A Laboratory Study on the Use of Overburnt Brick Aggregates in the Construction of Pavements

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***Abstract*— The current study attempted to investigate overburnt brick aggregate as a material for a sub-base course in the flexible pavement and an aggregate for a cement-treated base. The laboratory work included analyzing the properties of overburnt brick aggregate, such as the Los Angeles abrasion, water absorption, specific gravity, unit weight, the impact test, crushing value, and soil mixed soil with different proportions of overburnt brick aggregate. California bearing ratio (CBR) tests were performed on aggregates mixed with soil in various proportions [1]. The aggregates samples were prepared and tested without soil first, then with soil in varying weight percentages ranging from 15% to 50%. CBR tests show that increasing the percentage of coarse aggregates up to 75% increases the sample's CBR value for light dynamic compaction. The CBR value of the sample increases with the percentage of coarse aggregates up to 100% for light and heavy static compaction. Such weak aggregates will likely be crushed under traffic if used in bituminous mixes. As a result, it was decided to investigate the viability of using overburnt brick in lean cement concrete mixes. Several mixes with varying cement content were chosen. Compressive and modulus of rupture tests were also performed. This study discovered that the maximum CBR values in soaked conditions are 78% and 140% for light and heavy compaction, respectively, indicating that it is feasible to use.**

***Index Terms*—Overburn brick aggregate, California bearing ratio, Moisture content, Dry density**

I. INTRODUCTION

The quality of the component materials significantly impacts the performance of pavements. Bituminous and concrete pavements are made out of aggregate bitumen and cement. The remaining two are industrial products and so unaffected by local conditions. Aggregates, on the other hand, must be evaluated in the context of the projected construction area. There are many sites where suitable quality aggregates are unavailable and must be imported from distant locations, significantly raising the cost. Aside from raising environmental concerns about stone quarrying, investigating alternate aggregates is becoming more attractive.

The use of weak aggregates in pavement building has piqued the interest of people all over the world since it reduces the cost and consumption of suitable quality aggregates. Brick is a material nearly everywhere and is widely used throughout our country. Though brick aggregate is used in road building occasionally, its use is limited, and little research has been conducted on it, particularly on overburnt brick aggregate [3]. Furthermore, overburnt brick is not usable as bricks in construction and is considered a waste product in brick kilns. Aggregates derived from over burned brick were chosen for this inquiry to investigate their suitability for use in the building of flexible pavement subbase courses [7]. However, for comparison, stone aggregates have also been utilized in some circumstances.

Lean cement concrete with a cement percentage ranging from 6 to 8% and bituminous surfacing has been effectively utilized for road base and sub-base courses in the United Kingdom and the United States [2]. In the United Kingdom, lean cement concrete requires suitable quality aggregate with stringent grading and mix proportions to generate cube strength of 10 to 20 MPa at 28 days.in India, lean cement concrete is not widely used. The Ministry of Road Transport and Highways (MoRTH) has specified the quality, sizes, and proportions of aggregates, water characteristics, cement content, and concrete strength. The aggregates used must comply with IS:383, with a maximum aggregate to cement ratio of 14:1 and an average cube strength of 10MPa at seven days, with a minimum individual cube strength of 7.5MPa at seven days.

With the stated parameters for quality, gradation, and strength requirements, lean cement concrete bases may not be the most cost-effective highway building material. As a result, it is critical to determine the performance of lower strength aggregate used in lean cement concrete base, which could be easily used as a road basis or sub-base where traffic volume is low and cost-effective. This paper has three objectives: first, to investigate the feasibility of using overburnt brick aggregate as a sub-base in the flexible pavement; second, to determine the CBR of a mixture of soil with crushed stone and overburnt brick aggregate in different proportions at proctor density, and third, to study the feasibility of using overburnt brick aggregate in lean cement concrete, i.e., to find the best mix that will give adequate strength for use as a road base and sub base.

This research has been divided in five section, namely,1. Introduction 2. Literature Review 3. Methodology 4. Result and Discussion 5. Conclusion.

