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Technical Note: EFFECT OF INCORPORATING EXPANDED POLYSTYRENE AGGREGATE GRANULES IN CONCRETE MATRIX

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Abstract

Incorporating expanded polystyrene granules in concrete matrix can produce lightweight polystyrene aggregate concrete of various densities. Workability which is an important property of concrete, affects the rate of placement and the degree of compaction of concrete. Inadequate compaction leads to reduction in both strength and durability of concrete. In this research work, the effect of incorporation of expanded polystyrene aggregate granules in concrete was studied. The polystyrene aggregate granules was used to replace 0-40% of coarse aggregates. A mix proportion of 1:1.8:3.7 with water cement ratio of 0.47 were used. Concrete cubes of 150mm×150mm×150mm of coarse aggregate/polystyrene granules were cast and cured at 3, 7, 28, 60 and 90 days respectively. At the end of each hydration period, the three concrete cubes for each hydration period were crushed and their average compressive strength recorded. A total of ninety (90) concrete cubes were cast. The result of the compressive strength tests for 5-40% replacement of coarse aggregates with polystyrene granules ranges from 5.05-31.75N/mm^2 as against 23.59-36.08N/mm^2 for the control test. The workability for 5-40% replacement of coarse aggregates with polystyrene granules ranges from 15-63mm as against 10mm for the control test (0% replacement). The incorporation of the expanded polystyrene aggregate granules as concrete matrix results in the decrease in strength of concrete produced.

Keywords: polystyrene aggregate granules, coarse aggregates, compressive strength, workability

1. Introduction

Lightweight concrete can be produced by partially replacing the normal weight coarse aggregate particles with expanded polystyrene granules. The particle and bulk densities for the polystyrene aggregate used are 62 and 20kg/m^3 respectively. The expanded polystyrene aggregate is commercially available with suitable chemical coating, which is necessary to achieve a uniform dispersion in the fresh concrete mixture and to avoid segregation during mixing and handling of concrete. The polystyrene has negligible water absorption due to its closed cellular structure. [1] reported that the standard workability tests are not suitable for the polystyrene aggregate concrete since they are sensitive to the unit weight of concrete. [2] made similar observation when working with some materials together with polystyrene granules. The incorporation of polystyrene granules in concrete manufacture may provide a satisfactory solution to the problems posed by concrete production [3]. Finally, the incorporation of polystyrene granules should not impair concrete durability. Traditional assessment methods must therefore be adapted to evaluate this material [4].

This study contributes to the development of a methodology for assessing concrete manufactured from polystyrene granules. The methodology is based on the study of concrete containing this material.

The durability and the environmental impact of concrete are closely connected to its transport properties which control the kinetics of the penetration of water and aggressive agents into concrete [5]. The movement of chemical species within the material and the leaching of certain chemicals are also closely linked to concrete diffusivity [6].

Finally, the strength characteristics of concrete containing increasing levels of polystyrene granules were studied to identify the influence of the granules on concrete produced with it [7].

Table 1: Result of compressive strength obtained with 0% replacement of coarse aggregates with polystyrene granules.

Cube size (mm)	Age of cube (days)	Test load (kN)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
150×150×150	3	560	24.89	
150×150×150	3	520	23.11	23.59
150×150×150	3	512	22.76	
150×150×150	7	530	23.56	
150×150×150	7	590	26.22	25.48
150×150×150	7	600	26.67	
150×150×150	28	705	31.33	
150×150×150	28	633	28.13	29.11
150×150×150	28	627	27.87	
150×150×150	60	700	31.11	
150×150×150	60	796	35.38	35.50
150×150×150	60	900	40.00	
150×150×150	90	660	29.33	
150×150×150	90	821	36.48	36.08
150×150×150	90	955	42.44	

2. Methodology

Concrete mixtures with six levels of polystyrene granules ranging from 5, 10%, 20%, 30% and 40% and concrete mixtures with no polystyrene granules were investigated to determine their effect on the strength of concrete. The mixtures were labeled M0, M5, M10, M20, M30 and M40 with the different polystyrene granules replacement percentages of coarse aggregates represented by the final digits in the label. The mixtures were proportioned for a target cube strength of $43N/mm^2$ and had a cementitious material content of $340kg/m^3$, a fine aggregate content of $627kg/m^3$, a coarse aggregate content of $1273kg/m^3$ and a water cement ratio of 0.47.

Crushed expanded polystyrene granules angular in shape with a non toxic chemical coating and having a mean diameter of 3.5mm were used in the concrete mixtures. The fine aggregate used was clean river sand, free from deleterious substances with a specific gravity of 2.62 and bulk density of $1533kg/m^3$. The coarse aggregate was obtained from a local supplier with a maximum size of 20mm, specific gravity of 2.65 and bulk density of $1467kg/m^3$. Both aggregates conforms to [8] and [9] respectively for coarse and fine aggregates. The cement used was Ordinary Portland Cement (Ibeto) which conforms to [10].

2.1. Compressive strength test

Tests to determine density, workability and compressive strength were carried out in this study. For the compressive strength test, polystyrene aggregate granules was used to replace 0 to 40% of coarse aggregates by weight. For the compressive strength test

Table 2: Result of compressive strength obtained with 5% replacement of coarse aggregates with polystyrene granules.

