***ASSESSMENT REPORT*:**

APPLICABILITY OF RAP IN BASE AND SUB BASE OF FLEXIBLE PAVEMENT

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Government of the Peoples' Republic of Bangladesh
Local Government Engineering Department

Department of Civil Engineering
Bureau of Research, Testing and Consultation (BRTC)
Bangladesh University of Engineering and Technology
Dhaka – 1000, Bangladesh

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1. INTRODUCTION

Local Government Engineering Department (LGED) has been constructing roads, bridges, culverts, buildings and other civil infrastructures for more than three decades. Each infrastructure is built with specified construction materials and has a design life span. At the end of its useful design life, materials used in these infrastructures get deteriorated, loses their original characteristics and eventually become wastes. Similar situation is experienced by flexible pavements after its useful design life. At the end of service life of flexible pavements, significant quantities of deteriorated asphalt concrete extracted from the rehabilitation process become hazardous waste and pollute roadside soils and agricultural field unless they are properly disposed-off or reused in a safe manner. On the other hand, there is a significant scarcity of sources of construction materials in Bangladesh. Most of the construction materials are imported from outside either in raw forms or in finished forms requiring significant foreign currency expenditure. Although the reclaimed flexible pavement materials lose their original properties (e.g., binding capacity of bitumen or gradation of aggregates) to a certain extent, their usability and usefulness is not totally lost. To address these environmental issues and incorporate sustainability in infrastructure development and management, many developed as well as developing countries are using reclaimed road materials for construction/rehabilitation of roads.

With a vision of sustainable development, LGED has come forward to ensure the optimum use of its pavement waste materials through development and efficient application of indigenous cost-effective technologies/ methods. The current practice of LGED with regards to the use of reclaimed flexible pavement materials is to use them as sub-base and base course materials in rehabilitation or maintenance projects.

However, the reclamation process followed is quite crude, where harrows are used to scrape of the existing flexible pavement materials, and in this process the top asphalt concrete gets mixed with bottom aggregate layers making it difficult to separate them. Moreover, strength (e.g. bearing capacity i.e., CBR) properties and suitability of this mixed aggregate as subbase and base course material has not been properly evaluated for practical application and is being practiced as a makeshift arrangement. To this end, LGED collaborated with the Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET) to utilize the fund received from the Government of Bangladesh for conducting the research on how to utilize the reclaimed asphalt concrete materials in the best possible way in the maintenance and rehabilitation work either in its crude form or in combination with virgin materials (aggregate and bitumen). The objective of the consultancy service is to conduct a study and

research on the reclaimed construction materials of flexible pavement to develop working procedure for reusing the reclaimed materials in LGED roads.

To familiarize with the current practice of LGED in road maintenance and widening projects and the flexible pavement reclamation process, a site visit was organized on 2nd June 2022. BRTC, BUET consultant team visited an active site in Saturia Upazila of Manikgonj District. The BUET team was accompanied by local higher officials of LGED to give them a better perspective of the current practices and discussed various aspects of road maintenance issues. The LGED officials informed that, in rural road works specially in maintenance, and in widening projects, scarifying and loosening of existing top surface is done using harrows (up to the depth of 75mm using mechanical means) which brings base/sub-base course materials along with the reclaimed asphalt concrete. Due to continuous utilization of road and scarifying, base/sub-base course materials also lose their original shape which makes re-bonding with bitumen quite difficult. The consultant team then visited a part of Daragram GC-Bangladesh hat GC road which is part of "Widening and Strengthening of Important Upazila and Union Road under Dhaka Division Project" (DDIRWSP) under Saturia Upazilla, Manikganj District. The Google map location of the site is shown in Figure 1 (a). Figure 1(b) shows a picture of the visiting team of consultants.

(a) (b)

Figure 1: (a) Google Map Location of Sample Collection (b) Team of Consultants at Site

The Upazila Engineer, Saturia and the Sub Assistant Engineer, Saturia accompanied the consultants to the site. This was an upazilla road with existing road carriageway width of 12 ft, which is being widened to carriageway width of 18 ft.

