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Investigation into Strength Properties of Polymer-Sand Aggregate Concrete

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Abstract
Polymer concrete (PC) is a composite material formed by combining mineral aggregates such as sand or gravel with a monomer. This study investigated the strength properties of a polymer concrete using reprocessed Pure Water Sachet (PWS) as a binder and sharp sand as aggregate for possible replacement for conventional cement concrete in some areas of application. The polymer sand aggregate concrete was prepared by mixing reprocessed PWS with sand in different polymer-aggregate percentage replacements by volume (50%-50%, 60%-40%, 70%-30%, and 80%-20%) after sieve analysis had been carried out on the sand while the control specimen, that is, conventional cement concrete was prepared from a mix ratio of 1:2:4. Compressive strength test was carried out on all samples after 28 days curing in air and water for both polymer aggregate concrete and conventional cement concrete respectively. It was discovered that, the more the polymer (reprocessed PWS) content the lower the compressive strength. The compressive strength ranged from 2.0N/mm^2-0.5N/mm^2 (50%-50% to 80%-20%) at an average of 1.2N/mm^2; but very low compared to conventional cement concrete strength as specified in BS 8110 1-1997. However, modifying cement formulations with polymers provides many important properties that make a variety of applications possible, including concrete patch and repair, decorative cement overlays, ceramic tile adhesives, and many others.
Keywords: Polymer Concrete (PC), Pure Water Sachet (PWS), Polymer-Aggregate, Sieve analysis, Compressive Strength.

1. Introduction

The conventional Portland cement concrete is the most widely used construction material due to its better physical properties and relatively low cost of construction. This age long form of concrete however, has a number of limitations; such as low flexural strength, low failure strain, susceptibility to frost damage and low resistance to chemical attack (Blaga and Beaudoin, 2004a). These drawbacks are well recognized by the engineer and can usually be allowed for in most applications. In certain solutions these problems can be solved by using materials which contain an organic polymer or resin (commercial polymer) instead of or in conjunction with Portland cement (Raji et al, 2009).

The use of certain additives to improve the quality and performance of concrete had been carried out in many countries like Canada, India, Japan etc (Wahby, 2003; Blaga and Beaudoin, 2004b; Ohama, 2006; Islam et al, 2011). These addictives include among others asbestos, glass, nylon, carbon, polythene, fly-ash, polymer, epoxy, and super plasticizers. These materials offer the advantages of higher strength, improved durability, and resistance to damage from freeze-thaw cycle, high rate of strength gain and high coefficient of thermal movement, outstanding adhesion qualities and low shrinkage (Wahby, 2003; Mason, 2004; Ohama, 2006; Islam et al, 2011).

Polymer Concrete (PC) is a composite material formed by combining mineral aggregates such as sand or gravel with a monomer (Wahby, 2003; Garas and Vipulanandan, 1997; Ohama, 2006; Islam et al, 2011). Due to its rapid setting, high strength properties and ability to withstand a corrosive environment, PC is increasingly being used as an alternate to cement concrete in many applications, construction and repair of structures, highway pavements, bridge decks, waste water pipes and even structural and decorative construction panels. These widely divergent uses clearly indicate that no commercially available product could be compounded to perform all these tasks well; therefore, the term PC should never suggest only one product, but rather a family of products (Vipulanandan, 1993; Garas and Vipulanandan, 1997; Wahby, 2003; Islam et al, 2011). Advances in coupling agents and material science in general further optimize the PC mixtures. Information collected will be used in developing a database for polymer concrete and their corresponding properties and applications (Vipulanandan, 1993).

Polymer concrete is not like traditional concrete, although it uses some of the same types of materials. It is also used for construction projects in the same manner, but the polymer compounds give the concrete several characteristics that tend to make it safer or more durable than regular concrete (Vipulanandan, 1993; Wahby, 2003; Ohama, 2006; Islam et al, 2011). Polymer concrete tends to be more expensive than the traditional version and is measured more specifically in terms of density and shrinkage (Vipulanandan, 1993).

Polymer concrete is used for many kinds of specialized construction projects. Like other types of concrete, it can be used to join two different components or provide a structure or base. The material is used in electrical or industrial construction where the concrete needs to last a long time and be resistant to many types of corrosion (Wahby, 2003; Ohama, 2006; ACI, 2009).

The advent of sachet water popularly known as "Pure water" in Nigeria has contributed to the environmental pollution of this Country; due to its non-biodegradable nature. This "Pure Water Sachet" (PWS) which is a family of polymer has been discovered to be of interest in the Construction Industry. Thus the replacement of Portland cement with this polymer gives rise to a Polymer Concrete (PC) (kareem, 2005).However, this study investigates the strength properties of polymer (PWS) sand aggregate concrete as a possible replacement of conventional cement concrete in some areas of application and also to encourage the use of PWS in construction applications as a way of controlling indiscriminate littering of environment with this biodegradable PWS.

