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Improvement of Engineering Properties of Concrete with Replacement of Egg Shell Powder as Cement & Waste Demolished Concrete as Fine Sand

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ABSTRACT: Recycling material allows for a more efficient life cycle and contributes to environmental protection. In the construction field, this trend has gained important because of the shortage of natural resources and because of environmental problem caused by storing construction and demolition waste. Many past researchers utilised recycled material for lower grade application, because of its poorer mechanical properties and durability problems. Use in higher grade activates is rarely discussed. In order to overcome these difficulties and enable wider utilisation of recycled material in higher strength concrete, the two material mixing approach is a good technique to enhance the properties of recycled material when compared to normal mixing approach.

The concrete mix of M-30 was designed and produced by replacing cement and fine sand with egg shell powder and fine fraction of recycled concrete as sand. The total of five mix properties was prepared with varying percentage of ESP and C&D including one control mix. Cement in concrete was replaced with 0%, 2%, 4%, 6% and 8% with ESP by weight and fine sand in concrete was replaced with 0%, 10%, 20% 40% and 60% with fine fraction of recycled concrete as sand.

The compression test, split tensile strength test and flexural strength test were carries out to evaluate the strength properties for M-30 grade of concrete at 7 days and 28 days.

Keywords: EGG shell powder; C&D Waste; Fine sand; Concrete; Density; Strength; Specifications.

I. 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 India number of waste materials is produced by different manufacturing companies, thermal power plant, municipal solid wastes and other wastes. Solid as well as liquid waste management is one of the biggest problems of the whole world. During manufacturing of one tonnes Ordinary Portland Cement (OPC) we need about 1.1 tonnes of earth resources. Further during manufacturing of one tones of cement an equal amount of carbon dioxide is released in to the atmosphere which acts as a silent killer in the environment as various forms. In this backdrop, the search for cheaper substitute to OPC is a needful one.

Egg shells are agricultural throw away objects produced from chick hatcheries, bakeries, fast food restaurants etc. which can damage the surroundings and as a result comprising ecological issues/contamination which would need appropriate treatment. Egg shell also creates some allergies when kept for longer time in garbage. Use of egg shell waste instead of natural lime to replace cement in concrete can have benefits like minimizing use of cement, conserving natural lime and utilizing waste material. The egg shell primarily contains calcium, magnesium carbonate and protein. Egg Shell Powder (ESP) is the fine grained powder with suitable proportion which is sieved to the required size before use with concrete/mortar.

II. EXPERIMENTAL PROGRAMME

A. Material Properties

The materials used for concrete were Binder materials, Fine Aggregate (FA), Coarse Aggregate (CA), Egg Shell Powder (ESP), Waste Demolished concrete (C&D) and water. Binder used for this study is cement. Cement used was Portland Pozzolana Cement (PPC). Egg Shell Powder is used in the study to replace cement. Broken egg shells collected from the local sources. The shells cleaned in normal water and air dried for 5 days approximately at a temperature range of 25 – 30^{o}C. The shells then crushed ground and sieved through 90 µm sieve. Material passed through 90 µm sieve was used for cement replacement. Waste demolished concrete used in the study to replace fine aggregate. The waste demolished concrete particles passed through 1.0 mm IS sieve and retaining on 600 µm was used for replacing fine aggregate. Coarse aggregate used for the study was also collected from local quarry.

B. Mix Proportioning

The mix design for traditional concrete was carried out as per IS 10262: 2009 [1] for an M 40 mix. The mix proportion for M 30 mix is tabulated in Table 1. The nomenclature used in the study is in Table 2.

C. Workability

Workability of concrete it is observed that the slump test are decreasing from 0 to 8 % replacement of cement by egg shell powder and 0 to 40% replacement of fine sand by C&D. The slump test show from table 3.

Table 1: Mix Proportions for M30 Concrete.

Materials	Cement	FA	CA	Water	W/C ratio
Weight (kg/m3)	430	600	1147	197.8	0.46

Table 2: Nomenclature.

S. No	**Mix**	**Concrete Mix Proportion**
1	NC	M40-conventional concrete
2	ESP2-C&D10	Concrete with 2% ESP & 10% C&D replacement
3	ESP4-C&D20	Concrete with 4% ESP & 20% C&D replacement
4	ESP6-C&D30	Concrete with 6% ESP & 30% C&D replacement
5	ESP8-C&D40	Concrete with 8% ESP & 40% C&D replacement

Table 3: Slump test values for different percentage replacement of ESP & C&D in place of cement & Fine sand.

S. No	**% replacement of cement & fine sand by ECP AND C&D**	**Slump value mm**
1	NC	90
2	ESP2-C&D10	85
3	ESP4-C&D20	80
4	ESP6-C&D30	75
5	ESP8-C&D40	65

III. EXPERIMENTAL INVESTIGATIONS AND RESULT

The data obtained from the experimental investigations were analyzed to study the variations in Density, Workability, compressive strength of concrete, splitting tensile strength of concrete and flexural strength of concrete in conventional concrete and concrete with mixed egg shell powder and C&D material in given percentage.