2. LITERATURE REVIEW

In the Netherlands, Molenaar and Niekerk (2002) investigated the effect of composition, gradation, and degree of compaction on the mechanical properties of crushed concrete and masonry, followed by Mazumder and Kabir. (2006) and G.S. Patil et al. (2015) were used as references. Routine laboratory tests, such as Los Angeles abrasion, water absorption, specific gravity, and unit weight, are used to compare the properties of overburned bricks to the best possible quality picked or pick-Jhama Type A bricks from the same stockyards in Bangladesh.

Crushed concrete and demolition debris were investigated as sub-base coarse aggregate by O'Mahony and Milligan (1997) and Bennert et al. (2000). CBR experiments were carried out, and the behavior of recycled materials was compared to that of limestone. The results demonstrated that the CBR of crushed concrete was comparable to that of natural aggregate. In contrast, demolition debris had a relatively lower CBR, and in 2014 Hu et al. evaluated waste clay bricks from building debris as environmentally friendly materials for pavement sub-base research. Five sets of coarse aggregates were blended with sand and treated with 5% cement, containing 0, 25%, 50%, 75%, and 100% crushed bricks, respectively.

Motta (2005) and Fabiana et al. (2011) investigate the viability of using recycled construction and demolition waste (RCDW) aggregate in pavement applications. In a laboratory program that included geotechnical characterization, bearing capacity, and repeated triaxial load tests, Disfani et al. (2014) investigated the performances of cement-stabilized blends with recycled concrete aggregate and crushed brick as supplementary material.

In this study, Pal J. and Dey G. (2013) made a concerted effort to evaluate the feasibility of using brick aggregate made from locally available brick in standard concrete (M25 to M55 as per IS:456-2000). Because brick aggregate's high-water absorption (12% to 20% by mass) is a significant issue when used in actual work, an attempt has been made to suggest a realistic solution for real-world application.

D. Sarkar, M. Pal, and A.K. Sarkar (2014) investigated the use of low-quality or marginal aggregates in flexible pavement construction. The study aimed to determine the effects of using lower quality aggregates, such as overburnt brick aggregate, on the preparation of asphalt concrete for flexible pavements.

Sarkar D. and Pal M. (2016) investigated the use of overburnt brick aggregate in conjunction with waste plastic modified bitumen to reduce the aggregate shortage problem for road construction in India's North-Eastern region.

Jiang et al. (2015) developed a numerical test method based on the particle flow modelling technique PFC2D for the California bearing ratio (CBR) test on GCRs to better understand the mechanical properties of graded crushed rocks (GCRs) and to optimize the relevant design.

Montepara et al. (2012) investigated using RAP as a virgin aggregate supplement in an unbound mixture for sub-base layer applications. A series of non-destructive tests were carried out to assess the short- and long-term performance of a mixture containing 50% RAP, comparing the results to those obtained from a mixture containing only natural aggregates.

An experimental programmed was presented in this research by Ahmed Ebrahim (2013) to study the effect of using steel slag combined with limestone aggregates in different proportions on the density and sheer strength characteristics. To determine the best mixing ratio, the experimental programmed used the standard proctor test and the California bearing ratio (CBR).

3. METHODOLOGY

Step 1. Experimental programmed

Experimental work consists of various physical and engineering test on the selected materials. In the first stage, all experiments were done on the mother material aggregate and soil sample. To collect the several information on the selected aggregate and soil sample tests were done according to IS standard. Various test are mentioned below.

1. Aggregate Crushing Value
2. Aggregate Impact value
3. Los Angles Abrasion Test
4. Specific Gravity and Water Absorption of Coarse Aggregate
5. Flakiness and Elongation Index of the Coarse Aggregate
6. Determination Liquid Limit
7. Determination of Plastic Limit
8. Standard Proctor Test for light compaction
9. Modified Proctor Test for heavy compaction

Step 2. Preparation of CBR sample

1. California Bearing Ratio Test
   a) Statically Compacted specimen
   b) Dynamic Compacted specimen

Step 3. Lean cement concrete mix proportion

The concrete mix must be proportioned with a maximum aggregate cement ratio of 14:1 when using OPC and 12:1 when using PPC or PSC. The cementitious materials must be at least 140 kg/cum of concrete

Step 4. Lean cement concrete mix proportion

Trial mixes of dry lean concrete with moisture contents of 5.0, 5.5, 6.0, 6.5, and 7.0 percent were prepared using the cement content requirement of the aggregate-cement ratio as specified. The optimal moisture and density will be determined by preparing cubes with varying moisture contents. The mix must be compacted into three layers.

