secondary materials could offset virgin resource consumption.

Electronic plastic waste (E-PW) poses a higher risk than other plastic waste due to its incorporation of toxic heavy metals including mercury, lead, and cadmium. These contaminants exhibit significant leaching potential when improperly managed, posing substantial risks to both ecosystems and public health [10]. The scale of this challenge is particularly acute in Asia, where regional e-waste generation approaches 30 million metric tons annually according to global monitoring data. India accounts for approximately 3.2 million metric tons of this total, maintaining a concerning 10% yearly growth rate that positions it as the second largest contributor behind China [11]. Current waste management systems demonstrate limited capacity, with only 17.4% of this material undergoing formal recycling processes [12]. The predominant disposal methods - uncontrolled incineration and landfilling - create significant environmental and health hazards [13], underscoring the urgent need for alternative valorization pathways. The construction industry presents a promising avenue for E-PW utilization, with multiple studies investigating its incorporation into cementitious matrices. Research has demonstrated that partial substitution of coarse aggregates with processed E-PW can enhance compressive strength by up to 10% at optimal replacement ratios [14]. However, this strengthening effect exhibits threshold behavior, with excessive incorporation leading to progressive strength reduction - studies report declines of 24% in compressive strength and 15.4% in splitting tensile strength at 22% replacement levels [15]. Parallel investigations into fine aggregate replacement have yielded comparable findings, with 20% substitution producing concrete specimens achieving 32.2 MPa compressive strength and 4.8 MPa splitting tensile strength after standard 28-day curing [16]. These results collectively suggest that controlled incorporation of E-PW in concrete mixtures could simultaneously address waste management challenges while potentially enhancing certain mechanical properties.

Regarding the application of E-PW as a substitute for fine aggregate, studies are still limited, especially regarding the durability properties. This study aims to evaluate the use of plastic aggregate as a partial substitute for sand. It presents a study on the mechanical properties and some durability properties (water permeability-electric resistivity) of concrete. Furthermore, to enhance predictive accuracy and optimize mixture design, this research employs advanced machine learning (ML) techniques, specifically Random Forest (RF) and Linear Regression (LR) models, to forecast the mechanical properties of E-PW-modified concrete. A comparative analysis is conducted to determine which of these two ML approaches yields superior predictive performance. This research not only expands the existing literature on the use of electronic waste in concrete production, but also establishes a new paradigm for future research efforts aimed at developing environmentally friendly building materials.

2. Materials

The binder used in this study consists of Ordinary Portland Cement (OPC) Grade 53, complying with the specifications outlined in the Indian standard code IS 12269 [17]. For fine aggregates, natural river sand conforming to Zone II (as per IS 383:2016 [18]) was employed, with a specific gravity and a fineness modulus were 2.66 and 2.9respectively. Coarse aggregates comprised crushed limestone with a maximum nominal size of 20 mm, exhibiting a specific gravity of 2.7 and a fineness modulus of 7.26, consistent with IS 383:2016 [18].

The plastic used in this study was acrylonitrile-butadiene-styrene (ABS) and was obtained (keyboards, printers, computers, etc.) from a plastic waste factory in Tamil Nadu. The raw e-waste was collected, cleaned, dried, and shredded into small pieces, which were then crushed into small particles using an electric crusher . The specific gravity and fineness modulus of this fine plastic aggregate were 0.96 and 3.14, respectively.

3. Concrete mix design

M25 concrete mix was used to create four types of concrete mixes with a water-cement ratio 0.45 [19] containing EPW as a partial replacement for fine aggregate at varying proportions (5-10-15-20) %.

Table 1 shows the mixing proportions for all samples. The mixes were named according to the percentage of electronic plastic aggregate replaced.

Table 1: Concrete mixing proportion

Mix ID	Cement (kg/m3)	CA (kg/m3)	FA (kg/m3)	E-PW (kg/m3)	Water (kg/m3)
CC	420	1060	655	-	189
EPWFA-5	420	1060	622.25	32.75	189
EPWFA-10	420	1060	589.5	65.5	189
EPWFA-15	420	1060	556.75	98.25	189
EPWFA-20	420	1060	524	131	189

4. Experimental plan

To assess compressive strength, 150 mm cubic specimens were cast for each mixture and tested under a constant loading rate of 140 kg/cm²/min until failure, with the crushing load automatically recorded [20]. For splittin tensile strength, cylindrical specimens (150 mm diameter × 300 mm height) were prepared and tested in accordance with established procedures [21]. Additionally, flexural strength was determined using prismatic specimens (100 × 100 × 500 mm) subjected to third-point loading, following the guidelines outlined in [20]. For each concrete mix, three specimens were tested at 7 and 28 days to evaluate strength development over time. ity properties, an electrical resistance test was conducted following ASTM guidelines [22], and a water permeability test was performed on 150 mm x 300 mm cylindrical specimens based on ASTM D4491M-22 [23].

