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ARTIFICIAL STONE FOR ROADS USING CEMENT, SAND AND DUST: AN ENVIRONMENT FRIENDLY AND SUSTAINABLE WAY OF CONSTRUCTION

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ABSTRACT

Nowadays, pursuing potential alternatives is a common phenomenon to mitigate the adverse effect on ecology and to promote sustainability. Natural aggregates are mostly made by crushing bedrock, which causes detrimental influence on geology of that area. So, a way to substitute plays a predominant role to indulge the possibility to preserve ecological balance. Abatement of unsustainable practices and its sluggish effect, artificial stone avails a momentous rule. Sand and stone dusts were sieved according to ASTM C33. Stones were produced using different ratios of sand and dust. These materials had been mixed and tested its strength at 7, 28, and 56 days and compared with the specification requirements of Local Government Engineering Department (LGED), Roads and Highways Department (RHD), and Runway overlay project at Osmani International Airport, Sylhet. Based on findings, eventually, fruitful outcomes were witnessed.

Keywords: artificial stone, stone dust, sustainability, ecological balance

INTRODUCTION

Europe alone produces and consumes over 4 billion metric tons (mt) of aggregates annually, with over 91% of this quantity originating from natural deposits (Dobiszewska et al., 2022). Crushed aggregates can be made from a wide variety of rocks, both igneous and metamorphic (such as basalt, melaphyre, diabase, porphyry, gabbro, and granite) and sedimentary (such as sandstone and shale).Large amounts of rock dust are produced throughout the mining, mechanical processing, and screening processes (Bleischwitz & Bahn-Walkowiak, 2006; Kaza et al., 2018; Singh et al., 2016; Suman, 2018). This waste dust accounts for around 5 percent of the aggregate mass. Approximately 5,000 metric tons of waste dust is produced annually by a plant of a standard asphalt size. Each year, the stone industry processes around 68 million tons of rock worldwide, with countries such as Italy, Portugal, Greece, France, Turkey, the USA, Brazil, South Africa, India, and China processing more than a million tons of stone. During cutting, grinding, and polishing rock blocks, water is used to keep tools cool and moist, resulting to a semiliquid sludge waste of 20-30%. When water evaporates, it leaves behind dry dust that can be harmful to humans and the environment. But this stone dust, a byproduct of aggregate manufacture, is also useful in road construction (Bonavetti & Irassar, 1994; Çelik & Marar, 1996; Cordeiro et al., 2016; Karakurt & Dumangöz, 2022).

A sustainable solution to this problem can be the proper utilization of stone dust use for making artificial stone. This artificial stone is used as base course of road construction. This artificial stone could fulfill the specifications of LGED, RHD and Osmani Airport project.

So, Artificial stone made from stone dust (SD) reusing a road construction material for base course could lessens the use of natural resources and helps to solve landfill scarcity as well as environmental problems (Satyanarayana et al., 2013; Singh et al., 2016).

MATERIAL AND METHODOLOGY

The research work conducted to ensure the success of the project by identifying the hardened properties (compressive strength and density) as well as durability property (water absorption) of concrete made with assorted ratios of cement, sand, and dust. Figure-1 defines a framework that states an overview of the experimental program. The mixing ratios for the construction of cylinders selected to conduct the experiment. Physical properties of cylinders (LAA, ACV and AIV) were determined in

accordance with the specifications of LGED, RHD and Runway Overlay Project of Osmani International Airport, Sylhet.

