Sustainable Concrete Innovation: Enhancing Cement Efficiency with Eggshell Powder for Eco-Friendly Construction

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ABSTRACT

With rapid industrialization, the accumulation of industrial byproducts has raised significant environmental and economic concerns. One such waste, eggshells—generated in large quantities by hatcheries, bakeries, and fast-food industries—poses ecological challenges if not properly managed. Recognizing the potential of waste-to-wealth transformation, this study explores the feasibility of utilizing eggshell powder (ESP) as a partial replacement for cement in concrete production. Eggshells primarily consist of calcium compounds, making them a viable alternative to cement, which is a major contributor to greenhouse gas emissions. Given the global egg production of approximately 90 million tons annually and India's production of 77.7 billion eggs in 2010-2011, repurposing eggshell waste can contribute significantly to sustainable construction. In this research, M30-grade concrete was cast with varying percentages of ESP replacement (0%, 2.5%, 5%, 7.5%, 10%, and 12.5% by weight of cement). Key performance parameters, including workability, compressive strength, and tensile strength, were systematically evaluated. The findings offer insights into the structural efficiency and environmental benefits of ESP-incorporated concrete, presenting a promising approach to reducing cement consumption, preserving natural limestone reserves, and mitigating CO_2 emissions in the construction industry.

Keywords: egg shell powder(ESP), workability, tensile strength and compressive strength.

1. INTRODUCTION

Concrete, a fundamental component in modern construction, is composed of cement, fine and coarse aggregates, and water. With the rapid expansion of infrastructure, the demand for concrete continues to rise, placing immense pressure on natural resources. The extraction and processing of raw materials for cement production significantly impact the environment, leading to resource depletion, high energy consumption, and greenhouse gas emissions. It is estimated that the production of one ton of Ordinary Portland Cement (OPC) generates nearly one ton of carbon dioxide (CO_2), contributing substantially to global climate change. Given the finite nature of non-renewable energy sources and the urgent need for sustainable practices, the integration of industrial and agricultural byproducts as alternative materials in construction is gaining attention.

Eggshell waste, a major byproduct of the poultry industry, is often disposed of in landfills without proper treatment, resulting in environmental contamination and economic burdens. Eggshells are predominantly composed of calcium carbonate ($CaCO_3$), similar to limestone, which is a primary raw material in cement production. With millions of tons of eggshell waste generated annually, repurposing this biodegradable waste for construction applications presents an innovative and sustainable solution. Studies suggest that eggshell powder (ESP) exhibits properties that can enhance the performance of concrete while reducing reliance on conventional cement.

This study investigates the potential of eggshell powder as a partial replacement for cement in M30-grade concrete. The ESP replacement levels were varied at 2.5%, 5%, 7.5%, and 10% by weight of cement. Comprehensive tests were conducted to evaluate the workability, compressive strength, tensile strength, and durability of ESP-incorporated concrete. Additionally, a durability assessment was performed by immersing concrete specimens in a sodium sulfate solution to determine their resistance to chemical degradation. The objective of this research is to identify the optimal percentage of ESP that maintains or enhances concrete properties while reducing the carbon footprint and economic cost of cement production.

By integrating waste-to-value strategies in the construction sector, this research contributes to sustainable material innovation, circular economy practices, and the advancement of eco-friendly infrastructure solutions. The findings of this study are expected to pave the way for the large-scale application of eggshell-derived materials, promoting environmental conservation and resource efficiency in the building industry.

