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Characterization of Ternary Batched Concrete Parking Lots on the Ground Containing Saw Dust Ash and Egg Shell Powder

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The quality of a concrete parking lots, floors or slabs is highly dependent on achieving a hard and durable surface that is flat, relatively free of cracks and at the proper grade and elevation. The properties are determined by the aggregate characteristics, cementitious materials and the mixture proportions. Concrete industry is one of the largest consumers of natural resources due to which sustainability of concrete industry is under threat. The environmental and economic concern is the biggest challenge concrete industry is facing. This study addressed, the issues of environmental and economic concern through the use of saw dust ash and egg shell powder mixture as partial replacement of cement in concrete. Hydraulic Cement was replaced by the mixture of Saw Dust Ash and egg shell powder at 5%, 10%, 15%, 20% and 25% by weight. The cylindrical concrete specimens were tested for compressive strength, flexural strength, splitting tensile strength, slump and density .The compressive strength of the specimens was evaluated at the 3rd, 7th, 14th, 28th and 56th days of age. The flexural strength and the splitting tensile strengths were evaluated at 14th and 28 days of age. The results obtained satisfied the minimum specifications of relevant standards and manuals. The study concluded that mixture of saw dust ash and egg shell powder is a suitable supplementary cementitious material and can satisfactorily replace hydraulic cement up to 20% by weight in the construction and maintenance of concrete parking lot placed on the ground.

Keywords: compressive strength, concrete parking lot, egg shell powder, flexural strength, saw dust ash, supplementary cementitious material.

Introduction

According to ACI 330R, (2008), ACI 330.1M-14, (2015) and ACI 360R-10, (2010), concrete parking lots range in size from small, such as at corner convenience stores, to medium, such as at multi-unit housing projects, to large, such as those for shopping centers and office or commercial developments. Most parking areas include driveways, some of which need to accommodate relatively heavy loads. Special consideration may be needed if access to dumpsters is to be included. Accordingly, concrete parking lots are constructed with a wide variety of construction equipment, ranging from hand tools and vibratory screeds to large highway paving equipment or laser screeds. Because of the relatively high stiffness of concrete pavements, loads are spread over larger areas of the subgrade compared with asphaltic pavements. As a result, thinner concrete pavements can be used for the same subgrade material. Additional benefits of using concrete

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to construct parking lots include the following: (a). Concrete surfaces resist deformation from maneuvering vehicles; (b). Concrete surfaces drain well with only minimal slopes; (c). Concrete has relatively simple maintenance requirements; (d). Traffic lane and parking stall markings can be incorporated into the jointing pattern; (e). Concrete is minimally affected by leaking petroleum products; (f). The light-reflective surface of concrete can be efficiently illuminated with minimal energy requirements; and (g). Concrete parking lots reduce the impacts of the urban heat island effect relative to those of asphalt parking lots by producing lower surface temperatures, thus providing a cooler urban environment and reducing ozone production.

Parking lots have most loads imposed on interior slabs surrounded by other pavements, providing some edge support on all sides. Highway and street pavements carry heavy loads along and across free edges and are subjected to greater deflections and stresses. Street and pavements are usually designed to drain towards an edge where the water can be carried away from the pavement (ACI 330R, 2008, ACI 330.1M-14, 2015 and ACI 360R-10, 2010).

Concrete parking lots on the ground and Slabs-on-ground are defined as: slabs, supported by ground, whose main purpose is to support the applied loads by bearing on the ground. The slabs are of uniform or variable thickness and it may include stiffening elements such as ribs or beams. The slab may be unreinforced or reinforced with non prestressed reinforcement, fibers, or post tensioned tendons. The reinforcement may be provided to limit crack widths resulting from shrinkage and temperature restraint and the applied loads. Post-tensioning tendons may be provided to minimize cracking due to shrinkage and temperature restraint, resist the applied loads, and accommodate movements due to expansive soil volume changes (ACI 330R, 2008, ACI 330.1M-14, 2015 and ACI 360R-10, 2010). Fig. 1(a and b) show typical example of concrete parking lots and slabs on ground.

