Eco-Friendly Concrete: Enhancing Sustainability with Eggshell Powder as a Partial Cement Substitute

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ABSTRACT

With the rise of industrialization, the disposal of industrial byproducts and biodegradable waste has become a significant environmental and economic challenge. Eggshell waste, commonly produced by hatcheries, bakeries, and fast-food industries, contributes to ecological contamination if not managed properly. Given that eggshells are rich in calcium compounds, repurposing them as a sustainable material in concrete presents an innovative approach to waste utilization. This study explores the potential of eggshell powder (ESP) as a partial replacement for cement in M30-grade concrete, aiming to reduce the environmental impact of cement production. Cement manufacturing is energy-intensive and contributes significantly to CO_2 emissions; thus, substituting a portion of cement with ESP can help conserve natural limestone reserves, lower energy consumption, and mitigate pollution. Concrete specimens were prepared with ESP replacing cement at varying proportions of 0%, 2.5%, 5%, 7.5%, 10%, and 12.5% by weight. The workability, compressive strength, and tensile strength of the concrete were evaluated and analyzed to assess the feasibility of ESP as a sustainable alternative. The findings contribute to the growing research on eco-friendly construction materials and promote the circular economy by converting waste into valuable resources.

Key words: Eggshell Powder (ESP), Sustainable Concrete, Workability, Compressive Strength, Tensile Strength, Green Construction

1. INTRODUCTION

Concrete is a mixture of different materials like binder (cement), fine aggregate, coarse aggregate and water. Use of concrete is very large so availability of natural material is reduced and there is no material which plays the role of this ideal material. So,to fulfill the requirement of industries we have to replace fully or partially all the materials. In presence, concrete is broadly used for the shape of greatest of the buildings, bridges and so forth. Presently, the entire construction industry is in exploration of the precise and operative the wasted product that could significantly minimized the use of cement and in the end decrease the manufacture cost of concrete.Concrete materials are extensively used in the building and construction industries. Cement is considered as one of the oldest and irreplaceable building material [8]. It is a soft and fine constituent of various mixtures of elements including limestone, shale and clay. Cement when further mixed with water, sand and gravel forms into a hardsolid mass called the concrete. Tremendous amount of thermal and electrical energy is consumed during the manufacturing process of the cement which alone accounts for 40% of the operational cost. During manufacturing of 1 tonne of OPC we need approximately 1.1 tonnes of earth sources like limestone, etc. One of the main ingredients, Portland cement (PC) is generally expensive and yields carbon dioxide (CO2) emissions during its production (approximately 1 ton of CO2 greenhouse gases are generated for making 1 tonof PC) and consumes a lot of energy in its manufacturing process [1]. Energy performs animportant role in successful of growing nations like India. In the context of short availability of non-renewable energy sources fixed with the necessities of huge quantities of energy for Building materials like cement, the position of the usage of commercial waste cannot be underneath anticipated. Social and environmental issue of sustainability and energy conservation are assisting in

changing the PC industry by lowering and partially replacing its cement production with supplementary cementing materials (SCMs).

All the waste products are seriously polluting the environment. There are many types of waste disposal systems are possible. Such as land filling, open burning and river fill definitely indicate the solid waste.[1] Nowadays, waste products are used in construction industry and maximize the profit and reducing the amount of waste. The construction industry is searching for alternative products that can reduce theconstruction cost.[2] The eggshell has good characteristics when mixed with concrete andit has a good strength durability.[3] Most of the eggshell waste is commonly disposed in landfills without any pre-treatment because it is traditionally useless. Eggshell has a cellulosic structure. Egg Shell Powder (ESP) is the fine-grained powder with suitable proportion which is sieved to the required size before use with concrete/mortar

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 constrainedextra 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.

1.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 beused 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 aggregatequantities 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.

D. 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 cementin 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 aspartial 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 controlwhereas 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 themortar containing 0.5 per cent coconut fiber ± 5 per cent egg albumen was lower strengththan 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 shellmixture 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 eggshell 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 thetensile 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 flyashand 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 focuses on developing Eggshell Powder (ESP)-Based Sustainable Concrete as an eco-friendly alternative to conventional Ordinary Portland Cement (OPC) concrete. By incorporating eggshell waste as a partial cement substitute, the system aims to enhance concrete performance while reducing environmental impact, promoting waste utilization, and lowering carbon emissions.