2. LITERATURE REVIEW

Manzoor Ahmad Allie (2018) In this paper, it is studied that quality of construction material is an important issue which enhances the stability of the structure, an attempt has been made to study the possibilities of using Eggshell powder in paver block. Cement was partially replaced by Eggshell Powder at 5% intervals from 0% to 25% by the method of replacement by weight. The paver block Curing process is done for 7 days and 28 days, after curing it is checked for its Compressive Strength and flexural strength. It was noted that 13.4% increase of compressive strength at 10% replacement of Eggshell Powder. Flexural strength was also 19.5% increased at the same 10% replacement of Eggshell Powder. The result showed the Eggshell Powder can gives more strength if it was replaced as 10% of cement. Pradeep Sharma (2018) In this study performed to decide the very best excellent percent of eggshell powder as partial cement replacement. The creation industries are looking for 'alternative material that may lessen the Construction cost. Over 5% of world CO2 emissions can be credited to Portland cement manufacturing. Demand for cement maintains to develop different ESP concretes were established through replacing 4 to 16% of ESP for cement. Concrete performs the important thing function and a large quantity of concrete is being implemented in every introduction exercise. The egg shell commonly that are disposed, is used as an exchange for the cement for the reason that shell is manufactured from calcium. An egg shell is utilized in first rate combos to discover the feasibility of the use of the egg shells as an exchange to cement. Intention of this task is to prevent the pollution of environment with the aid of the usage of the wrong disposal of the eggshell waste, a live from eggshells domestic waste which includes schools, restaurant, bakeries, homes and rapid food accommodations, via the use of the usage of it as an additive fabric inform of ash & powder in traditional concrete with grade M35 because it's far usually utilized in manufacturing internet websites. N. Parthasarathi (2017) In this paper, concrete is broadly used for the structures. Cement is main material in concrete but due to high demand of cement is costly. And to minimize the cost of structure, alternate material is required to manage the wastes in eco-friendly way. The intention of this research work is to apply the egg shell powder constrained extra of cement. Eggshell powder is changed by using 5%, 10% and 15% weight of cement. An experimental study proves the strength capabilities consisting of spilt tensile strength take a look at that is decreased with addition of eggshell powder, compressive strength test and flexural strength take a look at which can be increased up to 15%. Amarnath Yerramala (2014) In this paper, it describes the usage of poultry waste in concrete thru the improvement of concrete and studied the Properties of concrete with eggshell powder (ESP) as cement alternative. Different ESP concretes had been advanced through replacing 5-15% of ESP for cement. Test are taken, compressive energy and split tensile strength take a look at turned into better than normal concrete for 5% of ESP alternative and it had lower strength than normal concrete with greater than 10% of substitute on the age of 7 & 28 days. The results proven that irrespective of ESP percentage substitute there has been proper relationship among compressive strength and split tensile strength.

D. Gowsika (2014) In this paper opinions the outcomes of experiments evaluating using egg shell powder from egg manufacturing company as partial opportunity for normal Portland cement in cement mortar. The chemical composition of the egg shell powder and compressive strength of the cement mortar changed into decided. The cement mortar of blend shares 1:3 where in cement is partly modified with egg shell powder as 5%, 10%, 15%, 20%, 25%, 30% with the aid of the use of weight of cement. The compressive strength turned into decided at curing a long time 28 days. There become a pointy lower in compressive power beyond 5% egg shell powder replacement. In this course, an experimental research of compressive strength, split tensile strength, and Flexural power changed into below taken to use egg shell powder and admixtures as partial alternative for cement in concrete. S. Karthikeyan (2012) Reduce and Reuse of the opportunity substances is a whole lot energetic to preserve our strength assets. In the field of construction, the use of admixtures and re-utilization of available wastage substances is not a new one. But it is deals with a look at of Egg Shell Powder as a partial substitute of cement in concrete, to improve the strength in addition to reuse & reduce the egg shell wastage. The various traits of ESP are examined and it's far allowed to concrete as a partial alternative of cement. The numerous proportions such as 2.5, 5 and 7.5% are tried on this research and the strength performed by way of ESP concrete is much higher than a nominal concrete. Every admixture has its own strength. There became a pointy decrease inside the power while the proportion of ESP is beyond the extent of 5%. Praveen Kumar (2006) Experimentally investigated the Partial Replacement of Cement with Egg Shell Powder. The goal of this takes a look at the chemical composition of the egg shell to locate its suitability of substitute within the concrete. To look at the probability of using the egg shell and silica fume as cement alternative cloth. To take a look at the strength parameters of the egg shell powder combined specimens and to examine it with traditional specimens. The scope of the look at is to the concrete samples and conduct the compressive strength check, split tensile strength take a look at and flexural power check at 7th & 28thday, with the desired mixtures of egg shell powder and evaluate it with the controlled concrete specimens. In this assignment M30 Concrete is designed for numerous combos. Egg shell with silica fumes is used in special combos to discover the possibility of using the Egg shells as a trade to cement Egg shell powder replaces 10%, 20% and 30% further with the silica fume by using 5%, 10%, 15% of weight of cement. Concrete is cast and Compressive check, split tensile and Flexural assessments were performed to discover the best combination which leads to optimum percent of power .AmarnathYerramala et.al, (2010): - “eggshell powder as cement replacement” studied the properties of concrete with eggshell powder as cement replacement. This paper describes research in to use of poultry waste in concrete through the development of concrete incorporating eggshell powder (ESP). Different ESP concretes were developed by replacing 5-15% of ESP for cement. The result indicated that ESP can successfully be used as partial replacement of cement in concrete production. The data presented cover strength development and transport properties. With respect to the results, at 5% ESP replacement the strengths were higher than control concrete and indicate that 5% ESP is an optimum content for maximum strength. In order to investigate properties of ESP concretes, five mixes were employed in this study, several laboratory trial mixes were carried out with 300kg/m3 cement. Water to cementations ratio, coarse and fine aggregate quantities was arrived for concretes to be tested from the trail mixes. IN this study, compressive loading tests, a loading rate of 2.5KN/s was applied as per IS:516-1959[10]. The test was conducted on 150mm cube specimens at 1,7 and 28 days. Compressive strength was higher than control concrete for 5% ESP replacement at 7 and 28 days of curing ages. ESP replacements greater than 10% had lower strength than control concrete. Addition of fly ash improved compressive strength of ESP concrete. Gowisiet.al, (2011): - "eggshell powder as replacement with cement in concrete" experimentally investigated the egg shell powder as replacement with Cement in Concrete. This paper reports the results of experiments evaluating the use of egg shell powder from egg production industry as partial replacement for ordinary Portland cement in cement mortar. The chemical composition of the egg shell powder and compressive strength of the cement mortar was determined. The cement mortar of mix proportion 1:3 in which cement is partially replaced with egg shell powder as 5%, 10%, 15%, 20%, 25%, 30% by weight of cement. The compressive strength was determined at curing ages 28 days. There was a sharp decrease in compressive strength beyond 5% egg shell powder substitution. The admixtures used are Saw Dust ash, Fly Ash and Micro silica to enhance the strength of the concrete. In this study it is proved that Egg Albumen Foamed Concrete (EAFC) can mix with 5% egg shell powder as partial replacement for cement. In this direction, an experimental investigation of compressive strength, split tensile strength, and Flexural strength was undertaken to use egg shell powder and admixtures as partial replacement for cement in concrete.