In a study Mohammad *et al* (2015), concluded that saw dust ash is a suitable material for use as a pozzolan, since it satisfied the requirement for such a material by having a combined (Sio_2+Al_2O_3+Fe_2O_3) of more than 70% and that Concrete becomes more workable as the saw dust ash (SDA) percentage increases meaning that less water is required to make the mixes more workable .This means that SDA concrete has lower water demand. They opined that the compressive strength generally increases with curing period and decreases with increased amount of saw dust ash (SDA). They suggested that only 10% substitution can be allowed at maximum and 5% substitution is adequate to enjoy maximum benefit of strength gain. Cement –saw dust ash concrete vary with mix proportion in a similar way as those of normal cement concretes (with 0% SDA) and the compressive strengths of cement-saw dust ash concretes increased with leanness of mix up to some level of leanness after which the strength reduced. The 50-day strength values of cement-saw dust blended concrete, sandcrete, and soilcrete are respectively 82-99%, 75-95%, and 74-96% of those for 100% cement concrete (Ettu et al, 2013). Early strength development was observed to be about 50-60% of their 28 days strength. Saw dust ash concrete can attain the same

a b

Fig. 1

Concrete parking lot on the ground (a, b) order of strength as conventional concrete at longer curing periods. Saw dust ash can be used as partial replacement of cement up to a maximum of 10% by volume (Marthong, 2012). In a study Sanjay and Rahul (2016) concluded that 10% replacement of saw dust ash gives 4.89% and 8.70% increase in the compressive strength of concrete at 7 days and 28 days.

Gowsika *et al* (2014) concluded that replacement of cement paste with 5% Egg shell powder + 20 % Microsilica gives no significant reduction in compressive strength properties and yields similar flexural strength when compared with that of conventional concrete. In a study, Anand *et al* (2017) concluded that the compressive strength of 20% Eggshell powder Concrete increases up to 19.5% than that of conventional concrete and the split tensile strength of 20% Eggshell powder Concrete increases to 5.16% than that of conventional concrete. The concrete compressive strength with egg shell powder as cement replacement material increases up to 15 percent without silica fume. Addition of silica fume also enhances the strength but in economical point of view only the egg shell powder replacement is sufficient enough for getting higher strength (Praveen, *et al* (2015).

Hydraulic cement is the most important and most expensive constituent of concrete, therefore the replacement of cement with certain percentage of these saw dust ash and egg shell powder to see their influence on slump, flexural strength and compressive strength at the same time reduces the cost of concrete and reduce the environmental hazard. These objectives justify the need for this research.

Materials and methods

Cementitious materials

The chemical analysis of the cementitious materials were carried out in line with the procedures specified in ASTM C114 – 15 (2015), ASTM D5370 – 14 (2014) and ASTM C311 / C311M – 17 (2017).

Aggregates

The sand (fine aggregate) used for this study is locally available well graded river sand passing through sieve 4.75mm but retained in sieve 2.36mm, 1.18mm, 600 micron, 300 micron and 150 micron. Crushed granites passing through sieve 31.5mm but retained in sieves 25mm, 18.75mm, 16.0mm, 12.5mm, 9.5mm, 6.25mm and 4.75mm was used as natural coarse aggregate (NCA). The natural coarse aggregate (NCA) and the fine aggregate were selected in accordance with the specifications of ASTM D 448 – 12 (2012), ACI 201.2R-16 (2016).ACI Education Bulletin E1-07 (2007), and ACI Education Bulletin E1-16 (2016).

Concrete mix ratio

The concrete specimens were batched at the mix ratio of 1: 2: 3 by weight of cementitious materials, fine aggregate and coarse aggregate and marked as shown in **Table 1.** The concrete specimens were batched in line with the specifications of NEH-NRCS PART 642 (2009), ACI 330R (2009), ACI 330.1M-14 (2014), ACI 360R-10 (2010), and ACI 201.2R-16 (2016).

Table 1

Measuring and mixing proportions for the concrete specimens at 1: 2: 3 mix ratio

Concrete specimen mark	Percentage replacement of cement with SDA and ESP (%)	Water-cementitious materials ratio	Cementitious materials (Kg/m^3)			Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)
			Cement	Saw dust ash (SDA)	Egg shell powder (ESP)		
SD-ES1	0	0.55	400	0.00	0.00	800	1200
SD-ES2	10	0.55	360	20	20	800	1200
SD-ES3	20	0.55	320	40	40	800	1200
SD-ES4	30	0.55	280	60	60	800	1200

Aggregate properties

Sieve analysis, specific gravity and water absorption were conducted for fine aggregate, and coarse aggregate in accordance with the specifications of ASTM D448 (2012), CADOT (2015), TXDOT (2015) and NYSDOT (2014). The aggregate impact value (AIV) test, aggregate crushing value (ACV) test and Los Angeles abrasion value test were conducted for the coarse aggregate in line with the specified procedures in ASTM D448 (2012), CADOT (2015), TXDOT (2015) and NYSDOT (2014).