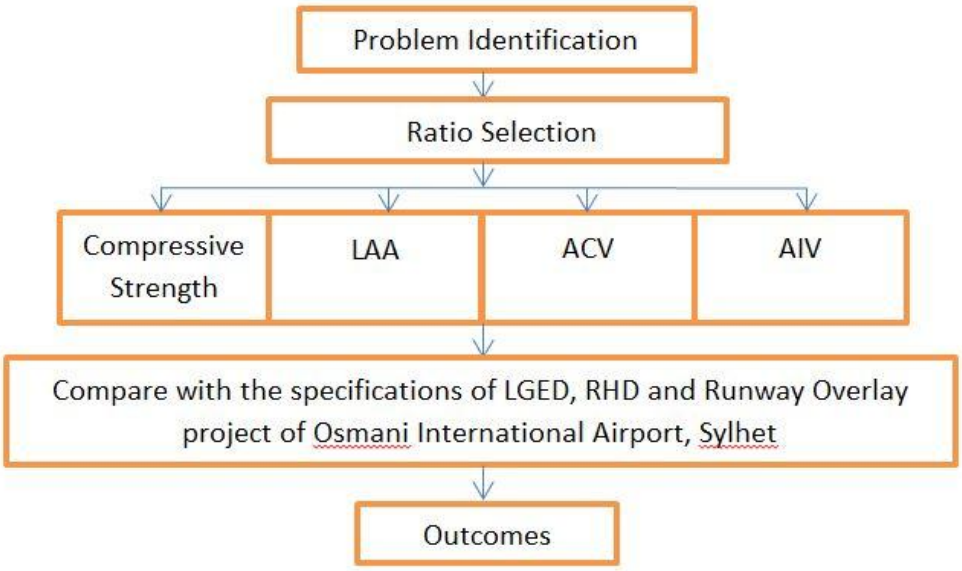

Figure 1 Flow Chart of pursuant steps

The features of aggregate materials are discussed in table 1 along with their ASTM standards.

Table 1 Different characteristics of aggregates material

Aggregate Name	Aggregate Characteristic
Cement	PCC Grade 42.5. In accordance with the technique stipulated in BIS 4031(part 1):1996, cement is 90 microns fine. To verify standard consistency, initial and final setting times as stated in ASTM C191, Vicat apparatus is utilized. Cement must comply with BIS 8112:1989 in terms of all of its attributes.
Natural sand	To achieve a sieve analysis in accordance with ASTM C 33, natural sand was passed through a set of sieves. As per ASTM C 128, C29 and D 1557, water absorption, specific gravity, bulk density and Maximum dry density of natural sand were extracted.
Dust	Dust was sieved through a set of sieves to obtain sieve analysis in accordance with ASTM C33. The specific gravity, water absorption, bulk density, and MDD of dust were determined using the procedures outlined in ASTM C128, C29, and D1557. The pycnometer method was used to calculate the specific gravity of dust.

Mix Proportioning of Concrete Ingredients

Initially, four sets of cylinder samples were created. Cement and sand\dust mixing ratios were 1:1, 1:1.5, 1:2.75, and 1:3. When all of the cylinders had been cast for 7 days, 28 days and 56 days, they were manually disintegrated to check their physical properties (LAA, ACV and AIV). Their specifications were compared to RHD specification and LGED specification and specification for Runway overlay project. The mixing ratios of 1:1 and 1:1.5 gave the better output than 1:2.75 and 1:3. As a result, the ratios of 1:1 and 1:1.5 were chosen for the construction of the cylinder. After deciding on a mixing ratio, many cylinders were created by varying the proportion of sand and dust with cement.

RESULT AND DISCUSSION

Physical properties of material

Different ingredients of aggregate are tested according to American Society for testing and materials (ASTM) and found to be meeting the standards (Table 2).

Table 2 Physical properties of material

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Aggregate	Test Name	Testing Method	Result
Cement	Fineness test	ASTM C595	92.4
	Initial and final setting times	ASTM C191	Initial setting time = 115 minutes Final setting time = 279 minutes
Natural sand	Fineness modulus	ASTM C136	FM= 1.21
	Specific gravity	ASTM C128	2.569
	Water absorption		3.26
	Maximum dry density	ASTM D1557	1.554
	Bulk unit weight of sand	ASTM C29	1.211 gm/cc
Dust	Fineness modulus	ASTM C136	FM= 1.96
	Specific gravity	ASTM C128	2.825
	Water absorption		1.13
	Maximum dry density	ASTM D1557	1.667
	Bulk unit weight of dust	ASTM C29	1.416 gm/cc

Compressive strength test of concrete

Cylinders made of cement: (sand + dust) (1:1)

The graph in figure 2 demonstrates the compressive strength with cement, sand and dust at a ratio of 1:1. Strength was at its apex at 56 days which was counted to be 42 MPa with a percentage of 100 dust mixture whereas 7, 28 days supplied the strength of 35.76 MPa and 39.27 MPa.