Freire et al carried out the investigation on egg shell waste and found out its use in a ceramic wall tile paste. Based on the presence of CaCO3 in egg shell it can be used as an alternative raw material in the production of wall tile materials they also found that egg shell can be used as an excellent alternative for material reuse and waste recycling practices.

Lau yih bling conducted the investigation in egg albumen and reported that foamed concrete was prepared by egg albumen which has reduce the cost and time of project. 1 per cent and 5 per cent egg albumen were used. From the investigation it is concluded that 5 per cent of EAFC consists of unstable compressive strength and higher flexural strength with increased density when compared with control foamed concrete which was 64 per cent and 35 per cent. In this study it is proved that Egg Albumen Foamed Concrete (EAFC) can produce light weight concrete which is more environment friendly and improved properties. Ngo slew kee investigated on the topic of. Effect of coconut fiber and egg albumen in mortar for greener environment. And reported the effect of coconut fiber and egg albumen on mortar compressive and flexural strength. 3 types of samples were tested to compare the strength development of each other's that was mortar control, mortar containing 0.1 per cent coconut fiber with 1 per cent egg albumen and mortar containing 0.5 per cent coconut fiber with 5percentegg albumen. The strength of mortar containing 0.1 per cent coconut fiber with 1 per cent egg albumen was higher than the mortar control whereas the mortar containing 0.5 percent coconut fiber ± 5 per cent egg albumen was lower strength than the mortar control. The strength of mortar containing 0.1 per cent coconut fiber with 1 per cent egg albumen was higher than the mortar control whereas the mortar containing 0.5 per cent coconut fiber ± 5 per cent egg albumen was lower strength than the mortar control. Okonkwo et al has concluded in his research that Egg Shell ash can be used as an alternate for cement which resulted in higher compressive strength on lateritic soil. Constant Cement of 6 and 8 per cent added with the egg ash powder of 0-10 per cent at 2 per cent intervals shows increase in 35 per cent of

compressive strength but fell short of the strength requirements the durability. Ultimately, they found that soil-cement egg shell mixture can be used for road pavements.
Arash Barazesh et al carried out the experiment on the effect of eggshell powder on plasticity index in clay and expansive soils and reported that plasticity index of the soil can be improved by adding egg shell wastes with the clay soil and can be used in construction projects including earth canals and earth dams.