2. Materials and Methodology

The Polymer sand aggregate concrete was produced using "Pure water" sachet, organic solvent (Kerosene), and sand as aggregate. Though, the production exists in three forms namely; laboratory scale, pilot scale and the industrial scale; the pilot scale method was adopted.

The pure water sachets were collected within the Ilorin environs; the collected PWS was shredded and air dried to remove any form of moisture that could be present. The dried shredded pieces were heated on a burner by dissolving in a solvent (kerosene) at a temperature ranging between 200^{o}C – 300^{o}C and equally being stirred intermittently. Stirring continued as heating was in progress until homogeneity was achieved. The solution was poured in a calibrated cylinder and sand aggregate added to it after Sieve analysis and Specific gravity tests had been carried out on it in accordance to ASTM D422-63 (2007) and ASTM C1884 respectively in four(4) different polymer-aggregate percentage replacements by volume (50%-50%, 60%-40%, 70%-30%, and 80%-20%). For each polymer-aggregate percentage replacement, the mixture was stirred evenly before being poured into 100mmx100mmx100mm metal concrete cube mould and allowed to cool and solidify for about 3 hours before being demoulded. This was allowed to cure for 28 days after-which compressive strength test was carried out on the sample in accordance to BS 1881, Part 1161 and compared with control sample, that is, cement concrete cube made from mixture of Ordinary Portland Cement (OPC), fine aggregate (Sharp sand), coarse aggregate (19mm sized granite) at a ratio of 1:2:4 and cured in water for 28 days as well. An average of four(4) samples were prepared for each percentage replacement, so, therefore, a total of 20 cubes were cast, that is, 16 cubes representing 50%-50%, 60%-40%, 70%-30%, 80%-20% polymer aggregate replacements and 4 cubes for the control sample.

3. Discussion of result

The result obtained showed that the polymer sand aggregate cubes irrespective of the percentage-mix do not crush under compression unlike the normal cement concrete cube but instead reduce in height and weight relative to strength and density respectively. They compressed under a small applied loads of values between0.5KN and 2.0KN between the different additive and percentages. The 50%-50% polymer aggregate percent replacement sample had the highest compressive strength of 2.0 N/mm^2 of all the different polymer sand aggregate percent replacements while the conventional cement concrete had a compressive strength of 25.4N/mm^2 which has met standard strength for reinforced concrete of grade 25 as reported by BS 8110 1-(1997) and Oyenuga (2008) that concrete characteristic strength, fcu, forms the concrete grade. The result also showed that conventional cement concrete had a density of 2400kg/m^3 as against polymer aggregate concrete whose density ranged between 1079kg/m^3 to 811kg/m^3 for the different polymer aggregate percentage replacements, that is, 50%-50% to 80%-20% at an average density of 973kg/m^3. Also, in all the percentage replacements, 50%-50% showed the highest density which might be unconnected to the lightness of PWS, hence the reason why compressive strength test revealed that the more the polymer in the concrete mix, the lower the strength and density respectively. However, the conventional cement concrete who displayed good (high) strength and density could not be unconnected to the stone-like or rocky-like nature cement binder always exhibits or transforms to when in contact with water. The reduction in the size (height and weight) of concrete cube when subjected to compressive load during the compressive strength test experiment and the cracks noticed on conventional cement concrete cube with little or no reduction in size (height and weight) when subjected to same load could be adduced to the polymer binder nature (lightness of PWS or its synthetic nature) and the rock-like nature of cement binder when solidified after coming in contact with water respectively. Also, the combination of aggregates, that is, sharp sand and granite used in the production of conventional cement concrete as against sand aggregate used for polymer aggregate concrete could also be responsible for low and high strength and density exhibited by polymer sand aggregate concrete and cement concrete respectively. Therefore, polymer sand aggregate concrete could be classified as light weight concrete and conventional cement concrete as dense concrete as reported by Oyenuga (2008) following their average densities of 973kg/m^3 and 2400kg/m^3 respectively. He affirmed that there are two types of concrete namely dense concrete and light weight concrete. He defined light weight concrete as those weighing less than 1920kg/m^3 and are made in densities down to about 160kg/m^3 and dense concrete as the most common form of concrete for reinforced concrete work with an average density of 2400kg/m^3.

Following the compressive strength test result, it could be deduced that polymer sand aggregate produced from PWS could not replace the conventional cement concrete in some areas of application especially in areas where strength is of utmost concern; but it could be used in areas where strength is of less concern, that is, areas where it is not expected to resist any or direct load such as in patch and repair, decorative cement overlays, ceramic tile adhesives, and many others. The relationship between the compressive strength and percentage mix of polymer-aggregate is shown on figure 1, while the Sieve analysis and Specific gravity results are presented in tables1 and 2.

4. Conclusion

Further to discussion of results, the following conclusions can be drawn;

- PWS Polymer sand concrete increases in strength as the polymer content decreases unlike in cement concrete that the higher the quantity of cement in the entire mass the stronger the concrete.
- PWS Polymer sand concrete increases in density as the polymer content decreases.
- PWS Polymer sand concrete reduces in size (height and weight) under a compressive load and the reduction is apparent as polymer content increases.
- PWS Polymer sand concrete is classified as light weight aggregate concrete and conventional cement concrete as dense concrete.
- PWS Polymer sand concrete has a lower compressive strength when compared to the conventional cement concrete.