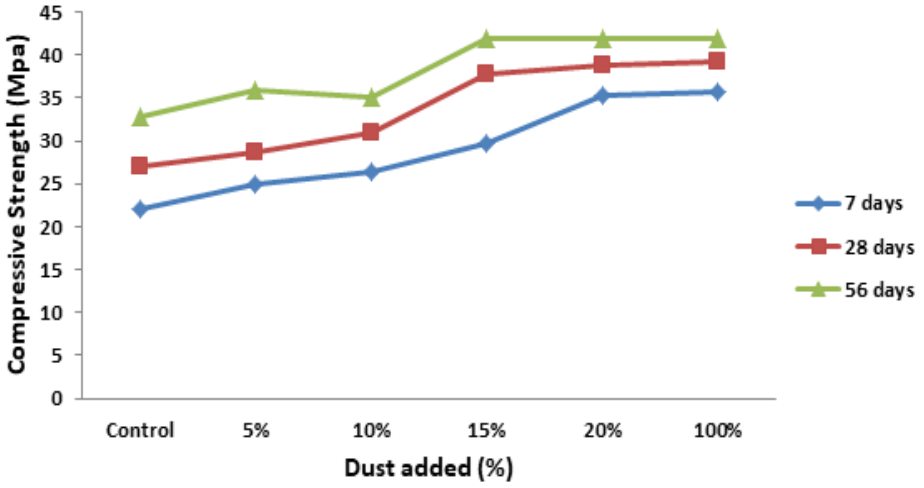

Figure 2 Compression Strength curve at various days with ratio of 1:1

Cylinders made of cement: (sand + dust) (1:1.5)

The graph in figure 3 upholds the compressive strength features of a cylinder which was made up of cement, sand and dust with a mixing ratio of 1:1.5. Considerable fluctuations were noticed at 7, 28 and 56 days. The pinnacle of its strength was 24.13 MPa, 34.06 Mpa and 38.22 Mpa with the addition of 15 percent dust at 7, 28 and 56 days. Addition of 100 percent of dust pointed out nearly values of 28.74 MPa at 56 days, 26.24 MPa at 28 days and 17.61 MPa at 7 days of casting.