Hardened Properties of Concrete:

Density of Concrete:

Density of concrete, based upon the 1-day weight of the cubes of 150mm×150mm×150mm at the time of demoulding after 24 hours of casting, was calculated and observations of density of concrete with increase in substitution rate of natural sand with sandstone quarry dust are given in Table 4.

It can be observed that with the addition of egg shall powder and C&D as a partial substitute of cement and fine sand, density of the concrete is increasing. The relationship between density of concrete mixes with increase egg shall powder and C&D in cement and sand substitution level is not linear, but it follows cubic variation.

Table 4: 1-day Density of Concrete Mixes.

Mix Designation	Weight of Cube (g)	Average Weight of Cubes (g)	Density (kg/m^3)
NC	8146	8147	2413.9
	8155		
	8140		
ESP2-C&D10	8186	8207	2431.7
	8210		
	8225		
ESP4-C&D20	8455	8457	2505.7
	8462		
	8454		
ESP6-C&D30	8445	8443	2501.6
	8434		
	8450		
ESP8-C&D40	8450	8441	2501.0
	8434		
	8440		

Concrete mix with 4% cement and 20% fine sand replacement has maximum density among all concrete mixes. Conventional concrete has a density of 2413.9 kg/m^3, whereas for concrete mix with 4% cement and 20% fine sand replacement, it has been increased to 2505.7 kg/m^3, density of concrete with 6% cement and 30% fine sand replacement shows a slight decrease in density, as compared to that of concrete with 4% cement and 20% fine sand replacement level.

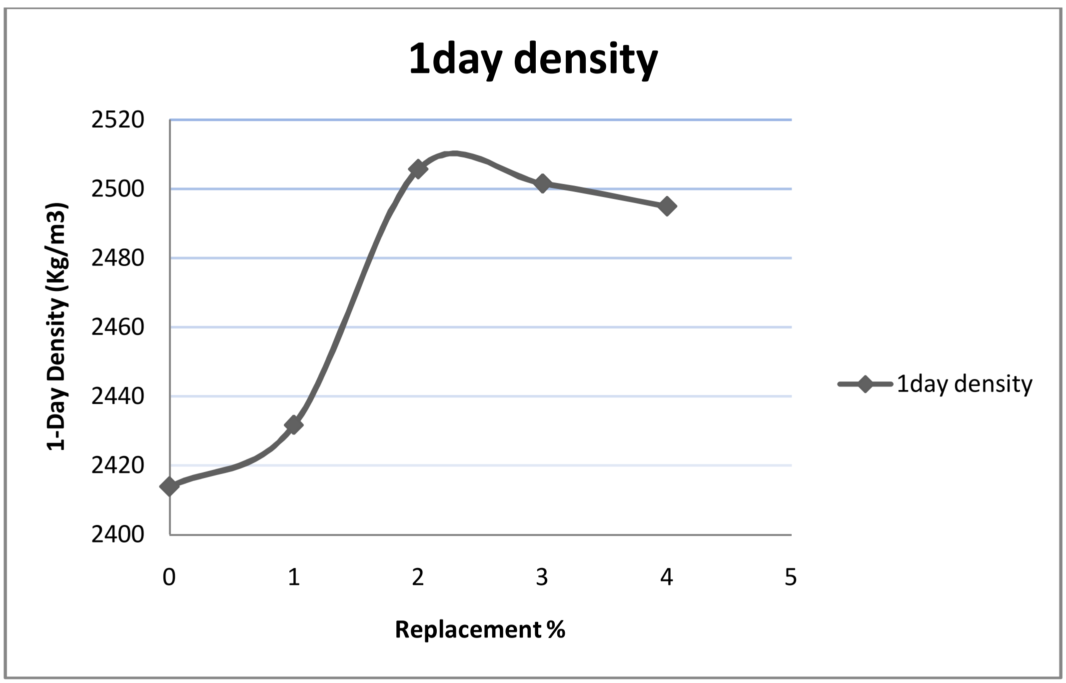


Fig. 1. Graphical representation of average 1-day density of different concrete mixes at various egg shall powder and C&D replacement levels.

The enhancement in density of concrete mixes with replacement of cement and fine sand with egg shall powder and C&D is mainly attributed to the filling effect of micro-fines present in the quarry dust, which tend to fill up the voids present in concrete and makes the microstructure of concrete more dense. Moreover, specific gravity of C&D quarry dust is greater than that of natural sand. Thus, we are replacing natural sand with comparatively heavier particles, which may also be the reason behind the increase in density of concrete. Thus, up to 4% egg shall powder and 20% C&D replacement level, density of concrete with sandstone quarry dust inclusion increases.

