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THE USE OF EXPANDED POLYSTYRENE IN RIGID PAVEMENT

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Abstract

The application of Expanded polystyrene (EPS) in civil engineering has offered solutions to several problems associated with pavement construction such as in building pavement over underground service, in low bearing capacity subgrade soils and in countries with extreme winters. EPS has been effectively used in several construction projects including subgrade for roads and highways, backfill for retaining walls and bridge abutments worldwide Expanded Polystyrene (EPS) was used to replace 33% of concrete as Base course in the layer of a rigid pavement on 19.4 m walkway of the School of Engineering, Yaba college of Technology, Lagos. In order to avoid the inefficient, and even the incorrect use of EPS, more has to be done to develop and proliferate technical knowledge. Compressive strength test conducted for the cast specimen after 7days, 14days and 28days indicated EPS as base course can only be used as low axle load pavement such as walkway. There is also room for research in the development of new and innovative applications for the use of EPS, and for the development of updated standards and test procedures.

KEYWORDS:
Expanded polystyrene, Concrete, Civil Engineering, Highway Engineering, Pavement, Yaba College of Technology

Introduction

The application of Expanded polystyrene (EPS) in civil engineering has offered solutions to several problems associated with pavement construction such as in building pavement over underground service, in low bearing capacity subgrade soils and in countries with extreme winters [1]. EPS as

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a subbase material in extreme cold region provides insulation as well as improved strength thereby preventing pavement damage by frost action [2]. Polystyrene is produced via polymerization of its monomer styrene which is a product of steam dehydrogenation of ethylbenzene[3]–[5]. EPS is a foam material produced by extruding expandable beads of polystyrene via steam heating before moulding into appropriate shape [1], [3].

EPS has been used extensively in many civil engineering applications; its application in pavement construction is dated to 1950s in Germany [6]. Its potential as cement replacement in mortars for joining bricks has also been explored [3]. Fresh EPS beads or powder has been utilised as aggregates in lightweight concrete in pavement industry, [1], [6]–[8]. It has also been employed as a geofoam stabilizer in embarkment [9], as insulation in roof and wall [1] and as interior and exterior decorative mouldings [10]. Because of its low density, easy installation, good physical and mechanical properties and easiness of cutting into desired shapes, EPS geofoams can be used as soil replacement as filling material [11]. In highway and geotechnical engineering, EPS has been applied as a super lightweight cellular geosynthetic material with numerous advantageous features for application. It has been effectively used in several construction projects including subgrade for roads and highways, backfill for retaining walls and bridge abutments worldwide [12], [13].

EPS as a waste is voluminous, non-biodegradable, release several toxins when burnt, clog drainages and waterways, enhance flood, increase death of aquatic or marine lives, hence it is not sustainable to landfill or incinerate. Therefore, the use of EPS as an alternative to some expensive construction materials have generated a lot of interests in recent years [3].

No study has totally replaced cement in mortars even as modern mortars have been developed from expanded polystyrene (EPS). Mortars are applied as a paste in filling the gaps between bricks and blocks [14]. The use of EPS beads and ground EPS as aggregates in mortar have been established by several researchers [6], [10], [15]–[22]. However, the application of EPS as aggregate substitute only addresses the recycling of the EPS and not the reduction of cement use. Although sustainability requirements are of prime importance in construction project, there are circumstances when priority is given to maximum reduction in material weight. Recent examples of this situation are reported by [23]–[25],in such cases EPS was substituted as a super lightweight cellular geosynthetic material comprising several beneficial characteristics for application in geotechnical and highway engineering [11]. It has also been used globally for several projects including backfill for retaining walls, bridge abutments and as subgrade for roads and

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highways effectively[12], [26].
In an attempt to reduce the consumption of construction materials such as cement, sand, water, additives and lime, this study explored the usage of EPS as a replacement for conventional base material in Yaba College of Technology Campus. A walkway of 19.4m in Yaba College of Technology was experimented with EPS as base material. Therefore, the aim of this study is to discover the fundamental engineering properties of the EPS in order to ascertain the suitability of engineering properties by fulfilling the structural requirements according to construction regulation standard for use in lateral load resistant applications.