Monisha T experimentally investigated the concrete using eggshell powder and polypropylene fibre. The food processing industries, hotels and restaurants are the places produces egg shell waste abundantly. Dumping of egg shell waste creates odour and various diseases. In order to overcome this problem, we have to dispose the egg shell waste safely without environmental hazards. As a result, utilization of egg shell waste in the concrete has developed. The aim of this project work is to use egg shell powder 20% constantly as replacement of fine aggregate and to use polypropylene fibre in the range of 0%, 0.2%, and 0.4% in the M20 concrete by the volume of fraction. Various tests such as compressive strength, split tensile strength and flexural strength were carried out. The strength properties obtained were compared with the conventional concrete after the curing period of 7, 14 and 28 days. From the results it was observed that, the waste of egg shell powder used in the concrete will be comparatively low cost when compared with normal concrete. Dinesh et al has conducted the experiment by replacing fine aggregate by rice husk ash and egg shell powder. Here they had replaced the Egg shell up to 10%, 20%, 30%, 40% & 50% using M25 grade concrete. They had conducted test for 7 days, 14 days and for 28 days. Based on the analysis in the present experimental work, they had concluded that the tensile strength, flexural strength was decreased with increasing egg shells percent. The compressive strength of the concrete is to meet required strength with 20% of the egg shell at the same time weight of the cubes are reduced up to 2kg to 2.8kg. Jayasankar et al has investigated the experiment by partially replacing cement with flyash and egg shell powder. They had conducted experiment by varying percentage of RHA, ESP, Fly ash in M20, M25 and M30 concrete. Based on the results obtained from the experiment it can be concluded that, RHA, fly ash and ESP mixed cubes has equal strength with that of conventional concrete cubes in certain categories. Karthick et al has conducted experiment by replacing the fine aggregate by egg shell. Here they had replaced the Egg shell up to 10%, 20%, 30%, 40% & 50%. They concluded that, the tensile strength, flexural strength was decreased with increasing egg shells percent. The tensile strength decreased from (2.36N/mm2) to (0.21 N/mm2) with increasing egg shell from (0 wt %) to (50 wt %). Mahendra Prasad et al had done the research to investigate the workability and flexural strength of cement concrete containing silica fume and polypropylene fibers. Silica fume content used was 0%, 5%, 10% and 15% by replacement of equal weight of cement in concrete. Polypropylene fibers were added in 0%, 0.20%, 0.40% and 0.60% by volume fraction of concrete. Silica fume appeared to have an adverse effect on the workability of fiber concrete. It is observed from slump test results of PF0S0 to PF0.6S15 that there is continuous decrease in workability of concrete with increase in polypropylene fiber content. The increase in flexural strength was found to be around 40% with the use of polypropylene and silica fume compared to the reference concrete.

3. PROPOSED SYSTEM

The proposed system aims to incorporate eggshell powder (ESP) as a sustainable partial replacement for cement in M30-grade concrete. By leveraging the high calcium carbonate

($CaCO_3$) content of eggshells, this research seeks to optimize concrete performance while reducing cement dependency, carbon emissions, and production costs.

The system consists of four key phases:

1. **Collection and Pre-Treatment of Eggshells** – Eggshell waste is collected from hatcheries, restaurants, and bakeries. The shells are washed, dried, and ground into fine powder using a mechanical grinder.
2. **Material Characterization and Mix Proportioning** – The eggshell powder is sieved to obtain a fine consistency, followed by chemical and physical analysis to confirm its suitability as a cement substitute. Concrete mixtures with ESP replacements at 0%, 2.5%, 5%, 7.5%, and 10% (by weight of cement) are prepared.
3. **Concrete Testing and Evaluation** – The ESP-based concrete undergoes workability tests (slump cone test), compressive strength testing, and tensile strength assessment at curing intervals of 7, 14, and 28 days. A durability test is conducted by immersing concrete samples in a sodium sulfate solution to simulate real-world environmental conditions.
4. **Analysis and Optimization** – The experimental results are analyzed to determine the optimal ESP percentage that balances strength, durability, and sustainability benefits.