5. Machine learning

The research used linear regression (LR) and random forest (RF) for analysis, where a comprehensive comparison model was developed to predict the mechanical properties of concrete. Random Forest (RF) is a powerful ensemble machine learning technique developed by Leo Breiman in 2001 that combines multiple decision trees to create more accurate and robust predictions [24]. The aim of Random Forest is to overcome the limitations of individual decision trees—particularly their tendency to overfit—by generating numerous trees trained on different random subsets of both the data (through bootstrapping) and features, then aggregating their outputs through majority voting for classification or averaging for regression problems [25]. This ensemble approach seeks to improve prediction accuracy, reduce overfitting, handle complex non-linear relationships without extensive preprocessing, provide reliable feature importance measurements, and create models that generalize well to unseen data while remaining robust against noise and outliers [26].Linear regression (LR) a foundational statistical technique dating back to the work of Francis Galton who introduced the concept of "regression to the mean," models the relationship between a dependent variable and one or more independent variables by fitting a linear equation to observed data [27]. The aim of linear regression is to identify the most appropriate linear relationship between dependent and independent variables by minimizing the discrepancy between observed and predicted outcomes. It seeks to find the optimal line (or hyperplane in multiple dimensions) that best represents the pattern in the data, allowing researchers to understand how changes in predictor variables correlate with changes in the response variable [28]. This enables both prediction of future outcomes and interpretation of the strength and direction of relationships between variables.

Although RF is highly effective in capturing complex and nonlinear patterns within data, its ensemble nature can sometimes limit transparency, making it harder to trace specific variable impacts. In contrast, LR models are advantageous when dealing with systems governed by straightforward, proportional relationships such as those often found in concrete mixes defined by precise material ratios. In this study, the combined use of both modeling approaches not only enhances the reliability of predictions but also deepens the understanding of material behavior, particularly when incorporating unconventional components like electronic waste-derived aggregates. This dual approach balances predictive power with interpretive clarity, supporting both technical innovation and practical application. Equations (1), (2), and (3) were used to measure model accuracy:

Mean Square Error, $MSE = \frac{1}{n}\sum_{i=1}^{n}(Y - Yi)^2$ (1)

Mean Absolute Error, $MAE = \frac{1}{n}\sum_{i=1}^{n}|Y - Yi|^2$ (2)

Root Mean Square Error, $RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Y - Yi)^2}$ (3)

6. Results and discussion

6.1. Compressive strength

Figure 1 shows the decrease in compressive strength with increasing EPW content after 7 and 28 days of curing. At a 5% replacement ratio, the strength decreased by 4.9%, and with each 5% increase, it decreased by 10.46%, 17.16%, and 23.85%, respectively, compared to CC after 7 days. The highest compressive strength value was 34.69 MPa at 0% replacement after 28 days of curing, which deteriorated by 3.69%, 9.25%, 17.21%, and 24.33% at replacement ratios of (5, 10, 15, and 20) %, respectively. Previous studies indicated a significant decrease in compressive strength when replacing fine and coarse aggregate with Polyethylene terephthalate (PET) contents of up to 74% and 79.8%, respectively, compared to the reference mixture [29]. Another study confirmed the same finding when replacing FA with (5-10-20%) plastic waste, with a decrease of 7.14, 12, and 23.8% [30]. This reduction could be attributed to the hydrophobic properties of plastic, causing it to accumulate excessively in the mixture and form a coating around the aggregates, thereby weakening the bond between the aggregates and the cement paste [31, 32].