1. Materials and Mix Design

- **Binders:** Cement is partially replaced with Eggshell Powder (ESP) at varying levels: 0%, 2.5%, 5%, 7.5%, 10%, and 12.5% by weight of cement.
- **Aggregates:** Conventional fine and coarse aggregates are used without replacement.
- **Water-to-Binder Ratio (w/b):** Maintained as per M30 mix design guidelines for optimal strength and workability.
- **Curing Methods**: Water Curing for 7 & 28 Days at ambient temperature.
  Moist Curing to ensure proper hydration and strength development.

2. Workability Assessment (Slump Test)

The slump test is conducted to evaluate the workability of ESP-modified concrete. With an increasing percentage of ESP, a gradual decrease in workability is observed due to the powder's finer particle size and higher water absorption. Necessary adjustments in water content or admixtures are considered to maintain optimum flowability.

3. Hardened Properties Evaluation

- **Compressive Strength Test:**

  Concrete cubes (15 cm × 15 cm × 15 cm) are cast and tested after 7 and 28 days of curing.
  The results indicate an increase in compressive strength up to 7.5% ESP replacement, after which strength slightly decreases due to excess ESP affecting cement hydration.

- **Tensile Strength Test:**
  Cylindrical specimens are tested to assess the split tensile strength of ESP-modified concrete.
  ESP replacement improves the tensile performance up to an optimal level, contributing to enhanced durability.

4. Key Findings

- **Optimal Performance:** 7.5% ESP replacement achieves the highest compressive and tensile strength, indicating an effective balance between cement hydration and ESP reactivity.
- **Workability Reduction**: Increasing ESP content reduces the slump value, requiring adjustments in water content or the use of superplasticizers.
- **Sustainability Impact:** The proposed system significantly reduces cement dependency, lowers CO_2 emissions, and promotes biodegradable waste utilization in construction.

The study highlights Eggshell Powder as a sustainable and cost-effective alternative to traditional cement, contributing to greener construction practices and circular waste management.

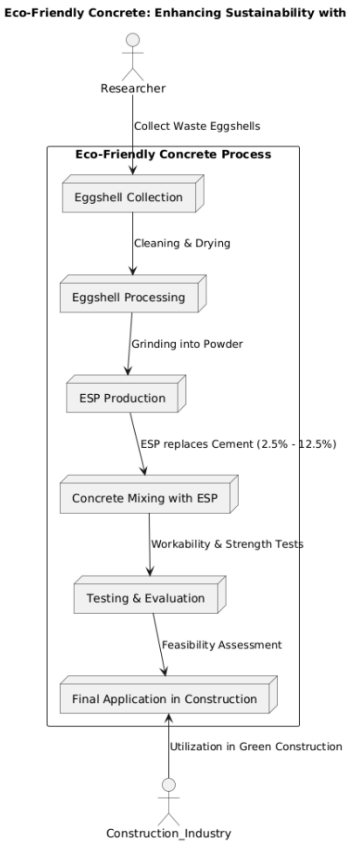

Figure 1 Presents the Block Diagram of Proposed System.

4. RESULTS AND DISCUSSIONS

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.