4. RESULT AND DISCUSSION

This document contains experimental data on the physical and engineering qualities of locally available aggregates and soils. The laboratory obtains and stores a large amount of dirt, jhama brick, and stone aggregates with nominal diameters of 20mm and 10mm. The brick sample was gathered from the Jirania brick field and was rejected for the laboratory program owing to distorted shape and overburnt. In the laboratory, soil and aggregate samples were characterized. To strengthen the pavement, varying percentages of local soil were blended with the dry weight of the aggregate sample. The heavy and light compaction tests for variation in maximum dry density (MDD), optimum moisture content (OMC), and California Bearing Ratio (CBR) are noted.

4.1 Experimental test result.

The crushing value, impact value, los angles abrasion value, water absorption value, sieve size analysis and specific gravity of aggregate also consistency limit of soil are shown in table 1. The maximum dry density (MDD), optimum moisture content (OMC), California Bearing Ratio test on locally available aggregate and aggregate mixed with soil are presented in details.

Table 1. Physical properties of brick and stone aggregates

Property	Over burnt brick	crushed stone	Standard code
Water absorption	4.4	0.8	IS:2386-1963- part 3
Specific gravity	1.95	2.64	IS:2386-1963- part 3
Aggregate impact value	32.68	22	IS:2386-1963- part 4
Aggregate crushing value	33.82	21.29	IS:2386-1963- part 4
Los Angles Abrasion Test	50	-	IS:2386-1963- part 4
Flakiness index	5.7	-	IS:2386-1963- part 4
Elongation index	16.1	-	IS:2386-1963- part 4

the liquid limit, plastic limit, shrinkage limit and plasticity index of the soil are 40.2%, 18.9%, 16.4% and 21.3% respectively.

The heavy and light both compactions were conducted to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the aggregate mixed with or without soil in different percentages. The value of MDD and OMC are presented in Table 2.

Table 2.MDD and OMC of the aggregate and aggregate soil mix

Sample	Compaction type	OMC	MDD
100% aggregate + 0% soil	Heavy	9.35	1.69
75% aggregate + 25% soil	Heavy	13.60	1.70

50% aggregate + 50% soil	Heavy	14.14	1.72
100% aggregate + 0% soil	Light	9.40	1.34
75% aggregate + 25% soil	Light	13.71	1.60
50% aggregate + 50% soil	Light	14.3	1.64
soil	Light	16.2	

4.2 CBR for light and dynamic compaction un-soaked CBR tests were performed on aggregate samples at OMC, first without mixing soil and then with soil mixed in varying percentages of 15%, 25%, and 50% in brick aggregates and 25% in stone aggregates by weight at a constant optimum moisture content of 16.5%. The load increases as the penetration value in the soil increases. CBR value of aggregate without mixing soil at OMC: 27% brick aggregate, 34% stone aggregate. Figures 1 and 2 depict the obtained results in graphical form.

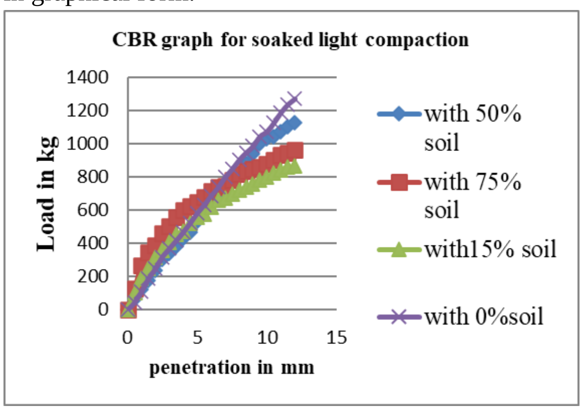

Figure1: Load penetration curve for aggregate mixed with different percentage of soil