Methodology

Material collection and characterization

The materials used were locally sourced expanded polystyrene foam, Cement, Coarse aggregate, Fine aggregate, Wire Mesh, and water. The EPS was obtained at local construction materials' market at Mushin in Lagos state, Nigeria with coordinates (Longitude 20° NW and Latitude 15° SE). The renown Dangote 3x Portland Cement was used as a binder in concrete making. Rectangular welded fabric wire of 3-inches openings were used in the construction. Aggregates were purchase in the vicinity of Yaba college of Technology, Lagos, Nigeria.
The aggregates were subjected to sieve analysis according to ASTM D2487–17 standard to know the particle size distribution. The aggregates densities were determined using pycnometer according to ASTM C127 standards. The impact test which measures the aggregates' resistance to sudden shock and the crushing value test which is the aggregates' strength index were determined using IS: 2386 (Part IV) – 1963 standard.

Preparation and testing of concrete specimens

The mix design ratio of 1:2:4 (M15) was used to prepare concrete cubes and cured using IS-456- 2000 and casted in sizes 150 mm x150 mm x150 mm. The compressive strength of characteristics concrete and mixing ratio according to IS-456- 2000 as shown in

Table 1.

Table 1:IS-456:2000 Compressive strength at different curing day [27]

Designation	Mixing ratio	Compressive strength (MPa)			IS-456-2000 application group
		7 days (65%)	14 days (90%)	28 days	
M5	1:5:10	3.25	4.5	5	Lean Mix
M7.5	1:4:8	4.875	6.75	7.5	
M10	1:3:6	6.5	9	10	Ordinary concrete

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M15	1:2:4	9.75	13.5	15	
M20	1:1:5:3	13	18	20	
M25	1:1:2	16.25	22.5	25	Standard concrete
M30	Design mix	19.5	27	30	
M35		22.75	31.5	35	
M40		26	36	40	
M45		29.25	40.5	45	
M50		32.5	45	50	
M55		35.75	49.5	55	
M60		39	54	60	High strength concrete
M65		42.25	58.5	65	
M70		45.5	63	70	
M75		48.75	67.5	75	
M80		52	72	80	

The concrete cubes were subjected to compressive strength test at 7 curing days interval using compression testing machine as shown in



Figure 2: compressive strength test of concrete cubes

Construction of the Expanded Polystyrene Rigid Pavement

Expanded Polystyrene (EPS) was used to replace 33% of concrete as Base course in the layer of a rigid pavement on 19.4 m walkway of the School of Engineering, Yaba college of Technology, Lagos. The construction steps of the Expanded Polystyrene Rigid Pavement involve; site investigation, planning, preparing the EPS, fabrication of the stamp mould, removal of the worn-out interlocking tiles,

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excavation, sub-grade preparation, concreting (bottom layer), Placing the Expanded Polystyrene, Concreting (top layer), Wearing Course, stamping with fabricated mould and painting. The component of the pavement is depicted in Figure 3.

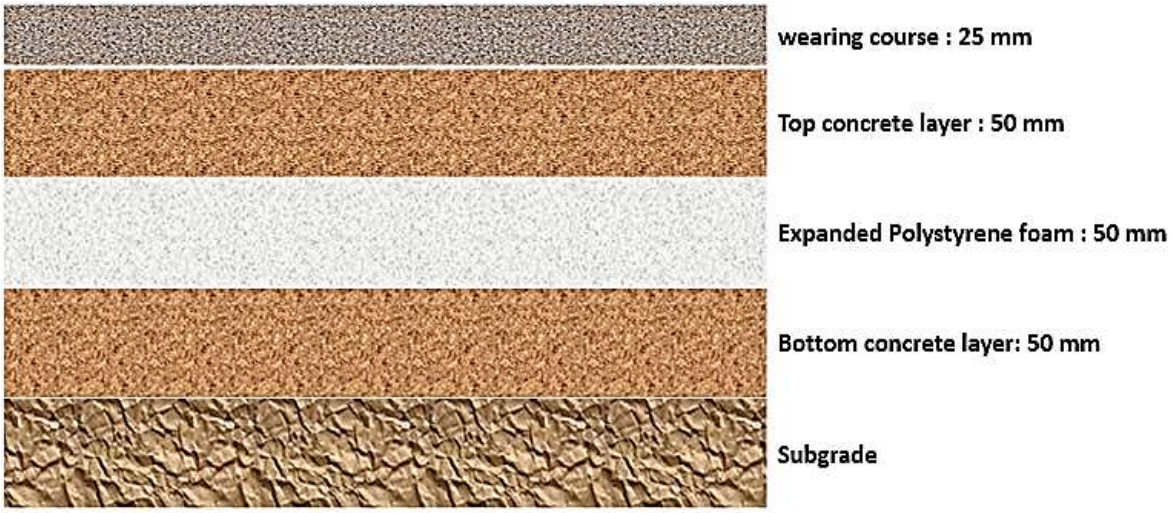

Figure 3: illustration showing the component of the pavement.