It means that 4% egg shall powder and 20% C&D replacement level may have optimum amount of micro-fines to fill up all the voids in concrete. So, at 6% egg shall powder and 30% C&D replacement level, the concrete may now have excessive micro-fines, which instead of filling the voids, start to occupy the main body of the concrete. This may be the reason that after 4% egg shall powder and 20% C&D replacement level, density of the concrete goes towards saturation and show a slight decreasing trend.

Compressive Strength: Compressive strength of different concrete mixes was evaluated at age of 7 days and 28 days to study the effect of partial substitution of cement and fine sand with egg shall powder and C&D and different observations are given in Table 5.

Table 5.

Mix Designation	Compressive Strength (MPa)			
	7 days		28 days	
	Individual	Average	Individual	Average
NC	31.13	30.56	35.64	35.95
	30.62		36.34	
	29.92		35.87	
ESP2-C&D10	33.13	33.82	37.88	38.36
	34.82		38.47	
	33.52		38.74	
ESP4-C&D20	35.62	35.52	40.88	41.63
	35.42		42.44	
	35.52		41.57	
ESP6-C&D30	35.13	34.32	40.41	40.12
	33.32		39.94	
	34.52		40.02	
ESP8-C&D40	33.36	33.91	38.64	39.85
	35.12		41.34	
	33.24		39.57	

It can be observed that inclusion of egg shall powder and C&D as replacement of cement and fine sand leads to significant enhancement in compressive strength of concrete at all ages as compared to conventional concrete mix. At 7 days, compressive strength of conventional concrete was 30.56 MPa, whereas compressive strength of ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes was 33.82, 35.52, 34.32 and 33.91 MPa, respectively. Similarly, at 28 days, compressive strength of conventional concrete mix was 35.95 MPa, whereas compressive strength of ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes was 38.36, 41.63, 40.12 and 39.85 MPa, respectively. It means that compressive strength of concrete goes on increasing with increase in egg shall and C&D and attains a maximum value at replacement level of egg shall 4% and C&D 20% and then starts decreasing.

At age of 28 days, percent increase in compressive strength of concrete for ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes as compared to conventional concrete was 6.7%, 12.67%, 8.58%, and 7.85%, respectively. However, at age of 7 days, increase in compressive strength of concrete for ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes as compared to conventional concrete was 10%, 16.2%, 12%, and 10.96%, respectively.

The increase in compressive strength of concrete at all ages by replacing cement and sand with egg shall powder and C&D may be mainly attributed to the increase in density of concrete. Regression analysis has been done to find out the relationship between 1-day density of each concrete mix with its respective compressive strengths at 7 and 28 days, is shown in Fig. From regression analysis, it is obvious that compressive strength of concrete mixes is directly proportional to the density of concrete at all ages. Coefficient of determination, R^2, was calculated at each age and the value of R^2 for the linear variation between 1-day density of concrete and compressive strength of concrete comes out to be 0.6408 and 0.8432 at 7 days and 28 days, respectively. Thus, there exists a strong correlation between density of concrete and compressive strength of concrete.