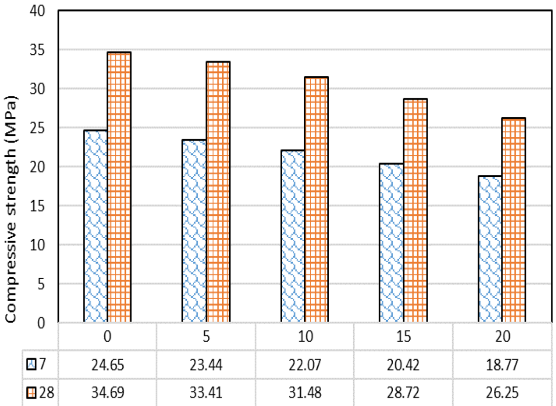

Figure 1. Compressive strength of all samples at 7 & 28 days

6.1.1. Machine learning methodology for compressive strength

Figure 2 shows a comparative analysis of the predicted and observed correlations using a box plot, a graphical tool for summarizing key statistical measures. These plots effectively demonstrate the distribution of data by highlighting four key measures: minimum, median, mean, and maximum. The graphs indicate limited dispersion in the results. Neither approach—Random Forest (RF) nor linear Regression (LR)—produced anomalous results. Figure 3 confirms the consistency between the experimental data and the predictions generated by the Random Forest (RF) and Linear Regression (LR) models, highlighting their dependability. The LR approach showed a strong correlation with a coefficient (R^2 = 0.9881), slightly outperforming RF, which had a coefficient (R^2 = 0.9783). The linear regression (LR) model recorded MSE, MAE, and RMSE values 0.325, 0.5, and 0.536, respectively. On the other hand, random forest (RF) model produced MSE, MAE, and RMSE values 2.737, 1.337, and 1.39, respectively. This demonstrates that the LR model is quite precise in acerating results.

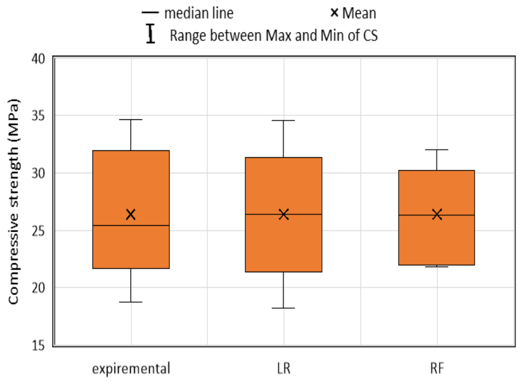

Figure 2. Box plot of compressive strength

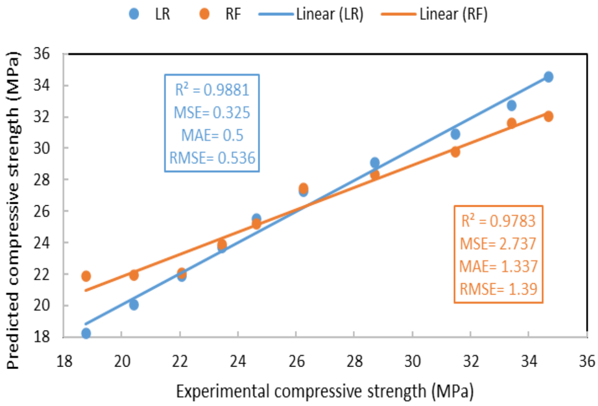

Figure 3.The correlation between experimental and predictive

6.2. Splitting tensile strength

Figure 5 shows that the split tensile strength increased with increasing curing age, with the average increase after 28 days being 27.746% compared to 7 days. Increasing the amount of E-PW in the mixture negatively affected the split tensile strength, as it decreased at replacement ratios of (5-10-15) % compared to EPWFA-0 to 3.6%, 6.3%, and 14.5%, respectively, at 28 days. This may be due to the smooth plastic surface, which creates poor adhesion between it and the cement mortar, as water accumulates on the surface of the plastic particles, reducing the elastic modulus of the plastic particles [33, 34]. EPWFA-20 recorded the greatest decrease, reaching 19.8% compared to CC at 28 days. Several previous researchers have observed a deterioration in STS test results when replace with plastic aggregate [35].

6.2.1. Machine learning methodology for splitting tensile strength

Figure 4 shows the distribution of the splitting tensile strength, with interquartile ranges of strength values ranging from 4.9 MPa to 3.25 MPa. The means of all data sets were within their respective squares, with slight outliers. Figure 6 shows the accuracy of the LR and RF approaches compared to experimental results, with the LR coefficient (R^2 = 0.9887) slightly outperforming the RF coefficient (R^2 = 0.9726). The linear regression (LR) appeared a mean square error (MSE) of 0.00346, a mean absolute error (MAE) of 0.054, and a root mean square error (RMSE) of 0.0589. The Random Forest (RF) method yielded values of 0.029, 0.1417, and 0.1728. The results of a study showed that the regression coefficient is statistically significant when testing the splitting tensile strength of fiber-reinforced foam concrete using Shapley's additive interpretation analysis (SHAP) [36].