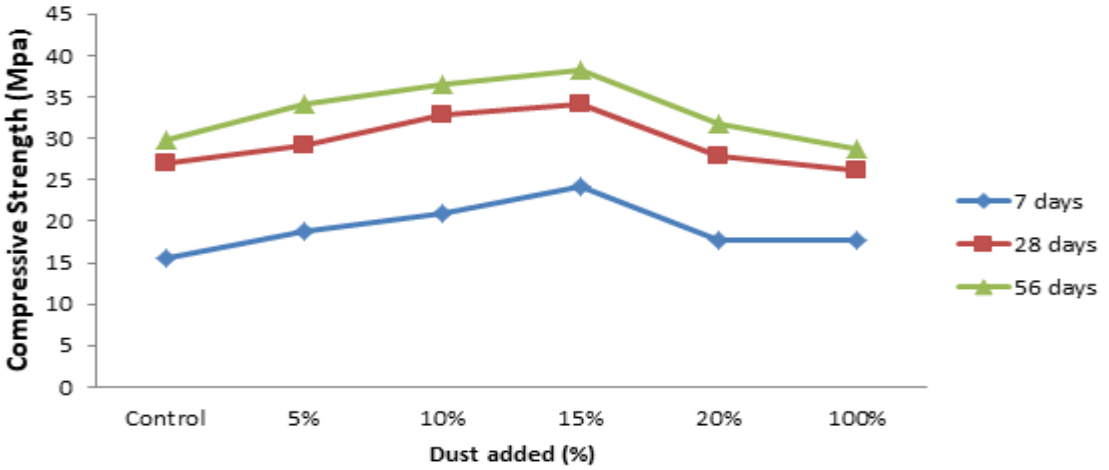

Figure 3 Compression Strength curve at various days with ratio of 1:1.5

Los Angeles Value artificial stone made of concrete:
Cylinders made of cement, (sand + dust) (1:1)

The ratio of 1:1 is used to present the graph in figure 4 which indicates the abrasion value. It was notable that with the increment of addition of dust, abrasion value achieved its diminution. At 7 days, the addition of 0%, 5%, 15%, 20% and 100% dust satisfied the specification for LGED, RHD and Runway overlay project with a value of 29.22%, 28.88%, 30%, 28.14% and 27%. At 28 days, the substitution of sand by dust gave optimized values at the percentages of 0, 5, 10, 15, 20, 100 satisfying LGED, RHD and Runway overlay project at Osmani International airport specifications. The value was counted to be 28.21%, 27.9%, 29%, 28.8%, 27.7%, 29.64%, 29.35%, 26.93%, 25.82%.

Finally at 56 days, marvelous outcomes were shown. All percentage replacements satisfied the specification for LGRD, RHD and Runway overlay project with a value of 27.17%, 26.14%, 26.96%, 26.48%, 25.76% and 24.68%.

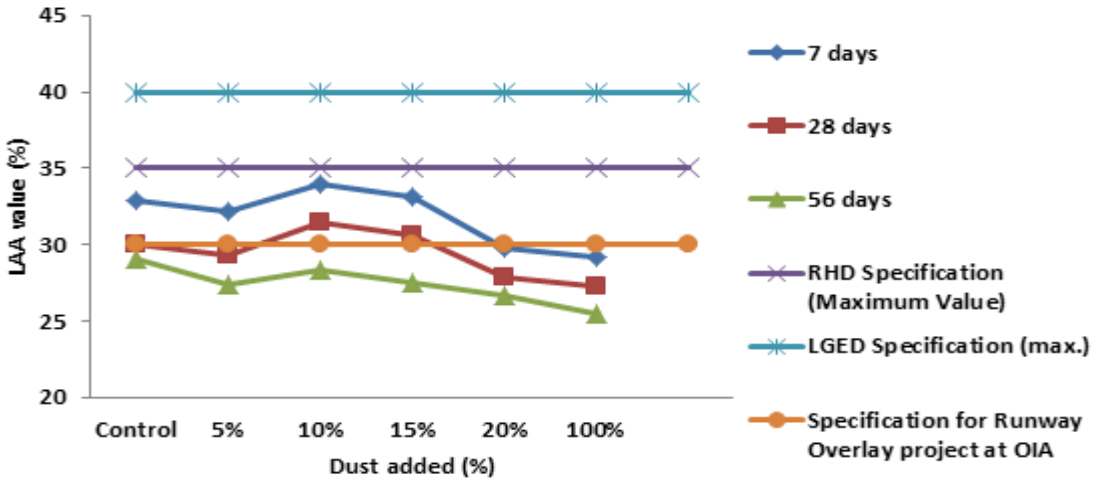

Figure 4 LAA curve at various days with ratio of 1:1

Cylinders made of cement, (sand + dust) (1:1.5)