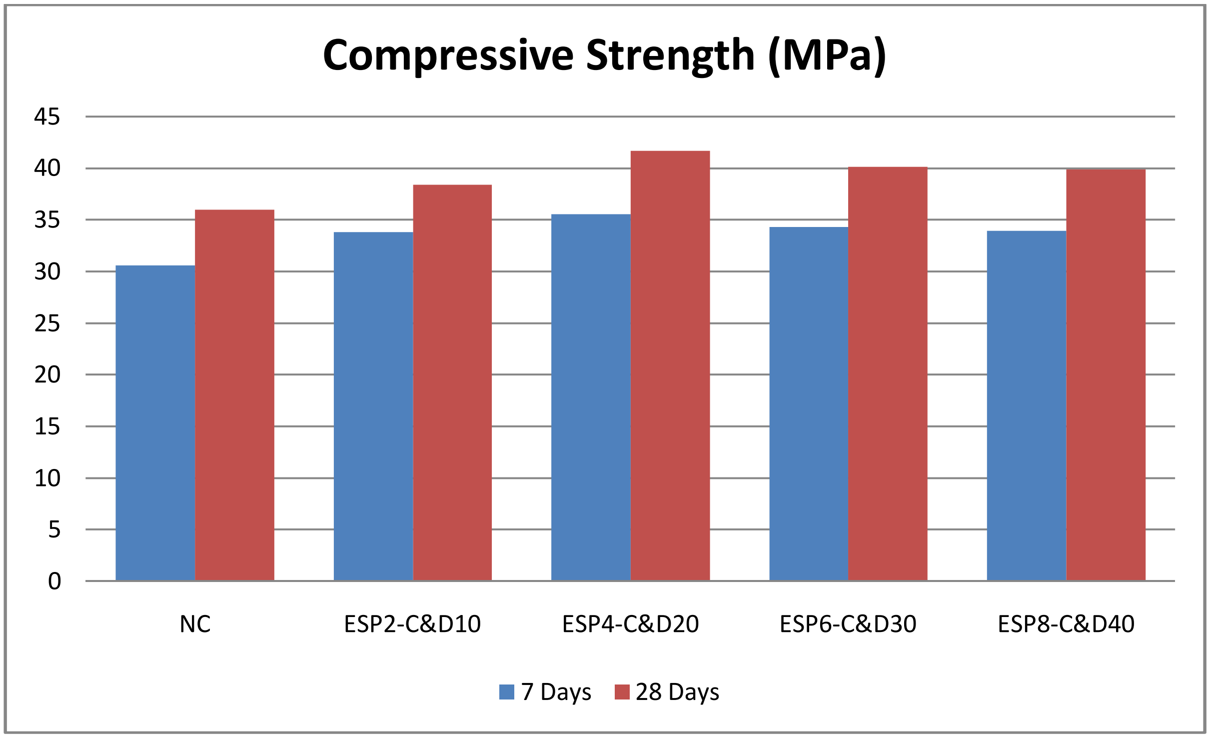


Fig. 2. Effect of Replacement of cement and fine sand with Egg shall powder & construction and demolition waste on Compressive Strength of Concrete.

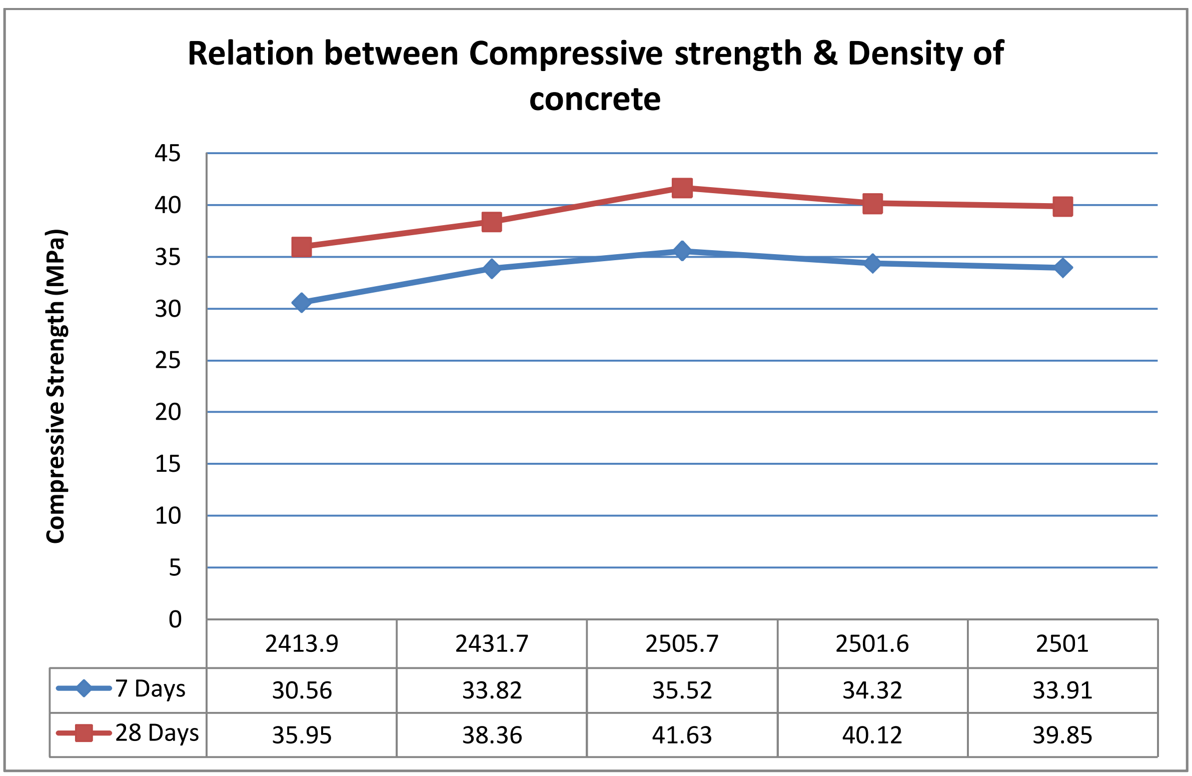


Fig. 3. Relation between 1-day Density and Compressive Strength of Concrete at all Ages.

Splitting Tensile Strength: Splitting tensile strength of different concrete mixes was evaluated at age of 7 days, 28 days to study the effect of partial substitution of cement and fine sand with egg shall powder and C&D and different observations are given in Table 6.