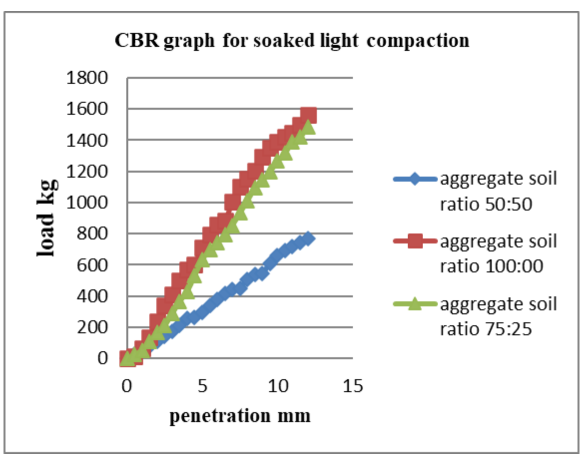

Figure 2: Load Penetration curve for stone aggregate mixed with different percentage of soil

4.3 CBR for light and static compaction

The soaked and unsoaked CBR test was performed on aggregate alone and aggregate mixed with various percentages of soil. The aggregate and aggregate-soil mix CBR values are summarised. The un-soaked CBR value of aggregate soil mix initially with 50:50 ratios is 54%, which varies from 60% to 80% as aggregate percentages increase. Soaked CBR value of aggregate soil mix initially with 50:50 ratios is 53%, which ranges from 58% to 78% as aggregate percentages increase. When aggregate and soil were mixed with a 100:00 ratio, the maximum un-soaked CBR value was observed to be 80%. When aggregate soil was mixed with 100:00 ratios, the maximum soaked CBR value was 78%. Result obtained are shown in figure 3 and 4.

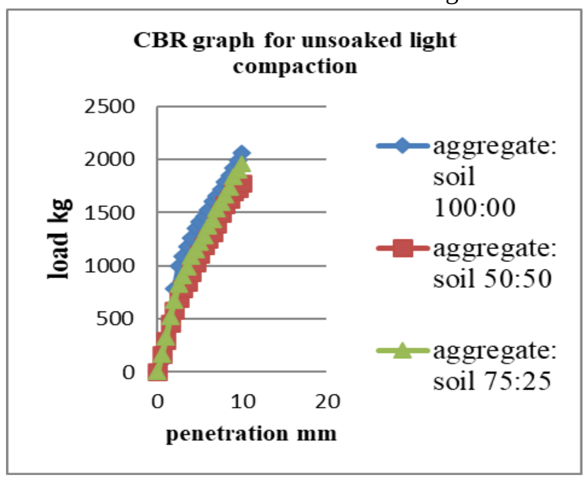

Figure 3: Load Penetration Curve for brick aggregate Mixed with Different Percentage of soil

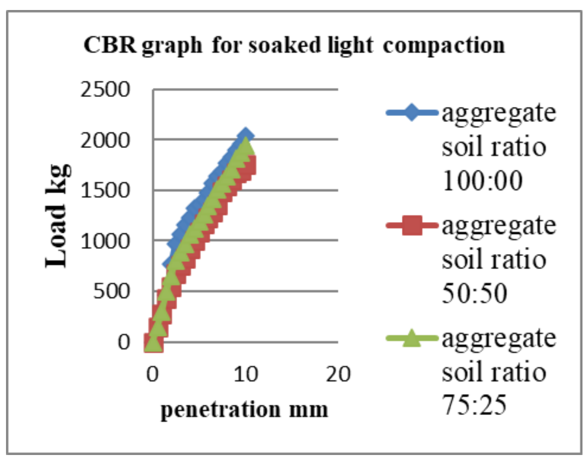

Figure 4: Load Penetration Curve for brick aggregate Mixed with Different Percentage of soil

4.4 CBR for heavy and static compaction

The soaked and unsoaked California bearing ratio test was performed on aggregate alone and aggregate mixed with various percentages of soil. The aggregate and aggregate-soil mix CBR values are summarised. The un-soaked CBR value of aggregate soil mix initially with 50:50 ratios is 78%, which varies from 132% to 144% as aggregate percentages increase. Soaked CBR value of aggregate soil mix initially with 50:50 ratios are 77%, which ranges from 106% to 140% as aggregate percentages increase. When aggregate soil was mixed with a 100:00 ratio, the maximum un-soaked CBR value was 144%. Similarly, when aggregate soil was mixed with 100:00 ratios, the maximum soaked CBR value was 140%. Obtained values are shown in Figures 5 and 6.