The graph in figure 5 depicts the abrasion value that was made with a ratio of 1:1.5 with a mixture of cement, sand and dust. It was notable that the increment of dust resulted in a decrement of abrasion value. It can be said that it produced a remarkable result at 56 days with Los Angeles abrasion value of about 25 percent when the composition of dust was 100 percent. The abrasion value at 7 days met the specification for LGED and RHD with a value of 32.94%, 32.22%, 33.98% and 33.08% at 0%, 5%, 10% and 15% replacement. 20% and 100% replacement of sand by dust met the specifications for Runway overlay project at Osmani International Airport, LGED and RHD with a value of 29.72% and 29.12%. At 28 days, the specification for LGED and RHD were met with value of 30.02%, 29.35%, 31.5%, 30.62%, 27.82% and 27.22% with the replacement of 0%, 5%, 10%, 15%, 20% and 100% sand by dust whereas the specification for Runway overlay project did not meet with the 15% replacement.

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At 56 days, all the specifications for LGED, RHD and Runway overlay project were met with optimizing values.

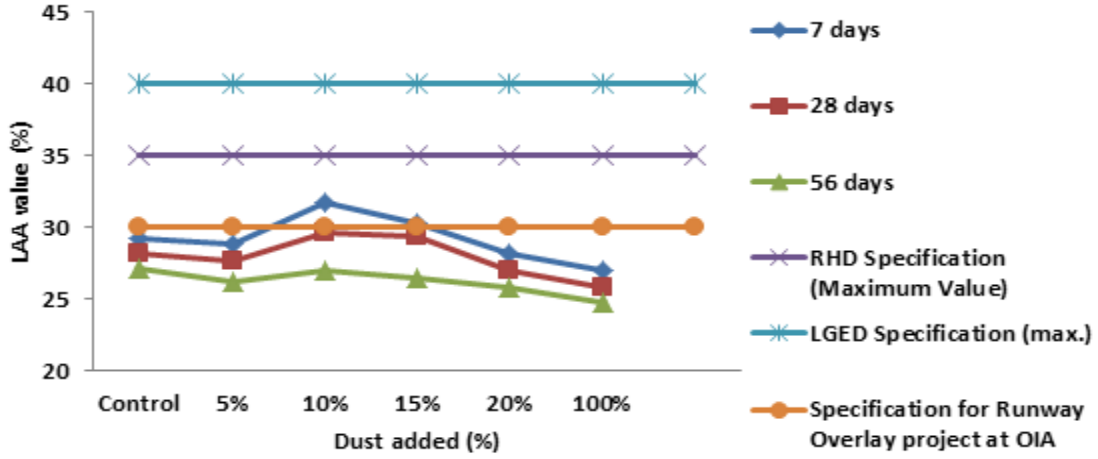

Figure 5 LAA curve at various days with ratio of 1:1.5

Aggregate Crushing Value (ACV) of artificial stone made of concrete: Cylinders made of cement, (sand + dust) (1:1)

Figure 6 exhibits the result of aggregate crushing, which fluctuated noticeably. The sample had a 1:1 mixture of cement, sand and dust. Here the accumulation of dust brought declination in the value. The crushing value at 7 days, met the specification for LGED and Runway overlay project at Osmani International Airport with a percentage value of 28.36, 27.51, 31.05, 28.68, 27.81 and 26.58 at the replacements of 0%, 5%, 15%, 20% and 100% whereas the specification for RHD met with all the replacements. At 28 days, the replacement values optimized with the specifications for LGED, RHD and Runway overlay project with a lowest value at 5% replacement which counts to be 24.05%. At 56 days, the outcomes were optimizing the specifications for LGED, RHD and runway overlay project with values of 23.18%, 22.86%, 24.16%, 23.54%, 23.55% and 23.28% at 0%, 5%, 10%, 15%, 20% and 100% replacement of sand by dust.