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

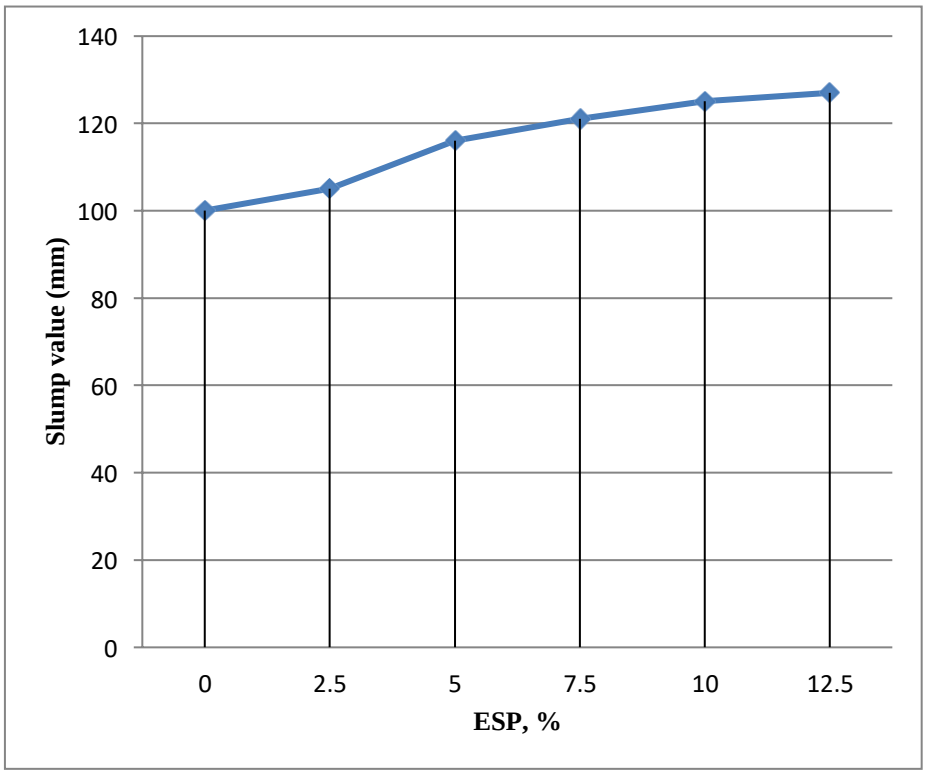

Figure 4.1: Slump test results

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

4.2 Harden properties of concrete

4.2.1 Compressive Strength Test

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 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

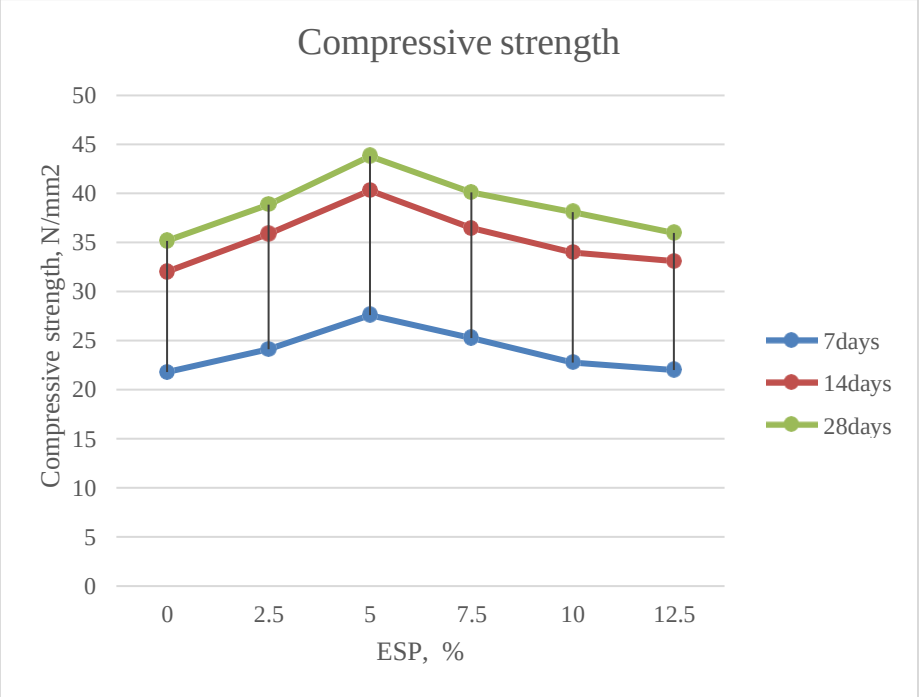

Figure 4.2 Effect of ESP on 7, 14 and 28days compressive strength

5. CONCLUSIONS

From our investigation for M30 grade concrete by replacing 5% also it attains 43.8Mpa. The percentage of increment in compressive and tensile strength as compare to the conventional concrete was 25.6% and 24.43%. So we can make it as a practice by replacing 5% in all conventional buildings. It also makes it as a economical and eco- friendly building. The above-mentioned work of various researcher and our present experimental work, it isclear that egg shell powder can be used as a partial replacement of cement in concrete because of its increased workability, strength parameters like compressive strength and split tensile strength.As disposal, utilization of egg shell powder in concrete will not only provide economic, itwill also help in reducing disposal problems.

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