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Case Study: Utilization of Locally Available Material for Pavement Sub Base Construction in Sitapura Region, Jaipur

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Abstract—*Now a day's civilization in Jaipur is increasing day by day and demand of aggregates is more, so the lots of blasting quarrying and transportation activities are consuming huge amount of energies and cost, also depleting natural resources day by day. On the other hand the waste from industries and other locally available used or unused material considered as environmental problem and its disposal is major issue. A study was recently done at the Sitapura region of Jaipur to investigate the possibility of using recycled concrete aggregates (RCA) and crushed clay brick (CCB) as aggregates in unbound sub base materials. The physical properties of the construction waste materials that is RCA and CCB has been studied and found that these material have excellent properties and can be used in the road base and sub-base application. The results showed that the use of 100% RCA increased the optimum moisture content and decreased the maximum dry density of the subbase materials compared to those of natural sub base materials. Moreover, the replacement of recycled concrete aggregates by crushed clay brick further increased the optimum moisture content and decreased the maximum dry density. This was mainly attributed to the lower particle density and higher water absorption of crushed clay brick compared to those of recycled concrete aggregates.*

Keyword*: Aggregates, brick, density*

1. INTRODUCTION

Over the last two decades, research has been undertaken to investigate the possibility of using recycled concrete aggregates in road base or subbase courses in order to provide a viable option for the use of construction and demolition (C&D) waste. Chini *et al.*[1] tested the properties of a road base sample using recycled aggregate produced from a demolished concrete pavement which had a design mix strength of 20 MPa. Test results showed that the road base sample passed all standard requirements with the exception of the soundness test using sodium sulfate. Chini *et al*. postulated that the mortar adhered to the recycled aggregate was reactive to sodium sulfate and contributed to an increased loss in the soundness test. Park [2] tested the physical and compaction properties of two different recycled aggregates obtained from a housing redevelopment site (RCA-1) and a concrete pavement rehabilitation project (RCA-2). It was apparent that the optimum moisture content increased with an increase in water absorption of the aggregates. Nataatmadja and Tan [3] tested the resilient response of a subbase material made with four different recycled aggregates. They found that the resilient response of a subbase material made with recycled aggregates was comparable to that made with natural aggregate. Also, the resilient response of a subbase material was found to be dependent on the strength of the original concrete, the amount of softer material in the recycled aggregates and the flakiness index of RCA. Molenaar and van Niekerk [4] found that the mechanical characteristics of an unbound base course made with recycled concrete and masonry rubble were mainly governed by the degree of compaction. Furthermore, Hansen and Angelo [5] found that it was possible to enhance the engineering properties of clayey soils for earthwork purposes by mixing the soils with recycled concrete fine aggregates.

In this paper, the feasibility of blending recycled concrete aggregates and crushed clay brick as subbase materials was studied. The results were compared with the subbase materials prepared with natural aggregates. This study was of great importance since landfills and reclamation sites in Sitapura area will be exhausted in the near future. If recycled concrete aggregates and crushed clay brick can be re-used as subbase materials, it would greatly alleviate the demand and extend the service life of the dumping facilities in Sitapura area.

2. STUDY AREA

The study area is belonging to the Industrial area of Jaipur named Sitapura having 22.43 km^2 area.

Sitapura Industrial region is the best modern and instructive point of Jaipur. It is the biggest fare part in northern India having some special highlights including water accessibility, control substation, media transmission, transportation and every one of the businesses should be without contamination. It has been wanted to suit the most ideal offices inside its 365 sections of land zone. The assembling exercises include diamonds and Jewelry, Electronics, Garments, Handicrafts, Engineering, Leather merchandise, stone and IT Park.

Fig. 1: Location of Sitapura

3. MATERIALS

3.1. Natural aggregate (NA)

Crushed granite was used as the natural aggregate in this project work. Its attributes are summarized below in Fig. 2.

Properties	Aggregate size			
	40 mm	20 mm	10 mm	<5 mm
Density-SSD (kg/m^3)	2622	2660	2577	2579
Density-oven-dry (kg/m^3)	2594	2644	2562	2492
Water absorption (%)	1.06	0.57	0.59	3.51
Ten percent fines – dry (kN)	–	190	–	–
Ten percent fines – soaked (kN)	–	190	–	–
Water-soluble sulphate content (g/L)	–	–	–	0.025
Soundness %	–	97.5	–	–
Particle size distribution (mm)	Percent passing (%)			
50.0	100	–	–	–
37.5	96.9	100	–	–
20.0	2.09	92.1	–	–
14.0	0.1	36.0	100	–
10.0	–	8.35	95.9	–
5.0	–	0.41	13.5	97.3
2.36	–	–	1.18	77.7
1.18	–	–	–	58.0
0.6	–	–	–	41.9
0.3	–	–	–	19.2

Fig. 2: Properties of natural aggregates

3.2. Recycled concrete aggregate (RCA):

Recycled concrete aggregate (RCA) was produced in a recycling facility located in sitapura region jaipur. The properties and attributes of the recycled concrete aggregates are summarized below in Fig. 3.