The expanded polystyrene was cut to dimension of 2500mm x 1200mm (length and breadth respectively). It was bonded with wire mesh at its top and bottom which serves as a reinforcing steel as illustrated in Figure 4.



Figure 4:Illustrations showing the preparation of the Expansion Polystyrene

The expansion polystyrene rigid pavement consists of three layers, excluding the wearing course which provided a good finishing surface, and also enabled the stamp. The sub-base was placed directly on the sub-grade. It has a thickness of 50mm which was made with mix ratio 1:2:4 concrete. The Expanded Polystyrene

occupied the middle layer of the pavement. It is 50mm in thickness. It was wire mesh for bonding at its base and top. The arrangement of the Expansion Polystyrene provided room for joint expansion along the cross-section of the pavement. The joint expansion will enable the pavement to expand in high temperature, and contras in low temperature, therefore, making the pavement a monolithic floor suitable for walkway.



Figure 5:Illustration showing the placement of the Expanded Polystyrene as base course

The blinder course, which has a thickness of 50mm was placed directly on the Expanded Polystyrene as depicted in Figure 5.. The mixing process and concrete characteristics is same as that of the bottom layer. This layer is responsible for transmitting the pedestrian load to the Expansion Polystyrene as base course, and to the sub-base, which finally is transmitted to the sub-grade soil.

A cement mortar of 1:1, with thickness of 25mm was provided directly on the blinder course as the surface course. This cement mortar layer helped to provide a good surface for stamp moulding. A square fabricated mould of 250mm x 250mm x 30mm with internal designs was used to make a stamp on the cement mortar layer. The stamps' major goal is to counter the frictional forces on the pavement, especially when it is wet. Five blows with hammer were applied on the mould for stamping. The stamp made a bulge line on the pavement which will aid in preventing sliding, especially when the pavement is wet. Also, the stamps added aesthetic to the pavement. Gloss paint was applied on the ground's surface kerbs and pavement floor as depicted in Figure 6 to provide aesthetic view for the pavements.



Figure 6:Illustration showing the construction stage at a close to its completion

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Results and Discussions

Particle size Analysis of aggregate

The result of the sieving analysis is depicted in Figure 7 and Figure 8. The aggregates were classified as uniform but poorly graded based on ASTM soil unified classification system [28].