It was observed that the wearing course and base course of existing road is removed manually where strengthening work is undertaken. The wearing course is of asphalt concrete (stone chips) and the base course is of brick chips. These two types of aggregate were then mixed together and put

them back in preparation of sub-base of new road. There wasn't any data available on the performance of strengthened road's sub-base where reclaimed bituminous coated aggregate has been used.

Figures 2 shows the field condition, sample collection process and Figure 3 shows the typical condition of the reclaimed aggregates. A close up view of the reclaimed is shown in Figure 4.

(a) (b)

Figure 2: (a) Sample aggregate collection from widened road sub-base. (b) Typical section of widened road (up to sub-base)

(a) (b)

Figure 3: Aggregate collected from sub-base of strengthened road

Figure 4: Close up View of Reclaimed Aggregates

The scope of work under this research projects includes, but not limited to, as follows: -

- Collection of data and information from the site through field visit.
- Conducting necessary tests to find out various materialistic parameter of reclaimed road materials.
- Determination of physical properties of reclaimed road materials and their appropriateness.
- Determination of gradation of RAP materials (RBCA & Wearing Course).
- Assessing the applicability of RAP materials as base and sub-base of flexible pavement by determining California Bearing Ratio (CBR- Soaked) of RAP using different mixing composition with aggregates.
- Assessing the applicability of RAP materials in Wearing Course of flexible pavement.
- Performing job mix formula using RAP to meet requirement for flexible pavement.
- Conducting comparative study of using RAP materials as wearing course, base course, subbase course of flexible pavement.

- Implementing simple techniques for removing coating from bituminous aggregates and examining their effectiveness for selecting the best performing one.
- Comparing the physical and mechanical properties of raw and surface modified reclaimed aggregates.

Some portion of the reclaimed aggregate from RAP is coated with bitumen around it and hence, will be termed as RBCA (Recycled Bituminous Coated Aggregate) from now on in this report. The potential of reclaimed material (RBCA) obtained from Reclaimed Asphalt Pavement (RAP) to be used as base and sub-base material has been comprehensively assessed and presented in this report.

2. REVIEW OF PREVIOUS STUDIES

Use of Reclaimed Asphalt Pavement (RAP) in different components of flexible pavements such as base and sub base has been investigated by many researchers at home and as well as abroad.

In Bangladesh, some researches (Islam,2018; Islam, 2019) investigated the prospect of Reclaimed Asphalt Pavement (RAP) as aggregate base and subbase by combining RAP at different dosages (100%, 70%, 60% and 50%) with virgin aggregate and determined the CBR values of each mix. Islam (2018) investigated the prospect of Reclaimed Asphalt Pavement (RAP) as Stabilized Base. The study suggests a method for creating asphalt mixes at various compaction temperatures. In this experiment, laboratory test samples of 100% RAP were compacted at various temperatures (130°C, 140°C,150°C and 160°C) and were evaluated for the mix's performance by various tests (Marshall stability, flow, and compressive strength). The RAP materials were collected from the wearing course of the road segment under the Banani overpass near Dhaka Cantonment during excavation process for utility shifting. Milling process was done manually with locally available cutting tools. Samples were collected in suitable pieces and then pulverized and sized manually. According to the findings, the optimum compaction temperature is 150°C which had a stability value of 9.5 KN. At this temperature, the compressive strength of the asphalt concrete specimen was 5.14 MPa. According to the study, asphalt mixes, including RAP, when utilized as a stabilized base with 20 or 30 mm of surface, can provide a service life more significant than that of 50 mm overlay.