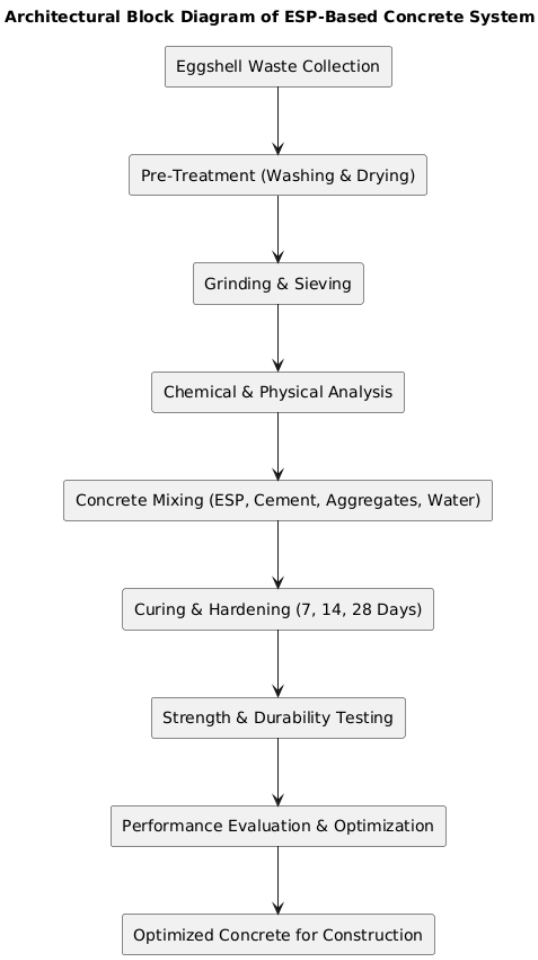

Figure 1 Presents the Block Diagram of Proposed System.

4. RESULTS AND DISCUSSIONS

4.1 General

The results of the strength and workability tests that were carried out on the five trial mixes of M30 grade concrete to evaluate their workability, strength related properties were presented in this chapter. The effects of egg shell powder on the properties of the concrete mixtures were discussed separately in this chapter.

4.2 Experimental outputs

4.2.1 Workability of concrete (Slump cone test)

Table 4.1: Result of slump test

S.No	% of ESP	Slump (mm)
1	0	100
2	2.5	105
3	5	116
4	7.5	121
5	10	125
6	12.5	127

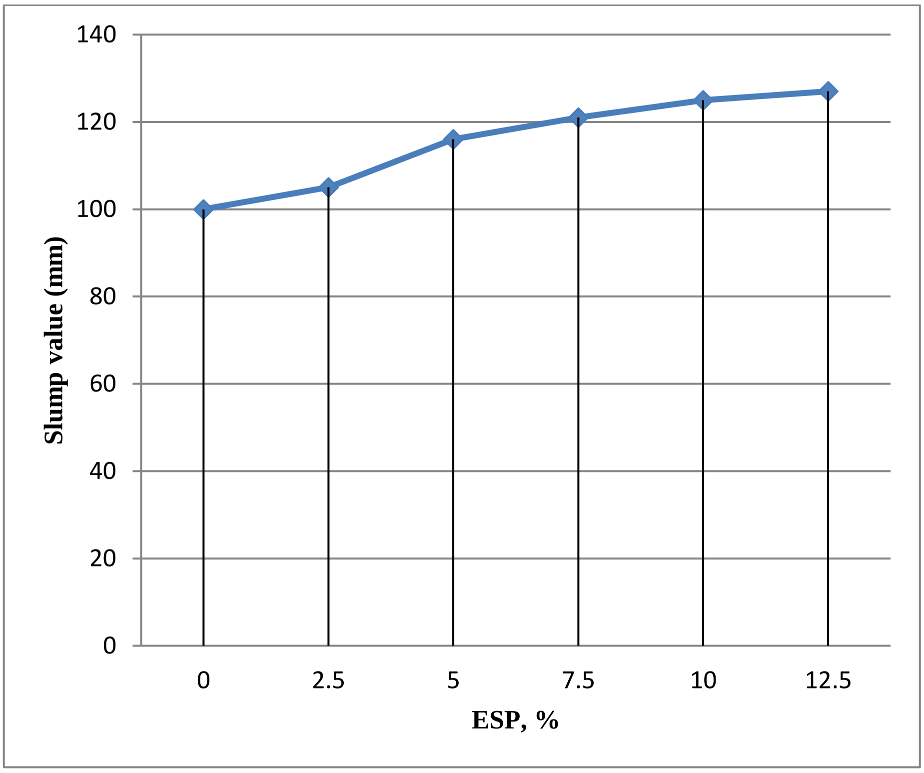

Figure 5.1: Slump test results

The above figure shows the slump results. It was observed that, the slumps increase as the egg shell powder content were increased in the mix.