Concrete properties

The slump value of all the fresh concrete mixtures were evaluated immediately after batching. The compressive strength value of the concrete were evaluated on the 3rd, 7th, 14th, 28th, and 56th days of age. The splitting tensile strength value was evaluated at the 14th and 28th day age. The specimens used for the compressive strength and splitting tensile strength tests were cylindrical in shape and measured 150mm diameter and 300 long. The flexural strength value was evaluated at the 14th and 28th day age. The beam specimens used for the flexural strength test measured 150mm width, 150mm depth and 700mm long. Depth to effective span ratio of 4 was maintained during the flexural test. The sump, compressive strength, splitting strength and flexural strength tests were carried out in line with the procedures specified in ACI 330R (2008), ACI 330.1M-14 (2015), ACI 360R-10 (2010), ACI 201.2R-16 (2016), CADOT (2015), TXDOT (2015) and NYSDOT (2014).

Results and discussion

Cementitious materials

The hydraulic cement used in this study conform to the specifications of ASTM C150/ C150-16 e1 (2016), ASTM C1157/C1157M-17 (2017) and AASHTO M85 (2016). The Egg shell powder was prepared in line with the specifications of ACI 232.1R-12 (2012), and ASTM C618-15 (2015). The saw dust ash conform to the specification of ASTM C618 -15 (2015), ACI Education Bulletin E3-13 (2013), FHWA-HIF-16-001 (216), ACI Education Bulletin E3-13 (2013), ACI 232.2R-96 (2002) and ACI 232.1R-12 (2012) for Class F fly ash. According to FHWA-HIF-16-001 (2016) and ASTM C618-15 (2015) ,class F fly ash is defined as having a sum of the oxides (SiO_2 + Al_2O_3+Fe_2O_3) equal or greater than 70% and Class C fly ash as having the sum of the oxides (SiO_2 + Al_2O_3+Fe_2O_3) equal or greater than 50%. Table 2 shows the chemical composition of Saw Dust Ash (SDA), egg shell powder (ESP) and Cement.

Table 2

Chemical composition of saw dust ash and Egg shell powder.

S/N	Oxides	Cement (%)	ESP (%)	SDA (%)
1.	SiO_2	21.8	0.08	65.79
2.	Al_2O_3	6.6	0.03	4.88
3.	Fe_2O_3	4.1	0.02	2.01
4.	CaO	60.1	52.1	9.39
5.	MgO	2.1	0.01	3.92
6.	Na_2O	0.4	0.15	0.07
7.	K_2O	0.4	-	2.68
8.	SO_3	2.2	0.62	0.98
9.	LOI	2.3	42.2	4.56
10.	Others	-	4.79	5.72

Aggregates characteristics

The results of the gradation of coarse aggregate, and fine aggregate are shown in Table 3. The results of the physical and mechanical properties of the coarse aggregate, and fine aggregate are shown in Table 4. The fine and coarse aggregate properties conform to specifications of ASTM D448 (2012), CADOT (2015), TXDOT (2015), NYSDOT (2014), ACI 201.2R-16 (2016), ACI Education Bulletin E1-07 (2007), and ACI Education Bulletin E1-16 (2016).

Table 3

Sieve analysis results of coarse and fine aggregate

Sieve size (mm)	Coarse aggregate (initial weight = 1000g)			Fine aggregate (initial weight = 1000g)		
	Percentage retained (%)	Cumulative percentage retained (%)	Percentage passing/finer (%)	Percentage retained (%)	Cumulative percentage retained (%)	Percentage passing/ finer (%)
31.5	0.00	0.00	100	-	-	-
25.0	1.3	1.3	1.3	-	-	-
19.0	12.4	13.7	86.3	-	-	-
16.0	21.84	35.54	64.46	-	-	-
12.5	28.78	64.32	35.68	-	-	-
9.5	22.65	86.97	13.03	-	-	-
6.5	9.8	96.77	3.23			
4.75	2.63	99.40	0.6	0.00	0.00	100
2.36	-	-	-	14.22	14.22	85.78
1.18	-	-	-	19.07	33.29	66.71
0.6	-	-	-	23.45	56.74	43.26
0.3	-	-	-	21.06	77.80	22.20
0.15	-	-	-	17.11	94.91	5.09
0.075	-	-	-	3.64	98.55	1.45
Total (%)	**99.4**	**398**	**-**	**98.55**	**375.51**	