Islam (2019) further examined the potentiality of RAP as aggregate base and sub-base by combining RAP at different dosages (100%, 70%, 60% and 50%) with virgin aggregate and determined the CBR values of each mix. According to the study, the CBR value is 15 when RAP aggregates are 100% which does not fulfill the minimum requirement of CBR value by LGED. When 50% of the RAP is replaced, a maximum CBR value

of 20 is discovered. The CBR values do, however, noticeably increase when RAP and VA combinations are treated with cement, reaching a maximum of 47 for 50% replacement of RAP treated with 5% cement. According to the study, the CBR value of the compacted collected RAP at 155°C is 37. However, the CBR value increases to 52 when 1% virgin bitumen is added and mixed at the same temperature. According to the study, collected RAP alone can only be used as a sub-base or base if it is used with binders to increase its strength. However, in both cases, RAP means the bituminous concrete part (wearing course and binder course only i.e. only stone aggregate)

In other SAARC countries, similar studies on RAP material for use in base and sub-base have been studied. In India, Kasu (2020) investigated on design and durability characteristics of cement treated reclaimed asphalt (CTRA) for base and subbase layers. This paper presented the mechanical, durability and microstructure characteristics of CTRA bases and sub-bases material produced by varying the percentage of virgin aggregate (VA) and recycled asphalt aggregate (RA) (100/0, 80/20, 60/40, 40/60 of RA/VA), and cement content (2.5%, 5.0%, 7.5%, and 10.0% cement contents by wt. of aggregate). It was found that the optimum moisture content (OMC) was in the range of 6.5 to 7.5% for all mixtures. Maximum dry density (MDD) lies in the range 2.20–2.28 g/cc. The addition of cement had a more pronounced effect than the addition of RA in the mixtures. When the high RA proportion is used in base/subbase layers, the cost saving in the construction of flexible pavements was observed about 26–32%. CTRA is recommendable for use in bounded pavement layers (base and sub-base for flexible pavements.
In Pakistan, Arshad and Ahmed (2017) focused on the characterization of blended materials containing 50% and 75% of RAP with fresh granular materials to evaluate whether they are suitable for granular base/subbase layers of flexible pavements. A series of laboratory tests was performed to determine the resilient modulus (M_R) and the constrained modulus (M_c) for both fresh granular materials and their blends. Statistically, the notable increase was found in the M_R values of the blended samples containing 75% RAP material and 25% fresh granular, particularly at higher levels of bulk stresses. It was also found that the accumulative strains during cyclic loading generally increase with an increase in the percentage of RAP contents in the blended samples. M_c test results show an increasing trend with the increasing level of axial stress, however, M_c value decreases with increasing percentage of the RAP content.

In Oman, Taha (1999) performed an experimental investigation on well-graded RAP contents having uniformity coefficient (Cu) and curvature coefficient (Cc) equal to 6 and 1.5, respectively, while the fresh granular material was a mixture of well-graded sand and gravelly sand with little or no fines. The blends were obtained by adding 20, 40, 60, 80 and 100% of the granular material with RAP. On the basis of

California Bearing Ratio (CBR) test results, they have suggested that up to *100% RAP* in subbase courses could be allowed but the amount of RAP in unbound granular base courses would have to be limited to *10%*.

In Egypt, Mousa (2021) also evaluated the feasibility of using RAP as base and subbase material through laboratory tests like particle size distribution, specific gravity, modified Proctor compaction, CBR, and hydraulic conductivity tests. Furthermore, resilient modulus test, static triaxial shear test, and X-Ray CT Scanning were conducted for the evaluation of material performance. In the laboratory, the RAP was blended with VA in percentage of 0%, 20%, 40%, 60%, 80%, and 100% by the total weight of the blend. It is important to control the gradation of the RAP/VA blends to cope with the gradation requirements as the RAP fractions tend to have lower fines content compared to the natural virgin aggregate. Based on the CBR, up to 60% RAP can be blended with crushed aggregates and used as a subbase material, however, RAP can only be used up to 20% in road base construction. Both CBR and hydraulic conductivity are lower for blends with higher amounts of RAP. Conversely, the increase in the RAP amount showed a significant increase in the resilient modulus. From the CT Scanning, it is found that the 0% RAP specimen had higher air voids content when compared to the 80% RAP specimen. This suggests that the lower air voids might lead to higher values of resilient modulus for samples consisting of a higher RAP amount.