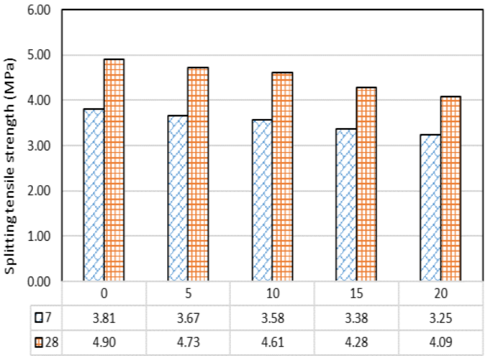

Figure 5. Splitting tensile strength of all samples at 7 & 28 days

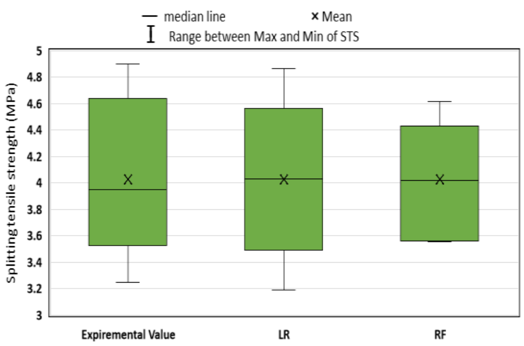

Figure 4. Box plot of splitting tensile strength

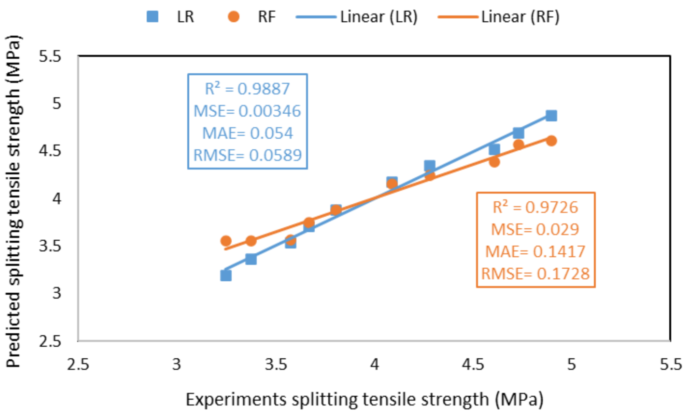

Figure 6. The correlation between experimental and predictive

6.3. Flexural strength

The highest flexural strength value was 5.97 MPa for the CC mixture after 28 days of curing, then began to gradually decrease as the replacement ratio was increased by 5%, as shown in Figure 7. The percentage decreases for the EPWFA-5, EPWFA-10, and EPWFA-15 mixtures were 4.02%, 8.2%, and 13.4% compared to CC at day 28, respectively. EPWFA-20 recorded the highest percentage decrease, reaching 16.08% compared to the control mixture. This decrease is attributed to an imbalance of parameters, as the modulus of elasticity of the e-plastic waste is lower than that of the cement paste, causing microcracks and thus poor mechanical properties [37]. We also note that by the 28-day curing period, hydration is almost complete, and the concrete has generally gained 90% of its strength. The average increase for all samples was 32.17% compared to the 7-day curing period.

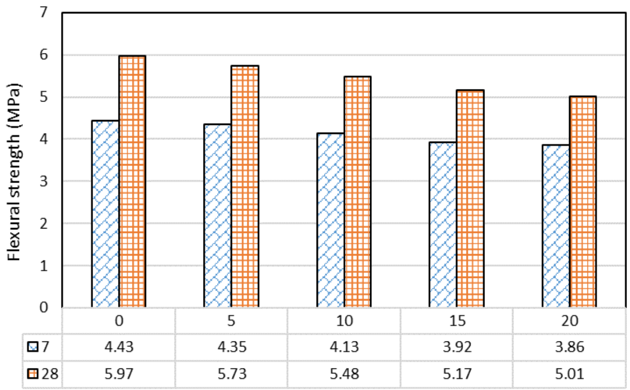

Figure 7: Flexural strength of all samples at 7 & 28 days

6.3.1. Machine learning methodology for flexural strength

The boxplot analysis in Figure 9 reveals that the median values of flexural strength predicted by both the Linear Regression (LR) and Random Forest (RF) models align closely with the experimental values, with the LR predictions exhibiting slightly greater variability and the RF predictions being more compact. The scatter plot further as shown in Figure 8 confirms that the LR model achieves a strong linear relationship with the experimental values (R^2 = 0.9898), while the RF model, despite a slightly lower (R^2 = 0.9615), The error values of the LR approach for MSI, MAI, and RMSI were 0.00542, 0.0586, and 0.0736, again outperforming the RF approach (0.05549, 0.1822, and 0.2356), respectively.