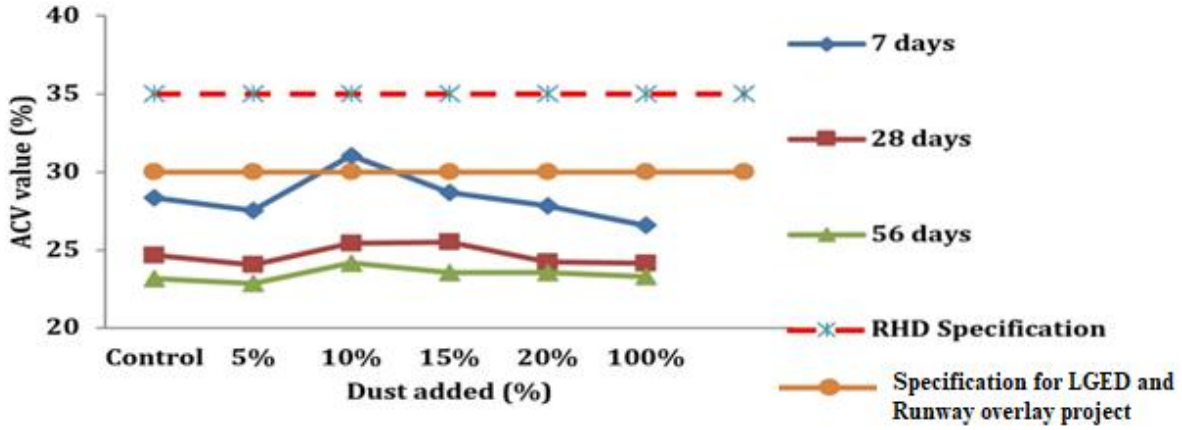

Figure 6 ACV value curve at various days with ratio of 1:1

Cylinders made of cement, (sand + dust) (1:1.5)

The graph in figure 7 depicts the aggregate crushing value of stone with a sample composed of cement, sand and dust in a 1:1.5 ratio. Addition of 10 percent of dust touched the extreme point of the specifications for Runway overlay project and LGED at 7 days with a value of 29.97 percent. With the inclusion of dust, crushing value began to decline. All the replacement percentages satisfied the specification for RHD. At 28 days all replacements satisfied the specification for LGED, RHD and Runway overlay project whereas 100% replacement of sand by dust gave the lowest value of 20.9% and 0%, 5%, 10%, 15% and 20% replacement gave the value of 27.27, 28.19, 29.07, 26.85, 26.69. At 56 days, the lowest value was counted to be 24.76 at 100 percent replacement of sand by dust whereas 0%, 5%, 10%, 15% and 20% replacement gave percentage values of 25.93, 26.99, 27.98, 25.35 and 25.09 which shows that all substitutions satisfied the specification for LGED, RHD and Runway overlay project at Osmani International Airport ensuring the success of result more optimizing than 28 days.