It can be observed that inclusion of egg shall powder and construction and demplition as replacement of cement and fine sand leads to significant enhancement in splitting tensile strength of concrete at all ages as compared to conventional concrete mix. At 7 days, splitting tensile strength of conventional concrete was 2.24 MPa, whereas compressive strength of ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes was 2.29, 2.44, 2.39, and 2.28 MPa, respectively. Similarly, at 28 days, splitting tensile strength of conventional concrete mix was 2.66 MPa, whereas compressive strength of ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes was 2.73, 2.92, 2.85, and 2.72 MPa, respectively. It means that tensile strength of concrete goes on increasing with increase in egg shall and C&D and attains a maximum value at replacement level of egg shall 4% and C&D 20% and then starts decreasing.

At age of 28 days, percent increase in tensile strength of concrete for ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes as compared to conventional concrete was 2.63%, 9.77%, 7.14%, and 2.13%, respectively. However, at age of 7 days, increase in compressive strength of concrete for ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes as compared to conventional concrete was 2.23%, 8.93%, 6.70%, and 1.93%, respectively.

Table 6.

Mix Designation	Splitting Tensile Strength (MPa)			
	7 days		28 days	
	Individual	Average	Individual	Average
NC	2.23	2.24	2.64	2.66
	2.27		2.66	
	2.21		2.67	
ESP2-C&D10	2.27	2.29	2.71	2.73
	2.29		2.74	
	2.32		2.73	
ESP4-C&D20	2.45	2.44	2.92	2.92
	2.42		2.90	
	2.46		2.93	
ESP6-C&D30	2.38	2.39	2.87	2.85
	2.39		2.85	
	2.40		2.84	
ESP8-C&D40	2.27	2.28	2.70	2.72
	2.30		2.71	
	2.28		2.74	

Graphical representation of splitting tensile strength results of all concrete mixes at different ages is given in Fig. 4.

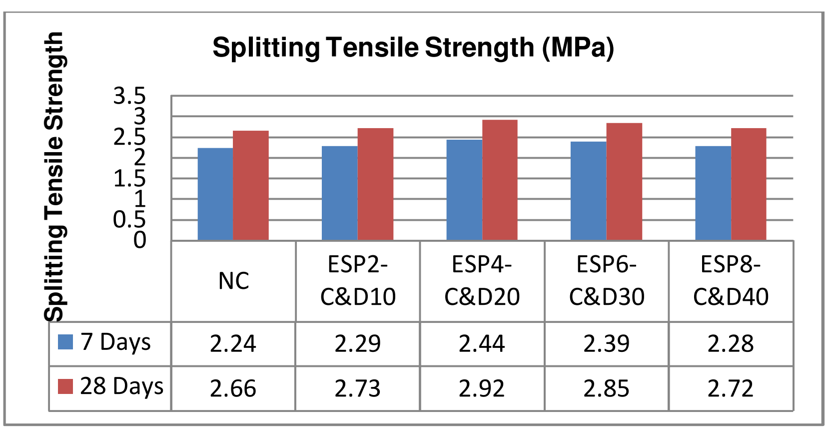


Fig. 4. Effect of Replacement of cement and fine sand with Egg shall powder & construction and demolition waste on Splitting Tensile Strength of Concrete.

The increase in splitting tensile strength of concrete at all ages by replacing cement and sand with egg shall powder and C&D may be mainly attributed to the increase in density of concrete. Regression analysis has been done to find out the relationship between 1-day density of each concrete mix with its respective splitting tensile strengths at 7 and 28 days, is shown in Fig. 5. From regression analysis, it is obvious that splitting tensile strength of concrete mixes is directly proportional to the density of concrete at all ages. Coefficient of determination, R^2, was calculated at each age and the value of R^2 for the linear variation between 1-day density of concrete and splitting tensile strength of concrete comes out to be 0.539 and 0.557 at 7 days and 28 days, respectively. Thus, there exists a strong correlation between density of concrete and splitting tensile strength of concrete. One of the important observations from Table 6 and Fig. 5 was that splitting tensile strength of concrete is maximum for concrete with ESP4-C&D20 percent replacement level and for further replacement of cement and fine sand by ESP6—C&D40 percent, the splitting tensile strength starts decreasing, at all ages of testing.