4.2.2 Compressive Strength of Concrete (in N/mm^2)

The 7, 14, 28 days compressive strength was studied and the values of 3 samples studied are shown in the tabular form. Table 5.2 shows the data of 7, 14, 28 days compressive strength obtained. Below tables gives the 7, 14, 28 days compressive strength of concrete with maximum nominal size of aggregates 20mm. The 7, 14, 28 days compressive strength was also plotted Fig 5.2 by taking the average of these three values overall an increase in the compressive strength was observed with addition of egg shell powder as compare to conventional concrete.

Table: 4.2 Compressive strength of concrete

% of ESP	Avg Compressive strength (N/mm^2)		
	7days	14days	28days
0	21.82	32.032	35.2
2.5	24.12	35.9	38.9
5	27.6	40.3	43.8
7.5	25.3	36.5	40.1
10	22.8	34	38.1
12.5	22	33.1	36

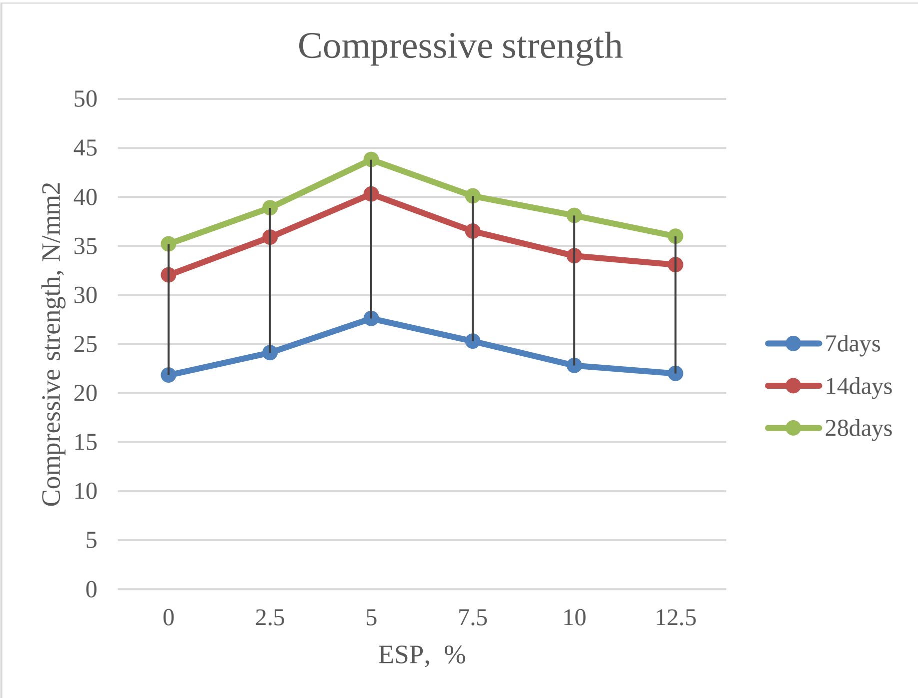

Figure 4.2 Effect of ESP on 7, 14 and 28days compressive strength

4.3 Tensile Strength Test

The Tensile test was performed on the beams of size 15dia x 30height cm to check the split tensile strength of the marble dust as fine aggregate replacement in the concrete and the results obtained while performing the tension test on CTM are given in Table 5.3 and Figure 5.3.

Table 4.3: Result of split tensile strength

S.No	% of ESP	Tensile Strength for 28 days (N/mm^2)
1	0	4.22
2	2.5	4.54
3	5	5.3
4	7.5	4.93
5	10	4.51
6	12.5	4.36