Properties	Aggregate size			
	40 mm	20 mm	10 mm	<5 mm
Density-SSD (kg/m^3)	2487	2546	2580	2310
Density-oven-dry (kg/m^3)	2411	2493	2523	2093
Water absorption (%)	3.17	2.17	2.29	10.3
Ten percent fines – dry (kN)	–	146	–	–
Ten percent fines – soaked (kN)	–	109	–	–
Water-soluble sulphate content (g/L)	–	–	–	0.032
Soundness %	–	96.3	–	–
Particle size distribution (mm)	Percent passing (%)			
50.0	100	–	–	–
37.5	96.4	100	–	–
20.0	3.98	98.4	–	–
14.0	0.23	31.4	100	–
10.0	–	4.73	93.8	–
5.0	–	0.18	7.6	100
2.36	–	–	1.6	73.6
1.18	–	–	–	48.3
0.6	–	–	–	31.1
0.3	–	–	–	17.7

Fig. 3: Properties of recycled concrete aggregates

3.3. Crushed clay brick (CB)

A clay brick partition wall sourced from a demolition site in sitapura region was fetched to our laboratory for this project study. The partition wall was crushed by assistance of man power and used a hammer to produce both coarse and fine aggregates ranged from 20 to <5 mm and they are referred to as crushed clay brick (CB) in this project. Crushed clay brick mainly comprises brick rubble and also a high amount of adhered mortar and other impurities such as tile, wood and dust. These impurities were not removed before the experiment. The properties of crushed clay brick are listed below in Fig. 3.

Properties	Aggregate Size		
	20 mm	10 mm	<5 mm
Density-SSD (kg/m^3)	1916	2147	2042
Density-oven-dry (kg/m^3)	1618	1797	1560
Water absorption (%)	18.4	19.5	30.9
Ten percent fines – dry (kN)	49	–	–
Ten percent fines – soaked (kN)	35	–	–
Water-soluble sulphate content (g/L)	–	–	0.206
Particle size distribution (mm)	Percent passing (%)		
37.5	100	–	–
20.0	98.9	–	–
14.0	54.2	100	–
10.0	8.75	94.9	–
5.0	1.37	7.6	100
2.36	–	1.4	65.5
1.18	–	–	43.5
0.6	–	–	31.3
0.3	–	–	23.1

Fig. 4: Properties of crushed clay brick

3.4. Comparison of individual aggregate properties

Each value presented in Fig. 2-4 is an average of two measurements. Test methods employed for determining the properties and attributes of the aggregate.

In general natural aggregates had the highest density values followed by recycled concrete aggregate and crushed clay brick. In contrast crushed clay brick had the highest water absorption values followed by recycled concrete aggregate and natural aggregate. Indeed the high amount of adhered mortar attached to the crushed clay brick particle prone to a decrement in particle density and an increment in the water absorption value.

The strengths of the aggregate particles were tested in terms of the 10% fines values in dry and soaked conditions. This test provides a relative measure of the resistance of the aggregate to crushing under a subsequently applied compressive load. A higher 10% fines value indicates a better resistance to crushing. The results indicated that the natural aggregate was the strongest, followed by the recycled concrete aggregate and the crushed clay brick. In fact crushed clay brick was much weaker than natural and recycled concrete aggregates. Furthermore it is worthwhile to note that the strengths of the natural aggregate in dry and soaked circumstances were same while the strengths of recycled concrete aggregate and crushed clay brick after soaking decreased from 146 to 109 kN and from 49 to 35 kN respectively. The corresponding reductions were approximately 25% and 28% for recycled concrete aggregate and crushed clay brick respectively.

Water soluble sulphate content was tested for every material. The results were identical between natural and recycled concrete aggregates with water soluble sulphate content values of 0.025 and 0.032 g/L respectively. However the water soluble sulphate content of crushed clay brick was much greater than those of natural and recycled concrete aggregates where a value of 0.206 g/L was perceived.