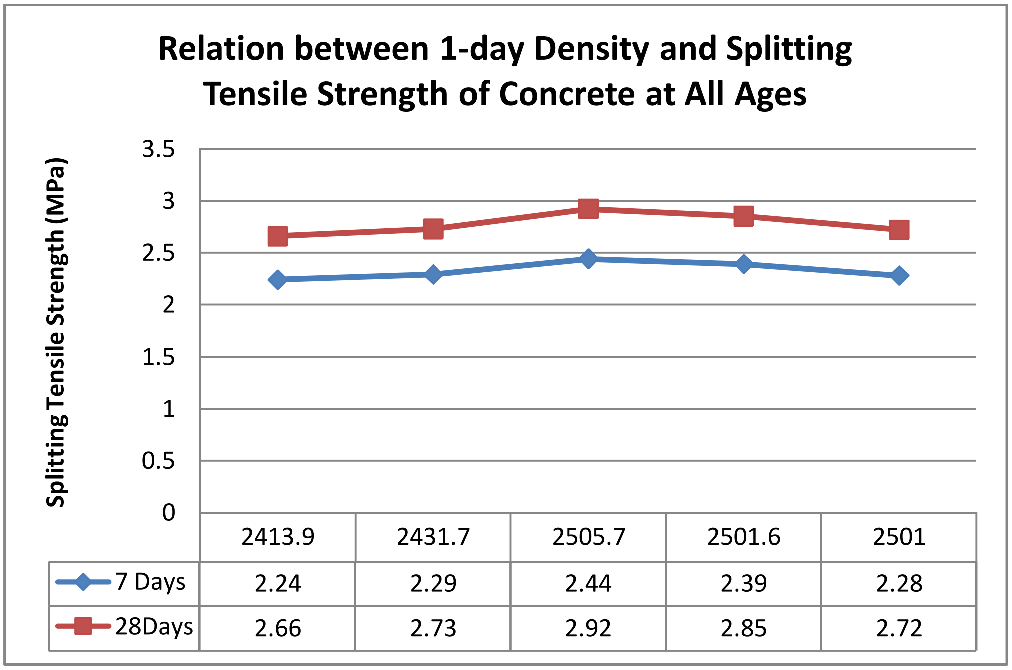


Fig. 5. Relation between 1-day Density and Splitting Tensile Strength of Concrete at All Ages.

Table 7: Flexural Strength Test Results of Concrete Mixes.

Mix Designation	Flexural Strength (MPa)			
	7 days		28 days	
	Individual	Average	Individual	Average
NC	3.52	3.52	3.88	3.89
	3.48		3.92	
	3.55		3.87	
ESP2-C&D10	3.60	3.61	3.97	4.00
	3.59		4.02	
	3.64		4.00	
ESP4-C&D20	3.70	3.73	4.09	4.11
	3.75		4.14	
	3.73		4.11	
ESP6-C&D30	3.64	3.64	4.06	4.05
	3.66		4.01	
	3.61		4.07	
ESP8-C&D40	3.54	3.54	3.95	3.94
	3.55		3.91	
	3.53		3.96	

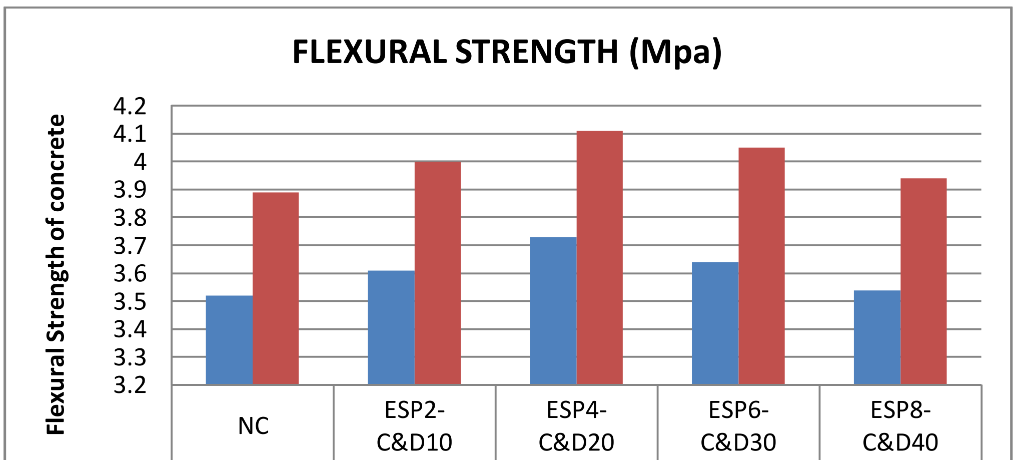
This variation is same as that was in case of compressive strength. Similar arguments can be made to explain this behaviour as in case of compressive strength.

Flexural Strength: Flexural strength of different concrete mixes was evaluated at age of 7 days, 28 days to study the effect of partial substitution of cement and fine sand with egg shall powder and C&D and different observations are given in Table 7.

It can be observed that inclusion of egg shall powder and construction and demolition as replacement of cement and fine sand leads to significant enhancement in flexural strength of concrete at all ages as compared to conventional concrete mix. At 7 days, flexural strength of conventional concrete was 3.52 MPa, whereas flexural strength of ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes was 3.61, 3.73, 3.64, and 3.54 MPa, respectively. Similarly, at 28 days, flexural strength of conventional concrete mix was 3.89 MPa, whereas flexural strength of ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes was 4.00, 4.11, 4.05, and 3.94 MPa, respectively. It means that flexural strength of concrete goes on increasing with increase in egg shall and C&D and attains a maximum value at replacement level of egg shall 4% and C&D 20% and then starts decreasing.