In United Kingdom up to a maximum of 50% RAP by weight is permitted in Type 1 and Type 2 unbound subbase mixtures. Up to 100% RAP is allowed in Type 4 unbound aggregate mixture (Manual of Contract Documents for Highway Works 2014). In United States, the acceptable field compaction criterion is specified in terms of a wet density of not less than 95% of the maximum wet density when determined in accordance with one-point AASHTO T 180, Method D (American Association of State Highway and Transportation Officials. AASHTO T 180-10 2010) . Florida Department of Transportation (FDOT) specifications allow the use of up to 100% RAP only for nontraffic base applications, primarily at paved shoulders and bike paths, as described in Section 283 (Florida Department of Transportation. Standard Specifications for Road and Bridge Construction 2013).

The Idaho Transportation Department (2012) specifies that RAP can be mixed in approximately equal proportions with granular borrow for subbase applications and up to 50% RAP is allowed in the granular subbase (Idaho Transportation Department. Standard Specifications for Highway Construction 2012)

Another study in Montana (Mokwa , 2005) conducted laboratory tests on four different types of granular material blended with varying percentages of RAP (20, 50 and 75%). They found that blending of RAP with

granular material resulted in only minor changes to the engineering properties of the fresh granular material. However, they suggested a limiting value of 50% RAP when used for the base course. Texas DOT and Washington State DOT specifications allow up to 20% RAP by weight in flexible bases.

3. APPROACH AND METHODOLOGY

Reclaimed asphalt pavement (RAP) is the most available material with great potential to substitute natural resources. Use of RAP as a construction material can decrease the cost, provides a way to conserve landfill space, preserves natural resources, protects the environment, and improves sustainability. While several factors influence the use of RAP in asphalt pavement, the two primary factors are economic savings and environmental benefits. RAP is a useful alternative to virgin materials because it reduces the use of virgin aggregate and the amount of virgin asphalt binder required in the production of HMA. The use of RAP also conserves energy, lowers transportation costs required to obtain quality virgin aggregate, and preserves resources. Additionally, using RAP decreases the amount of construction debris placed into landfills and does not deplete nonrenewable natural resources such as virgin aggregate and asphalt binder. Ultimately, recycling asphalt creates a cycle that optimizes the use of natural resources and sustains the asphalt pavement industry.

3.1 Approach

The approach towards this task is more of a research oriented one, with the prime objective of developing a sustainable and cost-effective methodology for efficient reclamation of valuable resources and use of reclaimed asphalt pavement materials in an environmentally friendly way which are otherwise dumped as waste materials. The work-flow chart below shows the overall approach for this task.