Table 4

Physical and mechanical properties of the aggregate used

Aggregate	Specific gravity	Water absorption (%)	Aggregate crushing value (%)	Aggregate impact value (%)	Los Angeles abrasion value (%)
Fine	2.633	1.434	-	-	-
Natural Coarse (crushed granite)	2.731	1.23	19.63	22.54	24.71

Concrete properties

Table 5, shows the slump, densities, and compressive strength values of concrete at different percentage replacement of cement with a mixture of saw dust ash and egg shell powder. The densities and slump values increase with increase in percentage replacement of cement. There is no significant change in compressive strength values of concrete containing 0% to 20% replacement of cement with a mixture of saw dust ash and egg shell powder as shown in Table 5 and Fig. 2. Concrete specimens containing Saw dust ash and egg shell powder mixture show increase in splitting tensile strength and flexural strength values as shown in Fig. 3 and 4. The compressive strength results of 0% to 20% replacement of cement with a mixture of saw dust ash and egg shell powder satisfied the minimum 28 days strength of 31N/mm^2 to 41N/mm^2 and 35N/mm^2 to 41N/mm^2 specified in ACI 330R (2008), ACI 330.1M-14 (2015), ACI 360R-10 (2010), ACI 201.2R-16 (2016), CADOT (2015), TXDOT (2015) and NYSDOT (2014) for standard and high performance Concrete Parking Lots on the Ground. The maximum compressive strength and density values occurred at 10% replacement of cement with SDA and ESP.

Table 5
Average Compressive Strength Test Results (f_{ck})

Cube mark	Percentage replacement of cement with SDA and ESP (%)	Slump (mm)	Density Kg/m³	3rd day N/mm²	7th day N/mm²	14th day N/mm²	28th day N/mm²	56th N/mm²
SD-ES1	0	93	2432	17.10	25.20	30.58	37.21	44.81
SD-ES2	10	111	2441	21.20	27.60	33.08	40.02	45.61
SD-ES3	20	109	2440	17.08	24.50	29.30	36.08	42.32
SE-ES4	30	121	2437	13.40	19.80	24.60	30.37	36.86

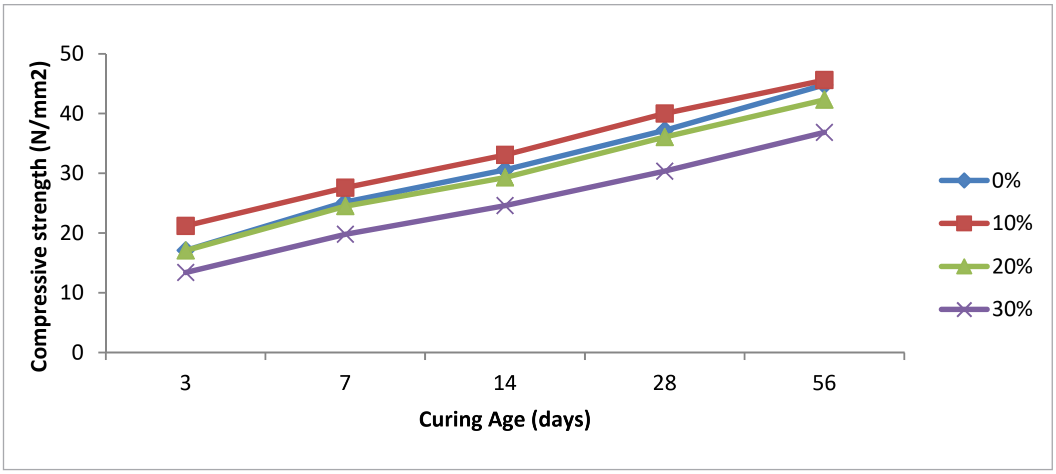

Fig. 2
Relationship between the compressive strength (N/mm²) and Curing age (days)