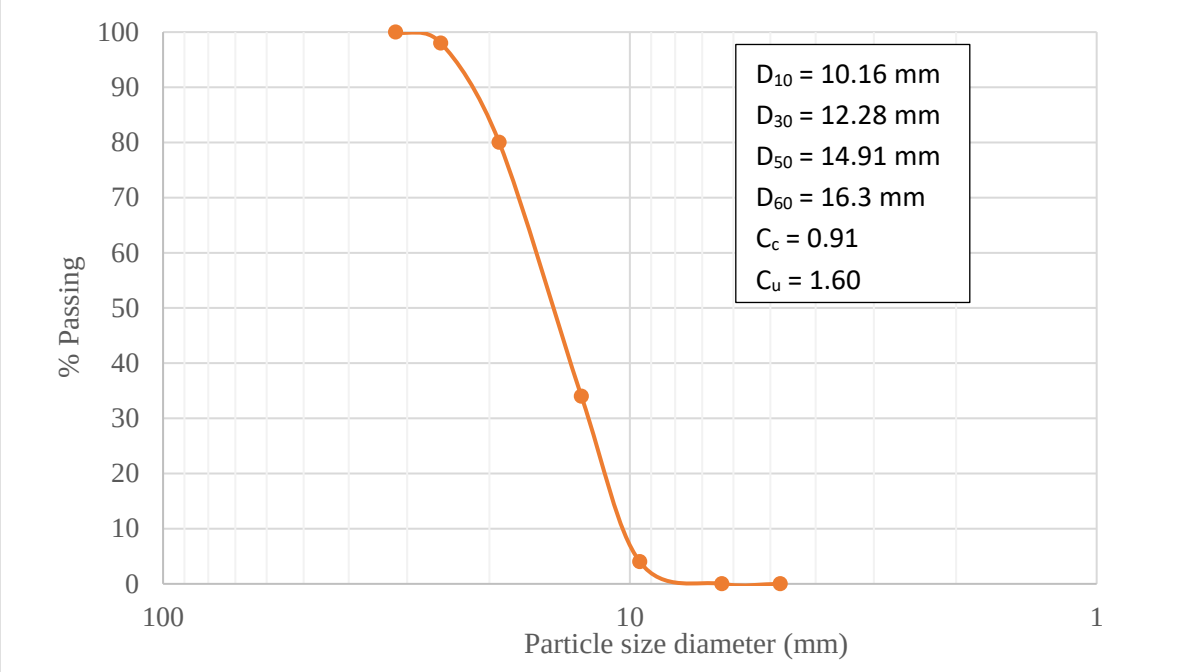

Figure 7: Particle size distribution for coarse aggregates

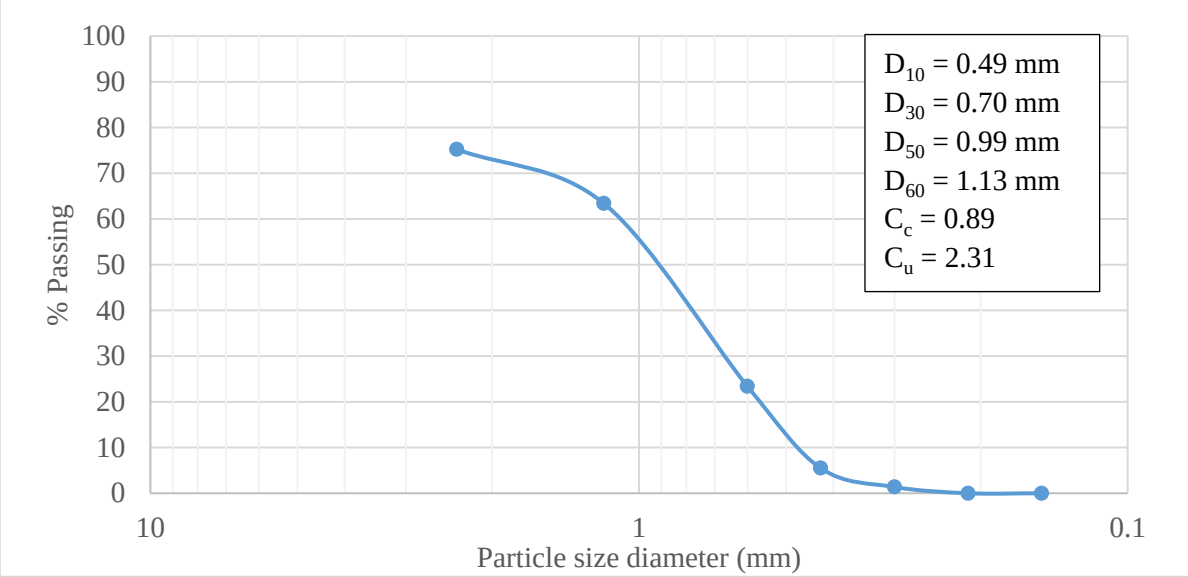

Figure 8: Particle size distribution for fine aggregates

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Analysis of aggregates' specific gravity

The average specific gravity value of fine aggregate (sand) is 2.65 while that of coarse aggregate (gravel) is 2.58 which both fall between the standard range of 2.5 to 3 [29], [30].

Aggregate impact value

The aggregate impact value is presented in

Table 2. From the result obtained, the aggregate impact value is 20.76% which falls between 20-30% indicating satisfactory application in road surfacing [28], [31], [32].

Table 2: Aggregate impact analysis

	weight of oven-dried sample. A (kg)	weight of fraction passing 2.36-mm Sieve. B (kg)	Aggregate impact value $\frac{B}{A} \times 100$ %
Trial 1	1.6	0.3	18.75
Trial 2	1.3	0.4	23.53
Trial 3	18.75	0.3	20
Average aggregate impact value			20.76

Aggregate Crushing value

The aggregates crushing value is presented in

Table 3. The aggregate crushing value is 7.22 % which is lower than the maximum 30% recommendation by Indian Road Congress (IRC) and Bureau of India Standard (BIS) indicating strong aggregates [31].