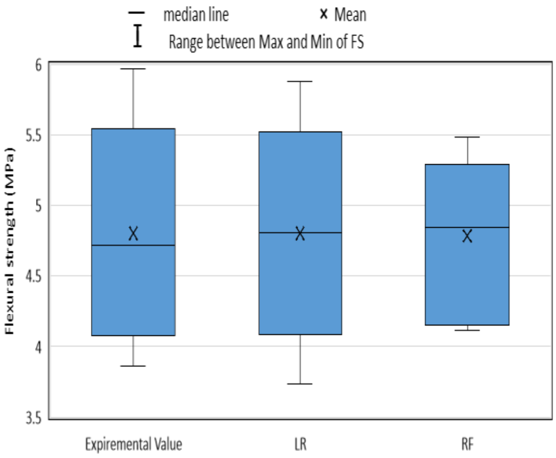

Figure 9. Box plot of splitting tensile strength

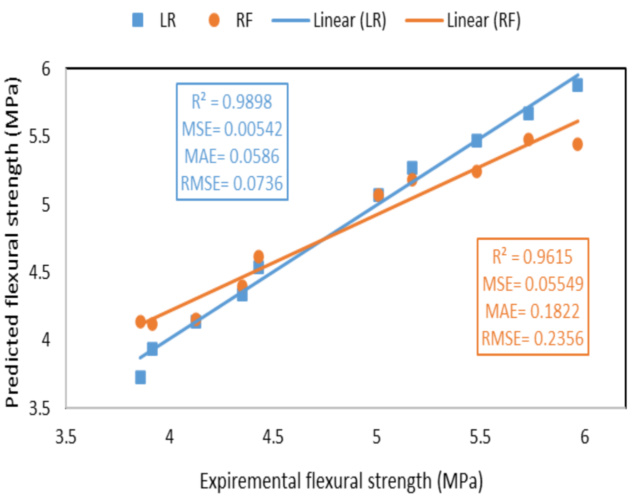

Figure 8. The correlation between experimental and predictive results

6.4. Water permeability

Figure 10 presents the water penetration depths of all specimens following 7 and 28 days of curing. The experimental results demonstrate that mixtures incorporating 5%,10% and 20% electronic plastic waste fine aggregate (EPWFA) replacement achieved water penetration depths of 19.81, 16.94 and 14.16 mm, respectively, after 28 days. Notably, EPWFA (5,10,20) mixtures exhibited lower penetration depths compared to their 7-day measurements. The EPWFA-15 mixture showed a significant reduction in water infiltration, decreasing by 33.75% and 44.07% relative to the conventional concrete at 7 and 28 days, respectively. Across all tested specimens, the inclusion of EPWFA consistently resulted in reduced water permeability compared to reference mix. In contrast, the reference mixture (EPWFA-0) displayed a markedly higher penetration depth of 27.43 mm at 7 days, suggesting potential deficiencies in its impermeability. These findings indicate that EPWFA incorporation enhances concrete resistance to water penetration.

Figure 11 presents the permeability coefficient measurements for different natural fine aggregate (NFA) replacement percentages. The results demonstrate a consistent temporal increase in permeability across all substitution levels, indicating a significant correlation between curing duration and material permeability characteristics. Among the tested mixtures, the 15% replacement formulation exhibited optimal performance, showing the lowest permeability values for both 7-day (14.6% reduction) and 28-day (28.8% reduction) curing periods compared to the control mix. The data reveal distinct behavioral patterns for different replacement levels. At 7 days curing, EPWFA (5,10,20) mixtures showed 7.1%, 19.3% and 43.9% higher permeability coefficients respectively relative to the control. However, after 28 days curing, EPWFA-5 demonstrated improved performance with a 8.47% reduction in permeability, and EPWFA-10 showed an 20% reduction, while EPWFA-20 presented an 12.88 % increase compared to EPWFA-0. Notably, the 20% replacement mixture consistently displayed the highest permeability values, particularly at 28 days curing, suggesting that excessive e-waste plastic aggregate incorporation may reduce the material's impermeability properties.

In a related study, researchers investigated the partial replacement of fine aggregate with polyethylene terephthalate (PET). The results indicated a 37% reduction in water permeability compared to the control sample when 50% of the fine aggregate was substituted with PET. This decrease in permeability can be attributed to the filling of interstitial voids within the concrete matrix by the plastic aggregate, which reduces interparticle spacing and overall porosity. The resultant denser microstructure impedes fluid flow, thereby diminishing permeability[38].Similar conclusions were found by a number of scientists who replaced natural aggregate with plastic waste, resulting in a decrease in water penetration by 23.8% and 26.3% after 7 and 28 days of treatment, respectively [39].