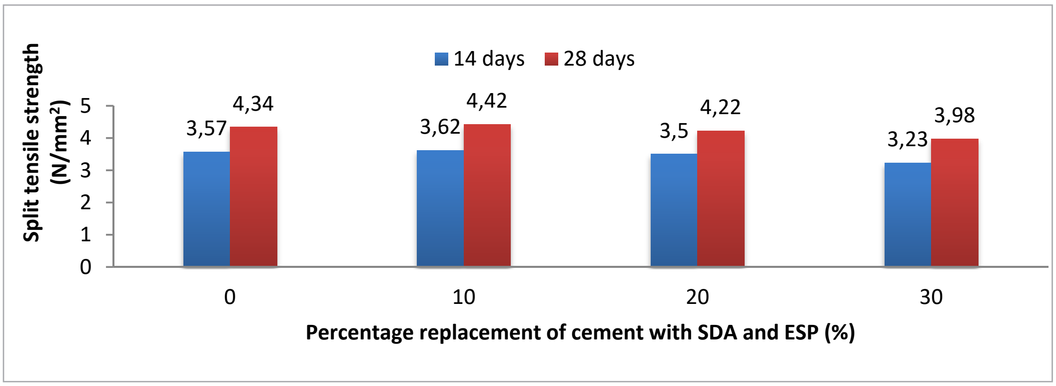

Fig. 3
Relationship of the 14th and 28th days splitting tensile strength with percentage replacement of cement with SDA and ESP

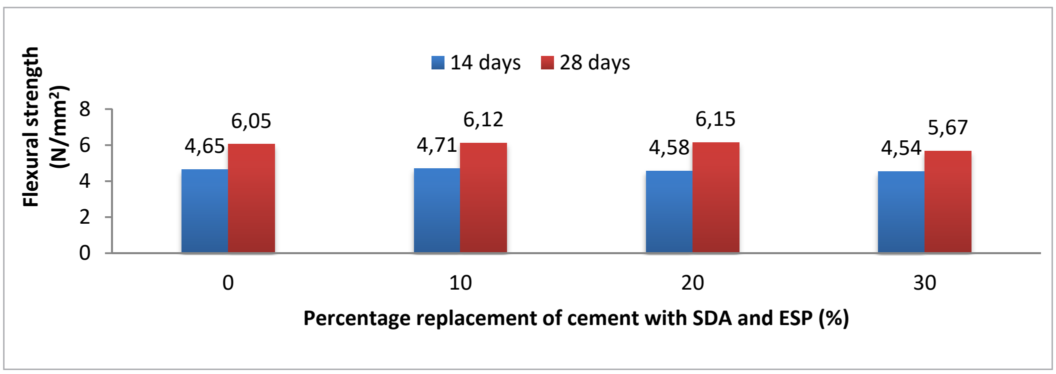

Fig. 4
Relationship of the 14th and 28th days flexural with percentage replacement of cement with SDA and ESP

Conclusions

The following conclusions were drawn at the end of this study.

1 A mixture of saw dust ash and egg shell powder gives good pozzolan and cementitious material and can used in ternary batched concrete parking lots on the ground.

2 The concrete batching and mixing proportion of 1: 2:3 of cementitious materials, fine aggregate and coarse aggregate gives cementitious content of 400kg/m^3 and fine to total aggregate of 0.4. This satisfied the minimum cementitious content of 300kg/m^3 to 360kg/m^3 and fine to total aggregate ratio of 0.35 to 0.45 specified in ACI 330R (2008), ACI 330.1M-14 (2015), ACI 360R-10 (2010), ACI 201.2R-16 (2016), CADOT (2015), TXDOT (2015) and NYSDOT (2014).

3 Using a mixing ratio and proportion specified by relevant standards, concrete mixtures containing up to 20% saw dust ash and egg shell powder exhibit similar characteristics compared to non-saw dust ash and egg shell concrete.

4 The use of saw dust ash and egg shell powder as supplementary cementitious material in preparing ternary concrete mixtures in construction and maintenance of concrete parking lots on the ground should be encouraged. This leads to cost effective and environmental friendly construction. It also leads savings in the quantity of cement that would have been consumed and as such sustainability of the cement industry can be guaranteed.

5 Concrete containing a mixture of saw dust ash and egg shell powder should be well compacted to give densities above 2400kg/m^3 and above. Above all the concrete must be prepared with well graded fine and coarse aggregate to give acceptable compressive strength values.

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