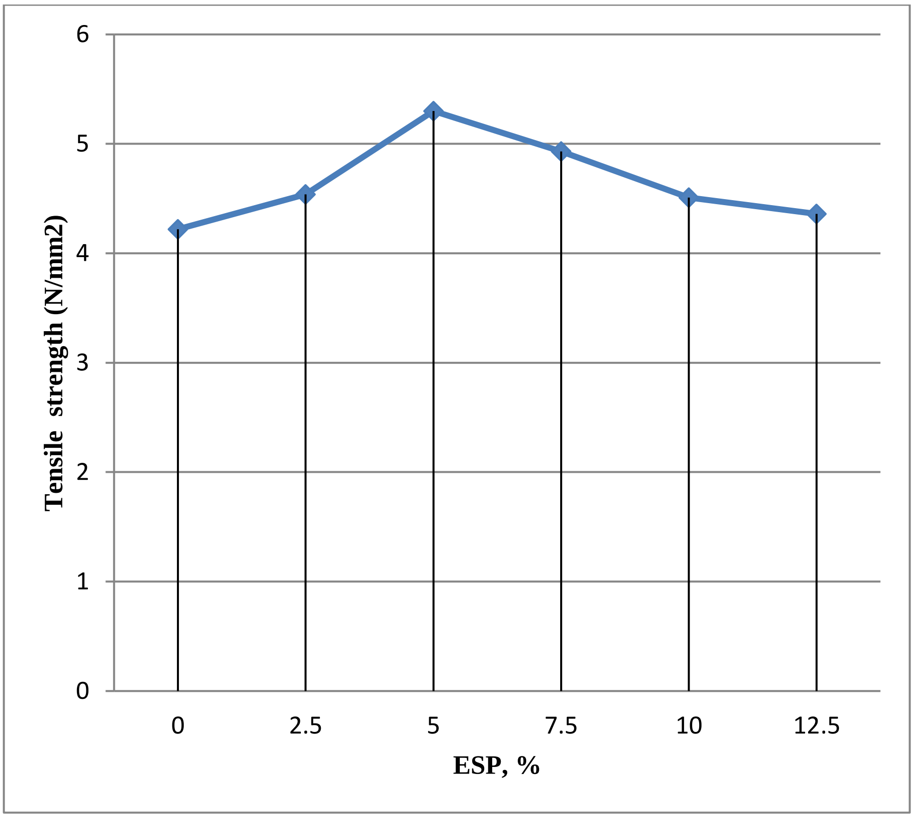

Figure 4.3 Effect of ESP on 28 days Tensile strength

From the above figure, it was observed that the tensile strength of ESP- based concrete was better than that of conventional concrete (i.e. at 0% replacement). The maximum tensile strength gained for 5% Cement replacement with egg shell powder.

5. CONCLUSION

The findings of this study demonstrate the viability of eggshell powder (ESP) as a sustainable partial replacement for cement in M30-grade concrete. The incorporation of 5% ESP resulted in a

25.6% increase in compressive strength and a 24.43% improvement in tensile strength, making it a promising alternative for conventional concrete applications. These enhancements can be attributed to the high calcium carbonate content of eggshells, which contributes to improved binding properties and densification of the concrete matrix.

Beyond structural benefits, the utilization of ESP addresses critical environmental and economic challenges. By repurposing eggshell waste into concrete production, this approach reduces landfill accumulation, lowers carbon emissions associated with cement manufacturing, and promotes a circular economy in construction. The successful implementation of ESP in concrete aligns with global sustainability goals, offering an eco-friendly and cost-effective solution without compromising structural integrity. Future research can further optimize ESP-based concrete by exploring nano-engineered modifications, durability assessments under extreme environmental conditions, and large-scale implementation in real-world construction projects. The integration of machine learning-based predictive models for ESP-concrete performance can enhance its adaptability in modern civil engineering applications.The study paves the way for a greener construction industry, proving that waste materials can be transformed into high-performance building materials while contributing to sustainable infrastructure development.

REFERENCES

[1]. Manzoor Ahmad Allie' A Review Study of Egg Shell Powder as A Cement Replacing Material in Concrete 'May 2018 Ijsdr | Volume 3, Issue5

[2]. Pradeep Sharma1'an experimental investigation on partial replacement of cement with egg shell powder and fine aggregate with copper slag in concrete 'Volume 5, Issue 10,June-2018

[3]. N. Parthasarathi1'Experimental Study on Partial Replacement of Cement with Egg Shell Powder and Silica Fume Vol. 10 | No. 2 |442 - 449 | April - June |2017

[4]. Amarnath Yerramala, Properties of concrete with eggshell powder as cement replacement. The Indian Concrete Journal October2014.