Table 3: Aggregate crushing value

	Sample 1	Sample 2	Sample 3	Average
weight of surface-dry sample (A) kg	5.9	5.7	5	5.53
weight of fraction passing (B) kg	5.7	5	4.7	5.13
Load (KN)	30	65	58	51.00
Aggregate crushing value (%)	3.39	12.28	6.00	7.22

Compressive Test

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The compressive test result from three samples in Day 7, 14 and 28 is presented in Table 4

Table 4

Table 4: compressive test result for 1:2:4 mix

	Strength (N/mm²)		
	Day 7	Day 14	Day 28
sample 1	7.1	12.5	14.49
sample 2	7.4	12.98	14.9
sample 3	7.2	12.53	15
Average	7.23	12.67	14.80
Standard deviation	0.15	0.27	0.27
coefficient of variation	2.11	2.12	1.83

From

Table 4, the average compressive strength of 7.3 N/mm² (standard deviation 0.15) ,12.53 N/mm² (standard deviation 0.27) and 15 N/mm² (standard deviation 0.27) were derived for the concrete after replacing it with 33% by volume of Expanded Polystyrene Concrete for 7,14 and 28 days respectively. As depicted in Figure 9, The strength increases rapidly between curing Day 7 (48.2 %) to 14 (84.5 %) and slower to Day 28 (98.6 %). This is lower than the standard strength variation with age; 65% at Day 7, 90% at Day 14 and 99% at Day 28 maximum.

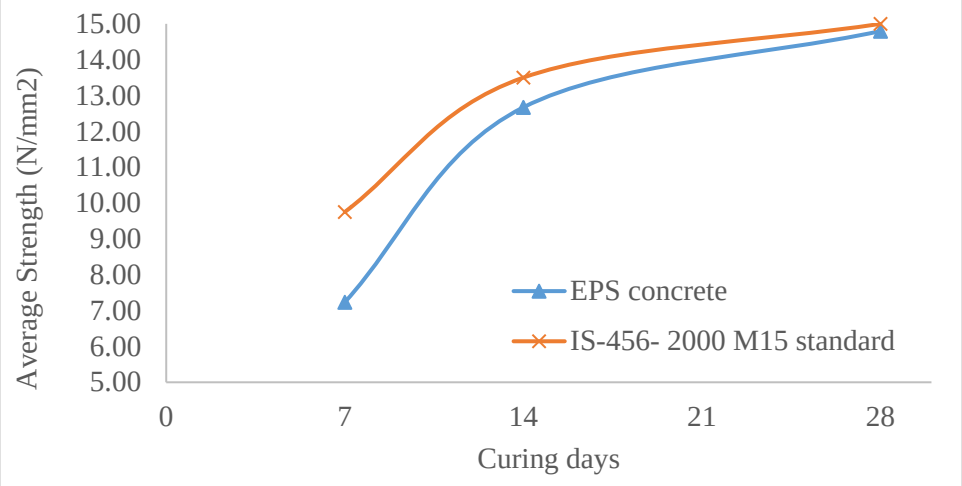

Figure 9: Average compressive strength with curing days

The compressive strengths are generally low compressive strength compared to compressive strength of standard concrete at the same curing days. it falls within

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the range for lightweight concrete. there are deductions that this strength could be increased through the addition of silica fume to the mixture and through a reduction in the size of the Expanded Polystyrene foam added to the concrete.

Conclusion

Expanded Polystyrene (EPS) was used to replace 33% of concrete as Base course in the layer of a rigid pavement on 19.4 m walkway of the School of Engineering, Yaba college of Technology, Lagos. Particle size analysis of the aggregates indicated uniform but poorly graded coarse and fine aggregates. The aggregate impact value is 20.76% indicating satisfactory application in road surfacing. The aggregate crushing value is 7.22 % which is) indicating strong aggregates. Compressive strength test conducted for the cast specimen after 7days, 14days and 28days indicated EPS as base course can only be used as low axle load pavement such as walkway. Expanded Polystyrene is also observed to decrease the compression strength of concrete in rigid pavement.

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