5. Recommendation

Further to the study carried out, the following recommendations are proffered;

- It is recommended that further study be carried out to substantiate the development of PWS Polymer concrete in comparison with conventional cement concrete as the curing age increases.
- It is recommended that further study be carried out on PWS Polymer concrete using both fine and coarse aggregates as obtainable in conventional cement concrete and their strength properties compared.
- Further study to increase the strength should be looked into in order to upgrade the strength so that it can compete with the conventional cement concrete putting into consideration cost and durability.

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Table 1: Result of sieve analysis of Sharp sand sample (1000g)

B.S sieve size	Sieve weight (g)	Sieve + sample retained (g)	Weight of sample retained (g)	Weight of sample passing (g)	% passing
2.36	427	457	30	970	97.0
1.70	413	447	34	93.6	93.6
1.00	520	600	80	856	85.6
0.85	430	449	19	837	83.7
0.50	491	738	247	590	59.0
0.40	416	614	138	452	45.2
0.30	326	516	190	262	26.2
0.25	410	548	78	184	18.4
0.212	357	427	70	114	11.4
0.09	4152	540	88	26	2.6
Pan	410	427	26	-	-

Table 2: Determination of specific gravity of sharp sand using ASTM C1884.

Weight (g)	1	2	3
Weight of specific gravity bottle M_1	26.50	26.50	26.50
Weight of specific gravity bottle +1/3 full of sample, M_2	73.00	66.00	65.00
Sample + water to full, M_3	89.00	98.50	98.00
Weight of specific gravity bottle + water only to full, M_4	75.00	75.00	75.00
Specific gravity	1.431	2.469	2.566
Average = (2+3)/2	2.518		

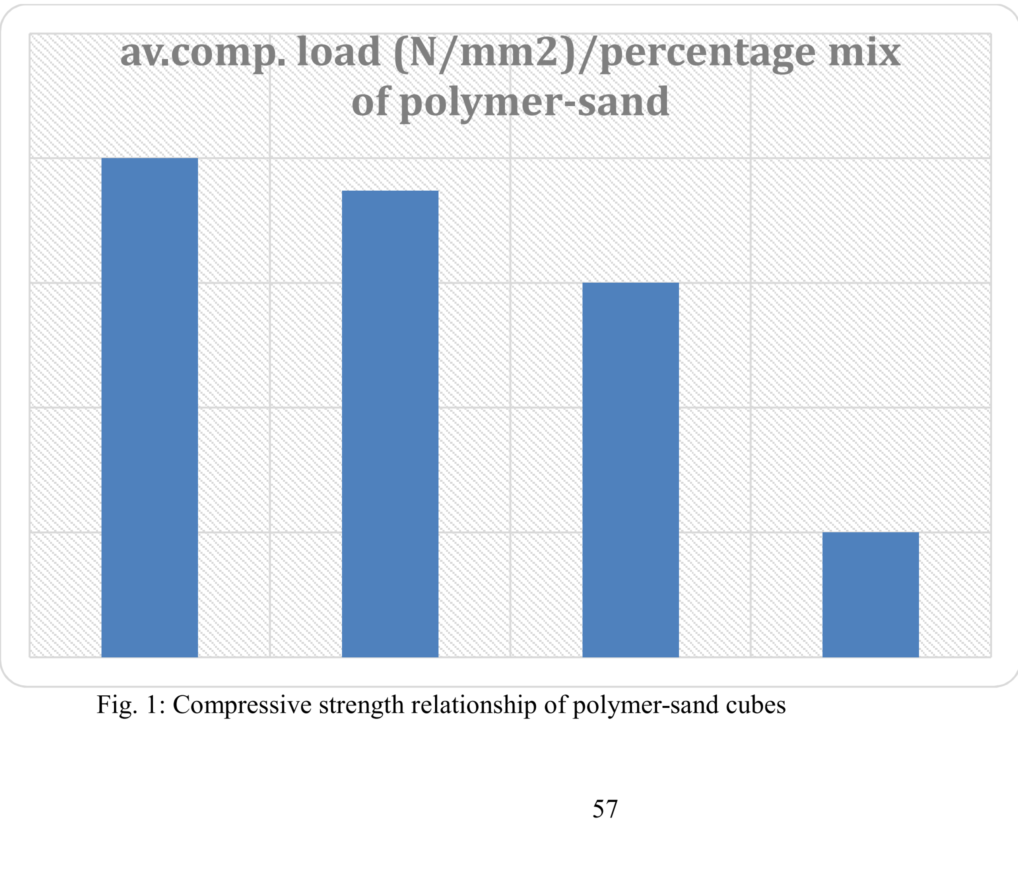

Fig. 1: Compressive strength relationship of polymer-sand cubes

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