At age of 28 days, percent increase in flexural strength of concrete for ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes as compared to conventional concrete was 2.83%, 5.65%, 4.11%, and 1.3%, respectively. However, at age of 7 days, increase in compressive strength of concrete for ESP2-C&D10, ESP4-C&D20, ESP6-C&D30, and ESP8-C&D40 concrete mixes as compared to conventional concrete was 2.56%, 5.97%, 3.40%, and 0.57%, respectively.

Graphical representation of splitting tensile strength results of all concrete mixes at different ages is given in Fig. 6.

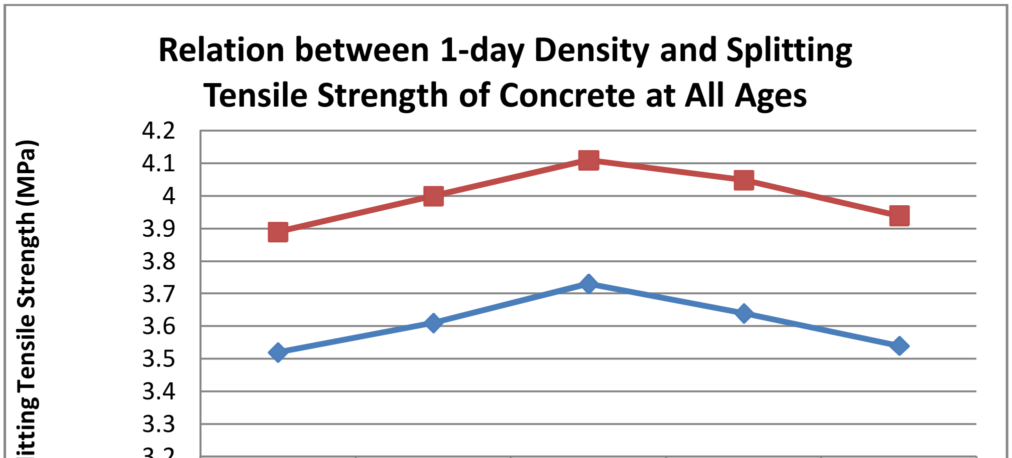


	NC	ESP2-C&D10	ESP4-C&D20	ESP6-C&D30	ESP8-C&D40
7 Days	3.52	3.61	3.73	3.64	3.54
28 Days	3.89	4	4.11	4.05	3.94

Fig. 6. Effect of Replacement of cement and fine sand with Egg shall powder & construction and demolition waste on Flexural Strength of Concrete.

The increase in flexural strength of concrete at all ages by replacing cement and sand with egg shall powder and C&D may be mainly attributed to the increase in density of concrete. Regression analysis has been done to find out the relationship between 1-day density of each concrete mix with its respective splitting tensile strengths at 7 and 28 days, is shown in Fig. 6.

From regression analysis, it is obvious that flexural strength of concrete mixes is directly proportional to the density of concrete at all ages. Coefficient of determination, R^2, was calculated at each age and the value of R^2 for the linear variation between 1-day density of concrete and flexural strength of concrete comes out to be 0.297 and 0.406 at 7 days and 28 days, respectively. Thus, there exists a strong correlation between density of concrete and flexural strength of concrete.



	2413.9	2431.7	2505.7	2501.6	2501
7 Days	3.52	3.61	3.73	3.64	3.54
28Days	3.89	4	4.11	4.05	3.94

Fig. 7. Relation between 1-day Density and Splitting Tensile Strength of Concrete at all Ages.

One of the important observations from Table 7 and Fig. 7 was that flexural strength of concrete is maximum for concrete with ESP4-C&D20 percent replacement level and for further replacement of cement and fine sand by ESP6—C&D40 percent, the flexural strength starts decreasing, at all ages of testing. This variation is same as that was in case of compressive strength. Similar arguments can be made to explain this behavior as in case of compressive strength.

CONCLUSIONS OF THE STUDY

Based on the laboratory tests conducted for this study the following conclusions are given below:

1. The egg shells and construction and demolished as a useful material instead of a waste material (harm to the environment) that they were hurled in many hundred tons annually had been use in an engineering applications.

2. Workability of concrete was decreased as the percentage replacement of cement and fine sand with egg shell powder and demolished sand was increased. The increase in specific surface area of fine aggregate due to the micro-fines present in demolished sand and the angular shape of egg shell powder and demolished sand particles increased the water demand of concrete and consequently resulted in decrease in workability. However, workability of all concrete mixes up to ESP8-C&D40 replacement was suitable in structural uses.