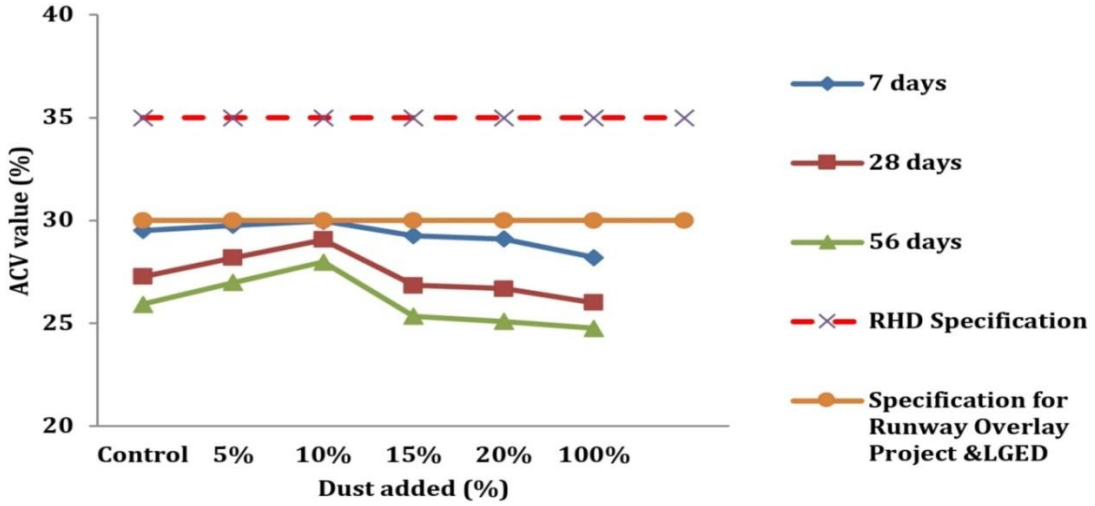

Figure 7 ACV value curve at various days with ratio of 1:1.5

Aggregate Impact value (AIV) of artificial stone made of concrete:
Cylinders made of cement, (Sand + dust) (1:1)

The graph in figure 8 illustrates the materials toughness with a mixture of cement, sand and dust in a ratio of 1:1. It was observed that all the specifications for RHD, LGED and Runway Overlay Project at Osmani International Airport were indulged fully. At very onset, the maximum point of specification for Runway Overlay Project was touched with a value of 29.73 percent at no replacement at 7 days. With the replacement of 5%, 10%, 15%, 20% and 100%% sand by dust the percentage impact value was 26.94, 28.05, 26.33, 26.09 and 22.86. At 28 days all replacements satisfied the specification for LGED, RHD and Runway overlay project whereas 100% replacement of sand by dust gave the lowest value of 20.9% and 0%, 5%, 10%, 15% and 20% replacement gave the percentage value of 26.55, 23.37, 24.65, 23.72, 23.55. A marvelous outcome was witnessed at 56 days where all replacements got optimized with the specification for LGED, RHD and Runway overlay project at Osmani International Airport supplying the percentage values of 23.88, 22.18, 23.3, 22.5, 22.56 and 20.32 at 0%, 5%, 10%, 15%, 20% and 100% replacement which assures that the 56 days outcomes were more optimizing than 28 days.

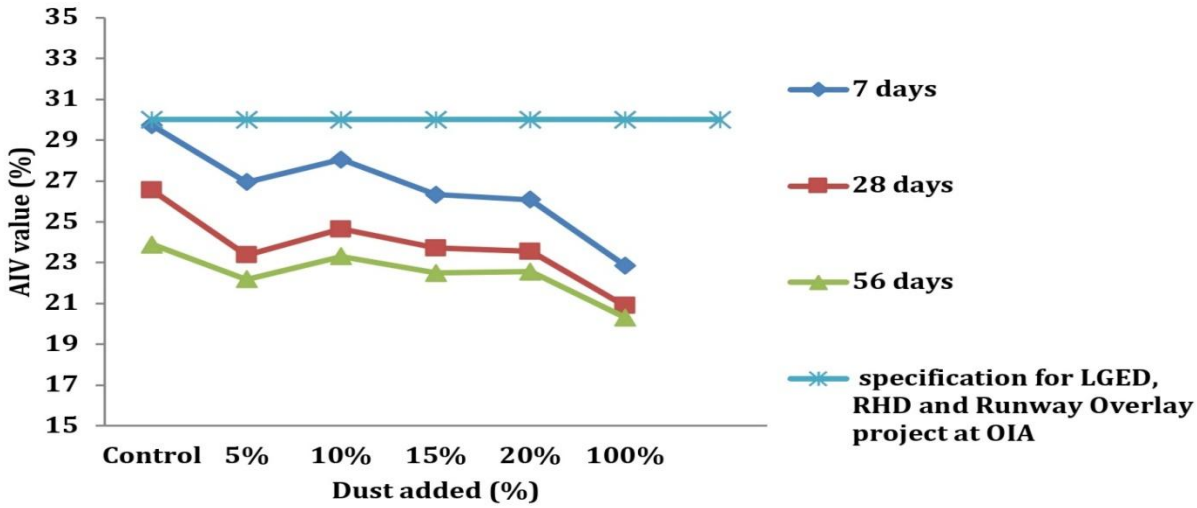

Figure 8 AIV value curve at various days with ratio of 1:1

Cylinders made of cement, (sand + dust) (1:1.5)