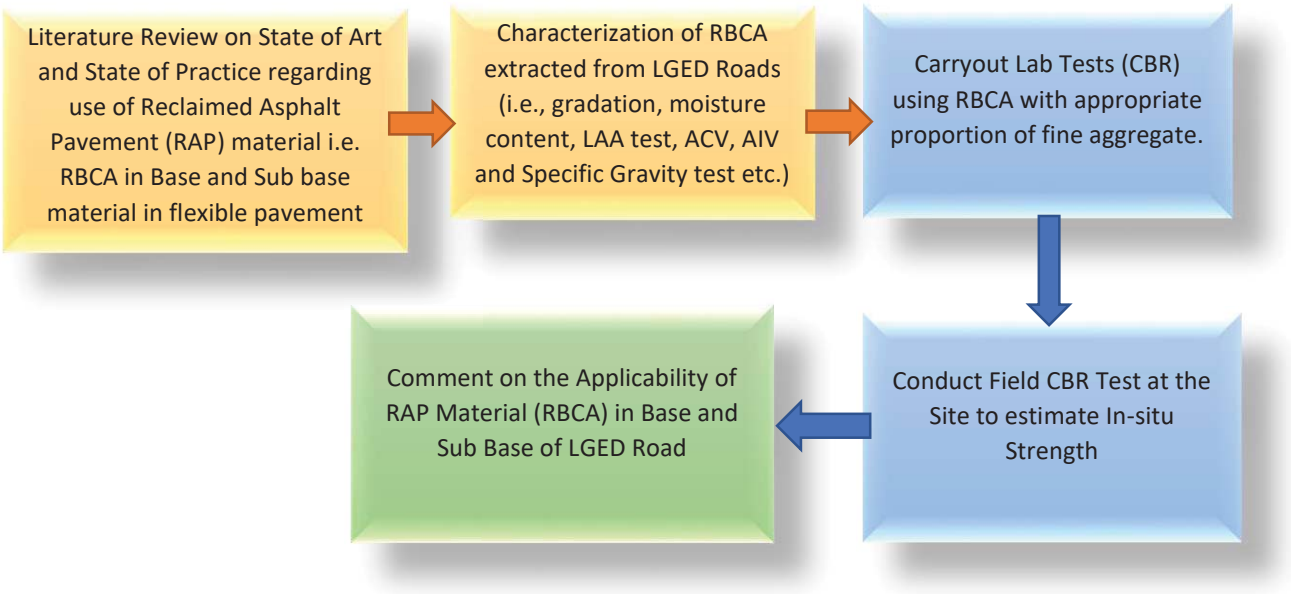


Figure 5: Work-flow chart of proposed RBCA usage as Base and Sub Base study

3.2 Methodology

The total work of this study can be divided into four parts- namely-

a) Literature review and LGED's flexible pavement construction practices, guidelines etc.
b) Characterization of Reclaimed Asphalt Pavement (RAP) materials i.e. RBCA through conducting standardized tests such as – Determination of specific Gravity, Gradation Test, Determination of Moisture Content, Aggregate Crushing Value Test, Aggregate Impact Value Test, Los Angeles Abrasion Test etc.).
c) Carry out base and subbase material related standard tests i.e. California Bearing Ratio (CBR) Test to ascertain suitability of RBCA in its original state or in combination with virgin aggregate in varying proportions (if necessary).
d) Carryout Field CBR Test on the site from where the materials have been collected to ascertain field performance.

The original proposed methodology proposed in the inception report has been slightly modified based of laboratory results and subsequent findings.

4. ANALYSIS and RESULTS OF TESTS PERFORMED ON RAP MATERIAL (RBCA) FOR ASSESSING THEIR APPLICABILITY AS BASE AND SUB BASE MATERIAL

In order to assess the applicability of RBCA as base and sub base various material characterization test has been performed and the results are shown below.

4.1 **Characterization Tests of RBCA:**

Particle size distribution: sieve analysis/gradation test was performed on the reclaimed bituminous coated aggregate (RBCA) according to ASTM C136. The results of the sieve analysis are shown below.

Sieve Size	Material Retained	Percent of Material Retained	Cumulative % Retained	Percent Finer	Fineness Modulus
mm	gm	%	%	%	
37.5	1581.0	11	11	90	**7.87 (Seven point eight seven)**
25.4	4510.0	30	41	59	
19.05	5816.0	39	79	21	
12.5	2820.0	19	98	2	
9.5	216.0	1	100	0	
6.3	0.0	0	100	0	
4.75	0.0	0	100	0	
2.36	0.0	0	100	0	
1.18	0.0	0	100	0	
0.6	0.0	0	100	0	
0.3	0.0	0	100	0	
0.15	0.0	0	100	0	
0.075	0.0	0	100	0	
Pan	57.0	0	100		
Total	15000				