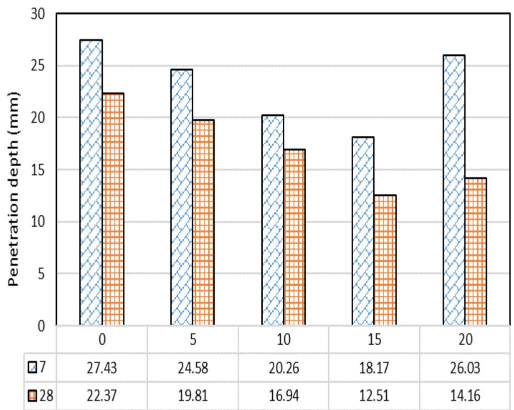

Figure 10. Penetration depth of all samples in 7 & 28 days

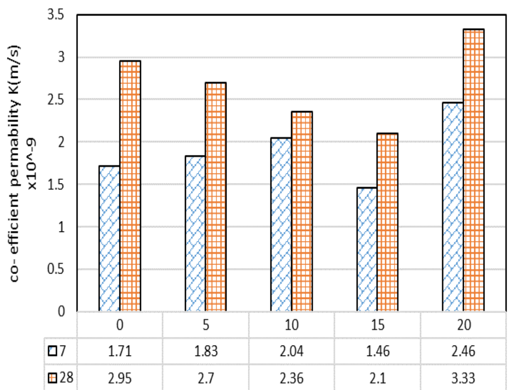

Figure 11. Co-efficient permeability of all samples in 7 & 28 days

6.5. Electric resistive test:

Figure 12 shows that plain concrete recorded the lowest electrical resistivity compared to the other samples, placing it in the very high corrosion risk category according to ASTM [22]. At all replacement ratios, the electrical resistivity increased after 28 days compared to 7 days, due to the continuous hydration process and the improvement of the concrete microstructure over time. As the plastic content increased, the electrical resistivity increased. EPWFA-5 showed an electrical resistivity value of 10.99 Ω-m after 7 days, which increased to 21.16 Ω-m after 28 days. EPWFA-10 and EPWFA-15 showed electrical resistivity of 16.88 and 22.07 Ω-m after 7 days, and 29.32 and 39.67 Ω-m after 28 days, respectively. EPWFA-20 showed the highest resistivity among all the other mixtures, reaching 28.88 Ω-m after 7 days and increasing to 68.54 Ω-m after 28 days.

A group partially replaced natural aggregate with recycled brick aggregate (RBA). The electrical resistance results showed that as RBA increased, the concrete resistance decreased immediately and over time (strength and resistance of recycled concrete made from recycled brick aggregate). Since plastic is an electrical insulator, the resistance increases. As moisture increases, the electrical resistance decreases [40]. Concrete with high porosity often exhibits lower electrical resistance because these pores allow the passage of electrical current [41].

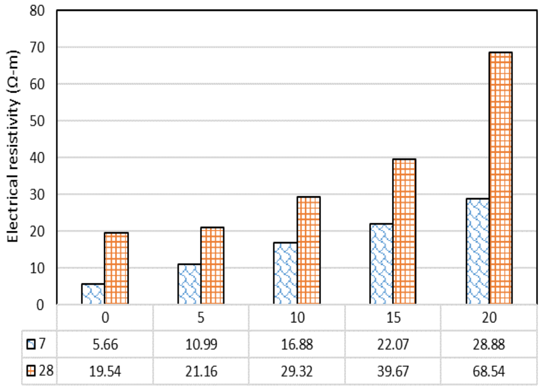

Figure 12. Electrical resistivity of all samples in 7 & 28 days

7. Conclusion

Based on the results obtained in this study, we can conclude the following:

1) Compressive strength decreased in samples containing e-plastic waste by rates ranging from 4.9% (at a 5% replacement rate) to 23.85% (at a 20% replacement rate) after 7 days of treatment. For 28 days, the rate ranged from 3.69% to 24.33%.
2) The percentage decreases ranged from 3.6% to 19.8% for split tensile strength and 4.02% to 16.08% for flexural strength after 28 days of curing. This decrease is attributed to the smooth plastic surface and its hydrophobic nature, as water forms a film around the blocks, creating weak bonds between the E-PW and the cement paste.
3) The best water permeability behavior was observed in the EPWFA-15 mixture. It exhibited lower permeability than the other samples, with decreases of 14.6% and 28.8% at 7 and 28 days, respectively, compared to the reference sample CC.
4) The EPWFA-20 mix had the best electrical resistivity among the five mixtures, reaching 68.54 Ω-m at 28 days.
5) The two approaches used showed close predictions of the experimental values. We observed that the linear regression (LR) outperformed the random forest (RF), with lower error measures and higher correlation coefficients.