3. Density of concrete was increased with increase in replacement of cement and fine sand with egg shell powder and demolished sand. Density of concrete mix with ESP4-C&D20 replacement level was maximum, which recorded a 3.8% increase in density as compared to control mix. Filling effect of egg shell powder and demolished micro-fines to produce a dense microstructure and the higher specific gravity of quarry dust as compared to natural sand was the reason behind the increase in density of concrete.

4. Compressive strength of concrete was increased with inclusion of egg shell powder and demolished fine sand as partial replacement of cement and fine sand. Concrete mix with ESP4-C&D20 replacement level had maximum compressive strength at all ages. The increase in compressive strength of concrete was mainly attributed to increase in density of concrete with the inclusion of egg shell powder and demolished fine sand and better conditions for hydration of cement in the presence of demolished micro-fines.

5. Splitting tensile strength of concrete was increased with inclusion of egg shell powder and demolished fine sand as partial replacement of cement and fine sand. Concrete mix with ESP4-C&D2 replacement level had maximum splitting tensile strength at all ages. The increase in splitting tensile strength of concrete was mainly attributed to increase in density of concrete with the inclusion of egg shell powder and demolished fine sand and better conditions for hydration of cement in the presence of demolished micro-fines, same as in case of compressive strength.

REFERENCES

[1]. Amarnath Yerramala, (2014). "Properties of concrete with eggshell powder as cement replacement" *The Indian Concrete Journal*, pp. 94102, October 2014.

[2]. Mohd Monish, Vikas Srivastava, V.C. Aggarwal, P.K. Mehta and Rakesh Kumar, (2013). "Demolished waste as coarse aggregate in concrete", *J. Acad. Indus. Res.* Vol. **1**(9), February 2013.

[3]. Abdullah Anwar, Juned Ahmad, Meraj Ahmad Khan, Sabih Ahmad, Syed Aqeel Ahmad, (2014). "Study of Compressive Strength of Concrete by Partial Replacement of Cement with Marble Dust Powder", *International Journal on Mechanical Engineering and Robotics,* Volume **2**, Issue 3, 2014.

[4]. Niya Eldhose, Divya Sasi, (2015). "An Experimental Study on Strength of Concrete by Partial Replacement of Cement by Egg Shell Powder and Aggregates by Crumb Rubber" 2015 *IJEDR,* Volume 3, Issue 4 ISSN: 2321-9939.

[5]. Mohamed Ansari M, Dinesh Kumar M, Milan Charles J, Dr. Vani G, (2016). "Replacement of Cement using Eggshell Powder" *SSRG International Journal of Civil Engineering (SSRG-IJCE)*, Volume 3 Issue 3–March 2016.

[6]. Dhanalakshmi M, Dr Sowmya N J, Dr Chandrashekar A, (2015). "A Comparative Study on Egg Shell Concrete with, Partial Replacement of Cement by Fly Ash" *International Journal for Research in Applied Science & Engineering Technology (IJRASET),* Volume **3**, Special Issue-I1, June 2015.

[7]. S.A. Raji, A. T. Samuel, (2015). "Egg Shell As A Fine Aggregate In Concrete For Sustainable Construction" *International Journal Of Scientific & Technology Research*, Volume **4**, Issue 09, September 2015.

[8]. Mrunalini Deshmukh, (2017). REUCRETE: "Replacement of Fine Aggregate by Demolished Waste Concrete" *International Conference On Emanations in Modern Technology and Engineering (ICEMTE-2017).*

[9]. G. Sivaprakasha, V. Saravana Kumarb and Lakhi Jyoti Saikia, (2016). "Experimental Study on Partial Replacement of Sand by Ceramic Waste in Concrete" Sadguru publication. *Int. J. Chem. Sci.:* **14**(S1), 2016, 266-274, ISSN 0972-768.

[10]. J. Vengadesh Marshall Raman, M. Sriram, (2017). "Study on Replacement Level of Concrete Waste as Fine Aggregate in Concrete" *International Journal for Research in Applied Science & Engineering Technology (IJRASET)* Volume **5** Issue II, February 2017.

[11]. IS: 516 (1959). Method of test for strength of concrete.

[12]. IS: 5816:1999. Method of test for Splitting tensile strength of concrete.

[13]. ASTM Annual Book of Standards (2004) Cement; Lime; Gypsum, West Conshohocken PA, Vol. 04.01.

[14]. IS: 456 - 2000, Plain and reinforced concrete - code of practice", Bureau of Indian Standards, New Delhi, India.

[15]. IS 10262: 1982, Indian standards recommended Guidelines for concrete mix design.

[16]. IS 2386-1963, Method of Test for Aggregate for Concrete, Bureau of Indian Standards, New Delhi.

[17]. M.S. Shetty, Concrete Technology Theory and Practice, 5th edition, S. Chand & Co. Ltd., New Delhi.

[18]. IS 2386-1963, Method of Test for Aggregate for Concrete, Bureau of Indian Standards, New Delhi.