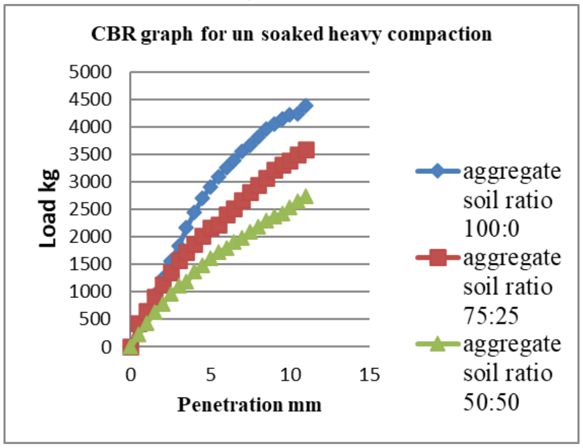

Figure 5: Load Penetration Curve for brick aggregate Mixed with Different Percentage of soil

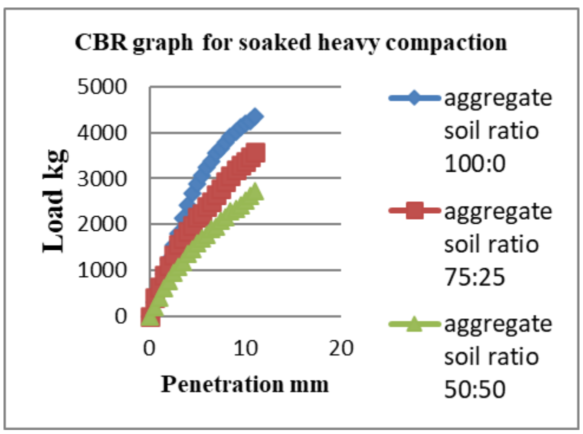

Figure 6: Load Penetration Curve for brick aggregate Mixed with Different Percentage of soil

Test data for various proportion of soil with brick aggregate light compaction and heavy compaction table 3 and 4.

Table 3: Test data for various proportion of soil with brick aggregate light compaction

Sl. no	Penetration mm	Load kg un soaked for various % of aggregate			Load kg soaked for various % of aggregate		
		100 %	75%	50%	100 %	75%	50%
1	0	0	0	0	0	0	0
2	0.5	72	145	144	92	166	165
3	1	234	300	282	261	323	302
4	1.5	468	500	432	490	524	455
5	2	768	650	552	788	673	582
6	2.5	972	800	672	994	826	694
7	3	1068	885	762	1092	904	784
8	3.5	1158	965	834	1180	988	848
9	4	1230	1065	918	1265	1088	940
10	4.5	1326	1125	1002	1349	1149	1024
11	5	1362	1195	1086	1415	1224	1108
12	5.5	1410	1260	1170	1466	1284	1193
13	6	1470	1350	1230	1527	1374	1254
14	6.5	1566	1415	1290	1604	1437	1315
15	7	1638	1510	1362	1661	1534	1395
16	7.5	1692	1575	1482	1717	1599	1499
17	8	1764	1645	1548	1786	1667	1571
18	8.5	1824	1715	1602	1848	1737	1625
19	9	1896	1815	1674	1920	1836	1695
20	9.5	1962	1880	1698	1986	1903	1732
21	10	2040	1940	1758	2065	1963	1782

Table 4: Test data for various proportion of soil with brick aggregate heavy compaction