The soundness test results for natural and recycled concrete aggregates were identical with corresponding soundness values of 97.5% and 96.3%, respectively. The soundness value is not shown in Fig. 4 for crushed clay brick because crushed clay brick completely demolished after the test. According to Chini *et al.* [1], the high amount of adhered mortar mingled to the brick particles became reactive to the sulphate used in the test which prone to the disintegration of the crushed clay brick aggregates. Nevertheless the soundness value after crushed clay brick was blended with recycled concrete aggregate as subbase materials will be presented in the next section.

Furthermore, the coarse aggregates (i.e. 40, 20 and 10 mm) of all materials confirmed to the grading limits for the single sized aggregate per BS 882 [11]. The fine aggregate of all materials also satisfied the grading limits for the fine aggregate per BS 882 [11] as well.

3.5. Properties of blended aggregates

In this study a portion of recycled concrete aggregate was replaced by crushed clay brick and used as the sub-base materials. The replacement levels were 25% and 50% by weight of the recycled concrete aggregate. Since both recycled concrete aggregate and crushed clay brick had distinctive material properties, the 10% fines It is prevailed that the increasing use of crushed clay brick reduced the 10% fines values in both the cases dry and soaked circumstances. The soundness values were reduced whenever does increment in the crushed clay brick content. The soundness losses were 21.6% and 39.3% for replacement levels of 25% and 50% respectively

4. BLENDED SUBBASES

Recycled concrete aggregate and crushed clay brick were blended to produce two series of subbase materials. Each series was distinguished by the material used for the fine aggregate. Series I and II used recycled concrete aggregate and crushed clay brick as their fine aggregates, respectively. Furthermore natural aggregates were used to produce a control mixture.

Each series comprised three mixtures. The first mixture used recycled concrete aggregate as the initial source of the coarse aggregate. The second and third mixtures in each series mixed crushed clay brick as a partial replacement of the recycled concrete aggregate in the fractions between 20 and 5 mm. The replacement stages were 25% and 50% by weight of the recycled concrete aggregate for the second and third mixtures respectively. The blend ratios (by weight) for the three mixtures in each series are summarized in Fig. 5. The notations 100RCA, 75RCA and 50RCA indicate the replacement levels of recycled concrete aggregate by crushed clay brick at 0%, 25% and 50%, respectively. The same blend ratio was also used for blending the control mixture except that natural aggregates were em-ployed instead of the recycled materials. Since the blend ratio was the same for each subbase material, the blended subbases had similar grading properties as shown in Fig. 6 also shows a photograph of a subbase mixture after blending

Blend ratios for subbase materials

Blend ratio, % (By weight)						
	Control					
Blend	40 mm	20 mm		10 mm		<5 mm
Control	20	10		40		30
	Series I (with recycled concrete aggregate as fine aggregate)					
Blend	40 mm	20 mm		10 mm		<5 mm
	RCA	RCA	CB	RCA	CB	RCA
100RCA	20	10	0	40	0	30
75RCA	20	7.5	2.5	30	10	30
50RCA	20	5	5	20	20	30
	Series II (with crushed clay brick as fine aggregate)					
Blend	40 mm	20 mm		10 mm		<5 mm
	RCA	RCA	CB	RCA	CB	CB
100RCA	20	10	0	40	0	30
75RCA	20	7.5	2.5	30	10	30
50RCA	20	5	5	20	20	30

Fig. 5: Blend ratios forsubbase materials

5. CALIFORNIA BEARING RATIO (CBR)

CBR tests were performed for all seven subbase mate-rials after they were compacted at their corresponding optimum moisture contents. CBR tests were carried out in both unsoaked and 4-day soaked conditions and the results is mentioned below in Fig. 6.

In an unsoaked condition, the subbase using natural materials had the greatest CBR value (85%). Mixtures 100RCA, 75RCA and 50RCA in Series I had CBR values of 66%, 62% and 43%, respectively. The CBR value gradually decreased as the coarse crushed clay brick content increased. One possible reason was the lower intrinsic particle strength of crushed clay brick which led to a decrease in the overall bearing strength of the subbase materials. Furthermore, blending crushed clay brick with recycled concrete aggregate possibly prone to a weak interconnected system which decreased the load scattering capability of the subbase materials.