The graph in figure 9 depicts the materials toughness with a mixture of cement, sand and dust in a ratio of 1:1.5. At 7 days, 5%, 10%, 15%, 20% and 100% replacement supplied the percentage values of 27.91, 29.03, 28.03, 28.24 and 26.81 which ranges within the specification for LGED, RHD and Runway overlay project. On the other hand, at 28 days, the lowest value was 25.74% at the replacement of sand by 100% dust whereas no replacement, 5%, 10%, 15% and 20% substitution supplied the percentage values of 29.54, 26.45, 26.92, 26.2 and 26.66. The results at 56 days were more optimizing than at 28 days. The outcomes at no replacement, 5%, 10%, 15%, 20% and 100% replacement were 27.78%,

25.29%, 25.97, 24.85%, 25.87% and 24.2% which satisfied the specification for LGED, RHD and Runway overlay project at Osmani International Airport.

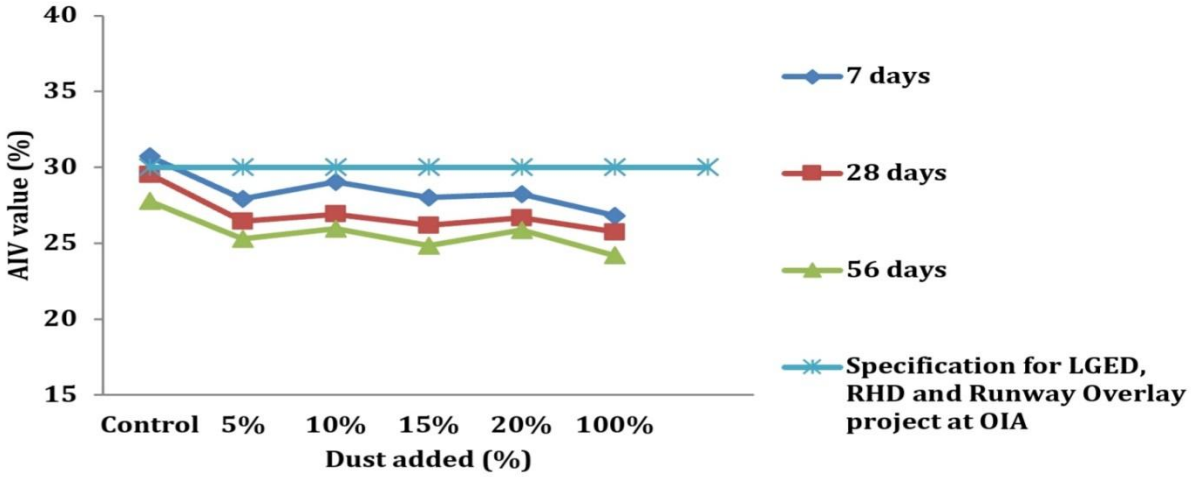

Figure 9 AIV value curve at various days with ratio of 1:1.5

CONCLUSION

The purpose of this research is based on the determination of suitability of using the crushed aggregate made from cement concrete applying sand and dust at assorted ratio to facilitate the sustainable development option.

I. Compressive strength of concrete was at a remarkable state with the ratio of 1:1 whereas 1:1.5 has shown a declination.
II. In case of Los Angeles Abrasion test, all the percentage replacement has strongly met with the standards of RHD, LGED and Runway overlay project at 56 days. Moreover, the addition brought a satisfaction at 7 and 28 days.
III. Optimizing values were found over the experimental analysis of ACV test, which satisfied the specifications of LGED, RHD and Runway overlay project at 7, 28 and 56 days.
IV. Addition of dust accorded with the specifications of LGED, RHD and Runway overlay project. It can be a vital coarse aggregate option for road construction which is profoundly standardized from the tests.

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