Sl. no	Penetration mm	Load kg un soaked for various % of aggregate			Load kg soaked for various % of aggregate		
		100 %	75 %	50 %	100 %	75 %	50 %
0	0	0	0	0	0	0	0
0.5	324	432	230	0.5	301	405	211
1	612	655	432	1	595	631	415
1.5	943	914	626	1.5	920	890	622
2	1245	1130	792	2	1220	1104	771
2.5	1555	1353	964	2.5	1530	1328	944
3	1836	1584	1108	3	1811	1560	1088

3.5	2160	1728	1188	3.5	2140	1702	1188
4	2448	1872	1368	4	2425	1848	1348
4.5	2700	2016	1490	4.5	2680	1991	1470
5	2916	2174	1612	5	2890	2150	1595
5.5	3096	2232	1728	5.5	3071	2235	1702
6	3254	2404	1800	6	3230	2381	1785
6.5	3384	2520	1908	6.5	3361	2495	1891
7	3564	2671	1980	7	3541	2648	1961
7.5	3672	2808	2102	7.5	3645	2785	2085
8	3816	2952	2188	8	3791	2927	2170
8.5	3952	3074	2304	8.5	3925	3051	2285
9	4046	3225	2376	9	4021	3200	2353
9.5	4140	3312	2426	9.5	4115	3288	2426
10	4219	3384	2534	10	4195	3360	2510
10.5	4248	3492	2656	10.5	4251	3467	2631
11	4392	3600	2736	11	4345	3575	2721

4.5 Use of over burnt bricks in lean concrete

4.5.1 Compressive strength and modulus of rupture

Three mixes with different cement-aggregate ratio were selected for over-burnt brick keeping in mind the maximum value of 1:14 for DLC as IRC: SP:49-2014. Compressive was found out for the mixes are shown in table 5.

Table 5: Compressive strength of various mixes at 7 days.

Percent of cement	Ratio of cement to aggregate	Percent of water	Compressive strength (MPa)
7.1	1:13	6.0	3.5
7.7	1:12	6.5	5.2
8.4	1:11	6.5	7.3

It is seen that compressive strength achieved by adding 8.4 percent cement is higher compared to the other mixes though the strength criterion of 10 MPa was not achieved after 7 days. since the aggregate is weaker one, we have to find a limiting value for strength and other parameters judiciously for using the aggregate as lean concrete and design the pavement accordingly. Modulus of rupture was found out by carrying out third point flexure test and the results are shown in table 6.

Table 6: Modulus of rupture of various mixes

Mix ratio	7 days M.R (MPa)
1:13	0.42
1:12	0.75
1:11	1.14

5. CONCLUSION

The experiment results show that the CBR of overburnt brick aggregate is improved and satisfactory by reducing the soil proportion. Various test programs were carried out in the laboratory to evaluate soil and aggregate's engineering and physical properties, and the results were almost satisfactory. There were numerous variations in those factors. However, as the soil percentage increased, the problem of workability was encountered during the experimentation because the soil replaced the coarse aggregate with its increased density.

The following conclusions can be drawn from the work done in this investigation in respect of over burnt brick aggregate as sub-base material and also as lean cement concrete material for road construction.

1. In case of CBR test with mix of brick and soil of varying proportions, it is seen that there was hardly any increase in the CBR value when brick content is less than 50 percent .it is noticed that CBR value of soil and over burnt mixture was near the soil and stone mixture.
2. Soil and over burnt aggregate mixture with brick aggregate content more than 50 percent satisfy the criterion for sub base material of CBR value 30 as per Ministry of Road Transport and Highways (M.O.R.T.H) specifications. More over the CBR value of mix increases with the increase in coarse aggregate percentage and the maximum value is 144%.
3. The compressive strength obtained by the mix of over burnt brick and cement is of reasonable strength except for the mix of 1:13(cement to aggregate ratio) where compressive strength is less than 5 MPa.
4. There is a reasonable result found in modulus rupture with the mix of over burnt brick and cement for the mix of 1:11.
5. The MDD and OMC of the brick aggregate and soil mix decreases with the increase in the percentage of aggregate proportion.
6. Other physical engineering properties of aggregate are also satisfactory as sub base material.
7. With the increase in the percentage of coarse aggregates in the soil, the workability is affected and will be uneconomical.

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