Cube size (mm)	Age of cube (days)	Test load (kN)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
150×150×150	3	500	22.22	
150×150×150	3	410	18.22	19.82
150×150×150	3	428	19.02	
150×150×150	7	560	24.89	
150×150×150	7	500	22.22	22.83
150×150×150	7	481	21.38	
150×150×150	28	599	26.62	
150×150×150	28	637	28.31	26.55
150×150×150	28	556	24.71	
150×150×150	60	680	30.22	
150×150×150	60	600	26.67	26.82
150×150×150	60	530	23.56	
150×150×150	90	655	29.11	
150×150×150	90	789	35.07	31.75
150×150×150	90	699	31.07	

Table 3: Result of compressive strength obtained with 10% replacement of coarse aggregates with polystyrene granules.

Cube size (mm)	Age of cube (days)	Test load (kN)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
150×150×150	3	320	14.22	
150×150×150	3	390	17.33	14.98
150×150×150	3	301	13.38	
150×150×150	7	400	17.78	
150×150×150	7	380	16.89	18.22
150×150×150	7	450	20.00	
150×150×150	28	480	21.33	
150×150×150	28	520	23.11	21.01
150×150×150	28	418	18.58	
150×150×150	60	490	21.78	
150×150×150	60	569	25.29	23.26
150×150×150	60	511	22.71	
150×150×150	90	545	24.22	
150×150×150	90	616	27.38	26.98
150×150×150	90	660	29.33	

Table 4: Result of compressive strength obtained with 20% replacement of coarse aggregates with polystyrene granules.

Cube size (mm)	Age of cube (days)	Test load (kN)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
150×150×150	3	268	11.91	
150×150×150	3	300	13.33	11.88
150×150×150	3	234	10.40	
150×150×150	7	351	15.60	
150×150×150	7	288	12.80	12.93
150×150×150	7	234	10.40	
150×150×150	28	293	13.02	
150×150×150	28	358	15.91	14.16
150×150×150	28	305	13.56	
150×150×150	60	420	18.67	
150×150×150	60	403	17.91	18.05
150×150×150	60	395	17.56	
150×150×150	90	504	22.40	
150×150×150	90	416	18.49	20.52
150×150×150	90	465	20.67	

Table 5: Result of compressive strength obtained with 30% replacement of coarse aggregates with polystyrene granules.

Cube size (mm)	Age of cube (days)	Test load (kN)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
150×150×150	3	100	4.44	
150×150×150	3	145	6.44	6.78
150×150×150	3	213	9.47	
150×150×150	7	235	10.44	
150×150×150	7	186	8.27	9.50
150×150×150	7	220	9.78	
150×150×150	28	194	8.62	
150×150×150	28	249	11.07	9.67
150×150×150	28	210	9.33	
150×150×150	60	283	12.58	
150×150×150	60	199	8.84	11.45
150×150×150	60	291	12.93	
150×150×150	90	303	13.47	
150×150×150	90	388	17.24	13.21
150×150×150	90	201	8.93	

150mm cube specimen were used. A total of 90 specimens were cast and cured in water at room temperature in the laboratory for 3, 7, 28, 60 and 90 days. At the end of each hydration period, three specimens for each were tested for compressive strength and the average recorded.

2.2. Workability test

For the workability, a standard slump cone measuring 300mm x 200mm x 100mm was used. The compaction was also in three layers as carried out in compressive strength, that is one third of its height, two-third of its height and filled up completely. Each layer was compacted using a tamping rod.

3. Results and Discussion

Table 1-6 shows the result of the compressive strength of concrete with 0-40% replacement of coarse aggregate with polystyrene aggregate granules. The result shows that strength development increases with increase in hydration period. The result of the compressive strength for 5-40% replacement of coarse aggregate with polystyrene granules ranges from 5.05-31.75N/mm^2 as against 23.59-36.08N/mm^2 for the control test. The result shows that there is a decrease in the strength of concrete produced as the percentage replacement level of coarse aggregates with polystyrene granules increases.

Table 7 shows the result of workability of concrete produced when polystyrene granules are used in a certain replacement level of coarse aggregates. The result of workability for 5-40% replacement of coarse aggregates with polystyrene granules ranges from 15-63mm

Table 6: Result of compressive strength obtained with 40% replacement of coarse aggregates with polystyrene granules.

Cube size (mm)	Age of cube (days)	Test load (kN)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
150×150×150	3	132	5.87	
150×150×150	3	92	4.09	5.05
150×150×150	3	117	5.20	
150×150×150	7	188	8.33	
150×150×150	7	163	7.24	8.45
150×150×150	7	220	9.78	
150×150×150	28	180	8.00	
150×150×150	28	206	9.16	9.44
150×150×150	28	251	11.16	
150×150×150	60	199	8.84	
150×150×150	60	233	10.36	10.61
150×150×150	60	284	12.62	
150×150×150	90	301	13.38	
150×150×150	90	207	9.20	11.64
150×150×150	90	278	12.35	

Table 7: Result of workability of concrete produced with 0-40% replacement level of coarse aggregates with polystyrene granules.

% Level of Polystyrene granules	Workability (mm)
0	10
5	15
10	22
20	40
30	49
40	63

as against 10mm for the control test. The result shows that the higher the workability of concrete produced, the lower the strength of concrete.

4. Conclusion

The conclusion of the study can be summarized as follows:

1. The incorporation of polystyrene granules in the production of concrete will reduce the strength of concrete produced.
2. The strength development in the concrete produced increases with the increase in hydration period
3. The strength of concrete decreases with the increase in workability.

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