[5]. D.Gowsika, Experimental Investigation of Egg Shell Powder as Partial Replacement with Cement in Concrete, International Journal of Engineering Trends and Technology (IJETT). Volume 14 Number 2. Aug2014.

[6]. J. Karthick, R. Jeyanthi, M. Petchiyammal (2012), Experimental Study on Usage of Egg Shell as Partial Replacement for Sand in Concrete. International Journal of Advanced Research in Education Technology, Vol.1, Issue 1, pp.7-11.

[7]. Praveen Kumar R, (2006). Experimental Study on Partial Replacement of Cement with Egg Shell Powder., International journal of innovations in engineering and technology,Volume5,ISSN:2319-1058

[8]. Dinesh.N, Ramesh Kumar.R, Arunachalam, Chandrasekhar, Gautam.P (2001), „Partial Replacement of Fine Aggregate by Rice husk ash and Eggshell Powder‟, International Journal of Innovative Science and research, Vol.3, Issue 1, pp.1-17

[9]. Jayasankar.R, Mahindran.N, Ilangovan.R (2010), „Studies on Concrete Using Fly Ash, Rice Husk Ash and Egg Shell Powder‟, International Journal of Civil and Structural Engineering, Vol. 1, Issue No 3, pp. 362-373

[10]. J.Karthick, R.Jeyanthi, M.Petchiyammal (2012), „Experimental Study on Usage of Egg Shell as Partial Replacement for Sand in Concrete‟, International Journal of Advanced Research in Education Technology, Vol.1, Issue 1, pp. 7-11
[11]. O. Amu, A. . Fajobi, and B. . Oke, "Effect of Eggshell Powder on the Stabilizing Potential of Lime on an Expansive Clay Soil," J. Appl. Sci., vol. 5, no. 8, pp. 1474– 1478, 2001.
[12]. Ngo slew kee (2010), Effect of Coconut fibre and Egg albumen in mortar for greener Environment, University of Malaysia, Pahang, Institution open access Journal
[13]. Lau Yih Bing,(2010) Effect of Foamed Concrete with Albumen Concrete, University of Malaysia, Pahang, Institution open access Journal
[14]. Freire M.N., and Holanda J. N. F., (2006), Characterization of avian eggshell waste aiming its use in a ceramic wall tile paste, Journal of Ceramica, Vol. 52, pp. 240-244.
[15]. Arash Barazesh, Hamidreza sab, Mehdi Gharib and Moustafa Yousefi Rad, Laboratory Investigation of the Efffect of Eggshell powder on Plasticity Index in Clay and Expansice soils, European Journal of Experimentl Biology, pp 2378-2384, 2012
[16]. Okonkwo U. N., Odiong I.C., and Akpabio, E. E. (2012), Effects of egg shell ash on strength properties of cement-stabilized lateritic, International Journal of Sustainable Construction Engineering & Technology Vol. 3.
[17]. A. L. Romanoff and A. J. Romanoff, The avian egg. 1949.
[18]. T. Nakano, N. Ikawa, and L. Ozimek, "Chemical composition of chicken eggshell and shell membranes," Poult. Sci., vol. 82, no. 3, pp. 510–514, Mar. 2003.
[19]. Z. . Abdel-Salam, A. . Abdou, and M. . Harith, "Elemental and ultrastructural analysis of the eggshell: Ca, Mg and Na distribution during embryonic development via LIBS and SEM techniques," Int. J. Poult. Sci., vol. 5, no. 1, pp. 35–42, 2006. [4] [4] A. M. King'ori, "A Review of the uses of poultry eggshells and shell membrane
[20]. P. Pongtonglor, E. Hooninvathana, P. Limsuwan, S. Limsuvan, and K. Naemchantha, "Utilization of waste eggshells as humidity adsorbent," 2Journal Appl. Sci., vol. 11, no. 21, pp. 3659–3662, 2011.
[21]. K. C. Das, M. Y. Minkara, N. D. Melear, and E. W. Tollner, "Effect of Poultry Litter Amendment on Hatchery Waste Composting," J. Appl. Poult. Res., vol. 11, no. 3, pp. 282–290, Sep. 2002.
[22]. C. P. . Moses, Alternative Fuels in Cement Production. 2011.
[23]. D. Giddings, S. Pickering, K. Simmons, and C. Eastwick, "Combustion and aerodynamic behaviour of car tyre chips in a cement works precalciner," J. Inst. Energy, vol. 75, no. 504, pp. 91–99, 2002.