8. References

[1]. Sobuz MdHR, Rahman MdM, Aayaz R, et al (2025) Combined influence of modified recycled concrete aggregate and metakaolin on high-strength concrete production: Experimental assessment and machine learning quantifications with advanced SHAP and PDP analyses. Constr Build Mater 461:139897. https://doi.org/10.1016/j.conbuildmat.2025.139897.

[2]. Kumar V (2024) Experimental Study on Concrete Incorporating Partial Replacement of Aggregates with Coconut Shell and Cement with Rice Husk Ash. Int J Res Appl Sci Eng Technol 12:1967–1971. https://doi.org/10.22214/ijraset.2024.63376.

[3]. Patel JS (2017) Study on Concrete Using Fly Ash, Rise Husk Ash and Egg Shell Powder. Int J Res Appl Sci Eng Technol V: 566–570. https://doi.org/10.22214/ijraset.2017.2084.

[4]. Demirboga R, Farhan KZ (2022) Palm oil fuel ash (POFA). Sustainable Concrete Made with Ashes and Dust from Different Sources 279–330. https://doi.org/10.1016/B978-0-12-824050-2.00006-1.

[5]. Pradhan S, Kumar S, Barai S V. (2024) Particle Packing Method of Mix Proportioning and Modified Mixing Approach. Particle Packing Method for Recycled Aggregate Concrete 37–47. https://doi.org/10.1007/978-981-99-7516-7_4.

[6]. Banerjee D, Nanda RP (2024) Waste materials as concrete aggregate - A systematic review. IOP Conf Ser Earth Environ Sci 1326:012149. https://doi.org/10.1088/1755-1315/1326/1/012149.

[7]. Jeyanth B, Sudharsanan R, Thillai Backiam M, Vijay M (2021) Sustainability of Natural Aggregates by Utilising CDW in Concrete. In: Integrated Approaches Towards Solid Waste Management. Springer International Publishing, Cham, pp 121–131.

[8]. Omran S, Sisupalan S (2024) Effect of Replacing Natural Aggregate with Plastic Aggregate on the Mechanical Properties of Concrete-Review. Civil and Environmental Engineering Reports 34:462–482. https://doi.org/10.59440/ceer/193933.

[9]. Alex Tullo (2022) The plastics industry will confront its carbon footprint. C&EN Global Enterprise 100:30–30. https://doi.org/10.1021/cen-10002-cover5.

[10]. Kumar P, Kumar P, Singh Thakur S (2024) E-Waste and Hazardous Elements: A Comprehensive Study of Chemical Components and Environmental Threats. International Journal of Innovative Science and Research Technology (IJISRT) 1074–1085. https://doi.org/10.38124/ijisrt/IJISRT24OCT1008.

[11]. The Global E-waste Monitor 2024 - E-Waste Monitor. https://ewastemonitor.info/the-global-e-waste-monitor-2024/.

[12]. Nithya R, Sivasankari C, Thirunavukkarasu A (2021) Electronic waste generation, regulation and metal recovery: a review. Environ Chem Lett 19:1347–1368. https://doi.org/10.1007/s10311-020-01111-9.

[13]. Priyashantha AKH, Pratheesh N, Pretheeba P (2022) E-waste scenario in South-Asia: an emerging risk to environment and public health. Environ Anal Health Toxicol 37:e2022022. https://doi.org/10.5620/eaht.2022022.

[14]. Biranagi PK, D SS, A S, et al (2024) An Experimental Study on Concrete by Using E-Waste as Partial Replacement of Coarse Aggregate. Int J Res Appl Sci Eng Technol 12:250–255. https://doi.org/10.22214/ijraset.2024.63018.

[15]. Mary Treasa Shinu NM, Needhidasan S (2020) An experimental study of replacing conventional coarse aggregate with E-waste plastic for M40 grade concrete using river sand. Mater Today Proc 22:633–638. https://doi.org/10.1016/j.matpr.2019.09.033.

[16]. Basha S M, Reddy Ch B, K V (2016) Strength behaviour of geopolymer concrete replacing fine aggregates by M- sand and E-waste. International Journal of Engineering Trends and Technology 40:401–407. https://doi.org/10.14445/22315381/ijett-v40p265.

[17]. IS: 269 (**2015**). Ordinary Portland Cement—Specification, New Delhi.

[18]. IS: 383 (2016). Coarse and Fine Aggregate for Concrete Specification, New Delhi.

[19]. IS 10262 : 2019: Concrete Mix Proportioning — Guidelines (Second Revision) : Bureau of Indian Standards. https://archive.org/details/gov.in.is.10262.2019.

[20]. IS: 516. Indian Standard Methods of Tests for Strength of Concrete, New Delhi, **2021**.