On the other hand mixtures 100RCA, 75RCA and 50RCA in Series II obtained CBR values of 38%, 40% and 35% respectively. The use of crushed clay brick as the fine aggregate evidently decreased the strength of the subbase materials. Although the same blend ratios (by weight) were used for the both series, the difference in density between the two materials resulted in a totally different material volume. On account of the lower particle density of crushed clay brick, the volume of the fine aggregate in Series II was higher than the volume of the fine aggregate in Series I. consequently the volume ratio of coarse to fine aggregates become lower for the mixtures in Series II than that of the mixtures in Series I. The lower coarse to fine aggregates volume ratio possibly decreased the CBR values as compared to those of Series I. Furthermore the intrinsic strength of fine crushed clay brick could also decrease the bearing strength of the subbase materials as well. Moreover it was perceived that mixtures in Series II had relatively same results when the content of coarse crushed clay brick increased. When a portion of coarse recycled concrete aggregate was replaced by coarse crushed clay brick, the volume ratio of coarse to fine aggregates increased. However the possible increase in the CBR value consequently increase in the coarse to fine aggregate volume ratio was offset by a decrease in the CBR value due to the incorporation of crushed clay brick which had a relatively low intrinsic strength. That was possibly the reason for similar CBR values obtained in Series II as the coarse crushed clay brick content increased.

Furthermore, it can be seen from Fig. 6 that the effect of the 4-day soaked period was found negligible on the CBR values of all the subbase materials. In sitapura jaipur a soaked CBR value of 30% is considered a minimum strength required for a subbase [14]. The results of this project proved that recycled concrete aggregate and crushed clay brick can be mixed together to produce a subbase which meets the prescribed requirement. Moreover the recorded swells for all subbases were less than 0.13% after a 4-day soaked period, which can be considered negligible

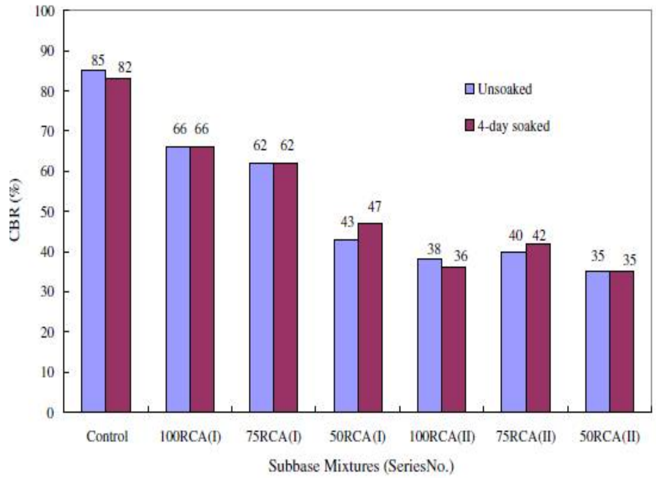

Fig. 6: CBR values (unsoaked and 4-day soaked) for each subbase material.

6. CONCLUSIONS

This paper presents the result of an investigation on the use of recycled concrete aggregate and crushed clay brick as aggregates in unbound subbases materials. Prior to the study the aggregate properties were foremost figured out. The following differences were found between the natural aggregate, recycled concrete aggregate and crushed clay brick:

1. Natural aggregate had the greatest density, followed by recycled concrete aggregate and crushed clay brick.
2. Crushed clay brick had the greatest water absorption value, followed by recycled concrete aggregate and natural aggregate.
3. The 10% fines values indicated that natural aggregate had the greatest strength, followed by recycled concrete aggregate and crushed clay brick. The soaked condition did not reduce the strength of natural aggregate as opposed to recycled concrete aggregate and crushed clay brick.
4. The water soluble sulphate content of crushed clay brick was much greater than those of natural and recycled concrete aggregates.
5. Natural and recycled concrete aggregates performed satisfactorily during the soundness test. However, the crushed clay brick particles completely disintegrated after the test. It was postulated that the high amount of adhered mortar was reactive to the sulphate used in the soundness test which prone to the complete disintegration. The use of crushed clay brick lowered the CBR value.

6. The subbase using crushed clay brick as the fine aggregate had a lower CBR value compared to the subbase using recycled concrete aggregate as the fine aggregate.
7. A 4-day soaked period had a negligible influence on the CBR values of the recycled subbases.
8. It was feasible to blend recycled concrete aggregate and crushed clay brick to produce a subbase with a soaked CBR value of at least 30%, which is a mini-mum requirement in Hong Kong.
9. All recycled subbases had a negligible swell after a 4-day soaked period.

On the other hand, the following conclusions can be made for subbase materials prepared with recycled con-crete aggregates and crushed clay brick: The subbase using crushed clay brick as the fine aggregate was less susceptible to moisture variations when compared to the subbase using recycled concrete aggregate as the fine aggregate.

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