[21]. IS: 5816. Method of Test for Splitting Tensile Strength of Concrete, New Delhi, **2004**.

[22]. C1760-12, A. Standard Test Method for Bulk Electrical Conductivity of Hardened Concrete.

[23]. D4491M-22. Standard Test Methods for Water Permeability of Geotextiles by Permittivity.

[24]. L. Breiman, Random forests, Mach. Learn. 45 (2001) 5–32. https://doi.org/10.1023/A:1010933404324.

[25]. Hastie, T., Tibshirani, R., & Friedman, J. (2009). The elements of statistical learning.

[26]. Liaw, A. and Wiener, M., 2002. Classification and regression by randomForest. R news, 2(3), pp.18-22.

[27]. Galton, F., 1886. Regression towards mediocrity in hereditary stature. The Journal of the Anthropological Institute of Great Britain and Ireland, 15, pp.246-263. https://doi.org/10.2307/2841583.

[28]. Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). Applied multiple regression/correlation analysis for the behavioral sciences (3rd ed.). Lawrence Erlbaum Associates Publishers. https://doi.org/10.4324/9780203774441.

[29]. Saxena R, Siddique S, Gupta T, et al (2018) Impact resistance and energy absorption capacity of concrete containing plastic waste. Construction and Building Materials 176, 415-421. https://doi.org/10.1016/j.conbuildmat.2018.05.019.

[30]. Mustafa MA-T, Hanafi I, Mahmoud R, Tayeh BA (2019) Effect of partial replacement of sand by plastic waste on impact resistance of concrete: experiment and simulation. Structures 20, 519-526. https://doi.org/10.1016/j.istruc.2019.06.008.

[31]. Kim KM, Cho YK (2024) Effect of Surface Hydrophilized Plastic Waste Aggregates Made by Mixing Various Kinds of Plastic on Mechanical Properties of Mortar. Materials 2024, Vol 17, Page 247 17:247. https://doi.org/10.3390/MA17010247.

[32]. Oddo MC, Cavaleri L, La Mendola L, Bilal H (2024) Integrating Plastic Waste into Concrete: Sustainable Solutions for the Environment. Materials 17:3408. https://doi.org/10.3390/ma1714340822.

[33]. Lavagna L, Suarez-Riera D, Mangani N, Pavese M (2024) Mechanical properties of mortars with waste plastic as replacement of natural aggregate. Magazine of Concrete Research 76:515–522. https://doi.org/10.1680/jmacr.23.00102

[34]. Ramakrishnan A, Jegan J (2023) Surface Modified Synthetic Plastic Aggregate for Concrete – Experimental and Analytical Studies. Materials Science 29:104–110. https://doi.org/10.5755/j02.ms.3112422.

[35]. Mohammed, A.A., Mohammed, I.I. and Mohammed, S.A., 2019. Some properties of concrete with plastic aggregate derived from shredded PVC sheets. Construction and Building Materials, 201, pp.232-245.34. https://doi.org/10.1016/j.conbuildmat.2018.12.145

[36]. Li, J., Yu, Y., Kim, T. and Hajimohammadi, A., 2023. Unveiling the underlying mechanisms of tensile behaviour enhancement in fibre reinforced foam concrete. Construction and Building Materials, 398, p.132509. https://doi.org/10.1016/j.conbuildmat.2023.132509.

[37]. Hossain M, Bhowmik P, Shaad K (2016) Use of waste plastic aggregation in concrete as a constituent material. Progressive Agriculture 27:383–391. https://doi.org/10.3329/pa.v27i3.30835.

[38]. Kumar Gupta, B., Kapoor, K., Nazeer, M. and Kaur, M., 2020. Waste plastic aggregates as a replacement of natural aggregates. In Sustainable Environment and Infrastructure: Proceedings of EGRWSE 2019 (pp. 249-258). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-51354-2_22.

[39]. Yücel, H.E., Dutkiewicz, M. and Yıldızhan, F., 2023. The effect of waste ballast aggregates on mechanical and durability properties of standard concrete. Materials, 16(7), p.2665. https://doi.org/10.3390/ma16072665.

[40]. P. Singh, K. Kapoor, (2024), Effect of course and fine recycled concrete aggregates on the performance of geopolymer concrete, Iranian Journal of Science and Technology, Transactions of Civil Engineering 48, 4061–4073. https://doi.org/10.1007/s40996-024-01370-4.

[41]. Sau, D., Shiuly, A. & Hazra, T, (2024). Utilization of plastic waste as replacement of natural aggregates in sustainable concrete: effects on mechanical and durability properties. Int. J. Environ. Sci. Technol. 21, 2085–2120. https://doi.org/10.1007/s13762-023-04946-1.