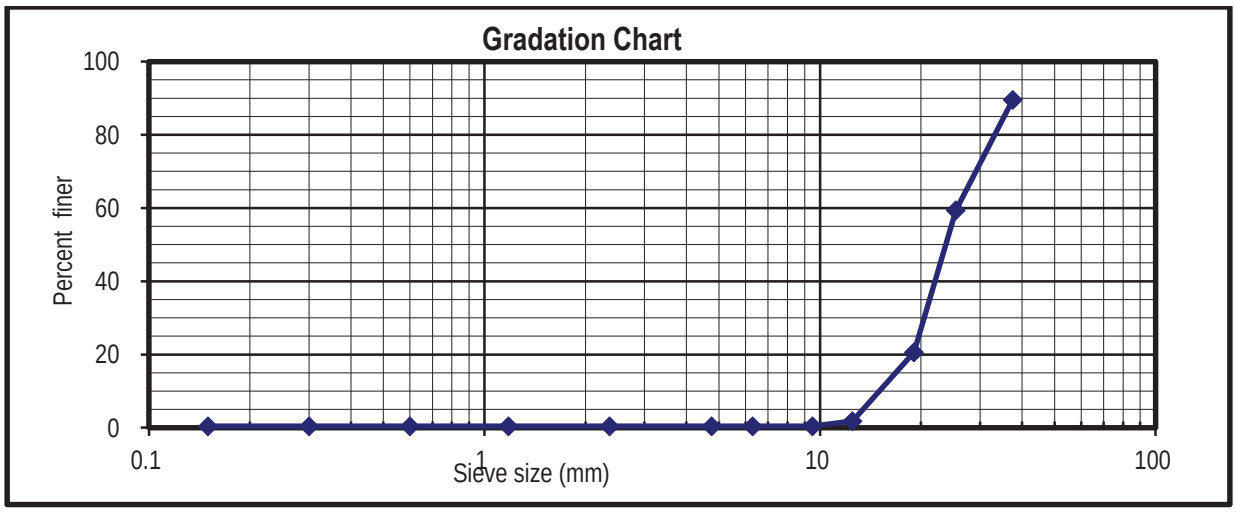


Figure 6: Gradation Curve of RBCA material (Whole Sample)

Close observation of the gradation of RBCA material revealed that, there are two kinds of coarse aggregate mixed together i.e. Stone aggregate from base course and binder course of reclaimed

pavement and brick aggregate (Picked Jhama) from sub-base course of reclaimed pavement. Also, it was evident that for greater than 1" size fraction, only brick aggregates (Picked Jhama) were present as seen in Figure 7. For this reason, the aggregate sample was separated in greater than 1" size and less than 1" size for carrying out the characterization tests.

Figure 7: Greater than 1" Size RBCA (Picked Jhama Brick Aggregate)

The grain size distribution curves for the investigated materials compared with the gradation limits for the granular base, sub-base and asphaltic concrete materials with LGEDs specification were compared.

Table 1: Aggregate Grading for Sub-Base and Base Course (LGED)

Sieve Size (mm)	% Passing By Weight	
	Grading for Sub-Base Course	Grading for Base Course/WMM
50 mm	100	100
37.5 mm	100	95-100
19 mm	55-95	60-80
9.5 mm	35-75	40-60
4.75 mm	25-60	25-45
2.36 mm	15-50	15-30
0.600 mm	10-35	8-22
0.300 mm	10-25	-
0.075 mm	5-15	0-5

Bulk Specific Gravity (BSG): The bulk specific gravity as well as water absorption capacity test was carried out on the two fractions of RBCA (greater than 1" size and less than 1" size) according to ASTM C127 /AASHTO T85-91 standard test method. Test results are shown below.

Table 2: Bulk Specific Gravity and Absorption Capacity of different RBCA fraction

Sample ID	***Remarks***	***Bulk Specific Gravity***	***Absorption Capacity (%)***
RBCA (Greater than 1")	Brick Chips (Picked Jhama)	1.94	8.50
RBCA (Less than 1")	Mix of Stone & Brick Chips	2.44	2.40
RBCA (Less than 3/4")	Mix of Stone & Brick Chips	2.45	2.30

Moisture Content: Moisture content of the two fractions of RBCA (greater than 1" size and less than 1" size) were also determined using ASTM C566 standard test method. Heating oven has been used to determine the moisture content of different fractions of the reclaimed bituminous coated aggregate. Test results are shown below.

Table 3: Moisture content of different RBCA fraction

Sample ID	***Remarks***	***Moisture Content (%)***
RBCA (Greater than 1")	Brick Chips (Picked Jhama)	3.80
RBCA (Less than 1")	Mix of Stone & Brick Chips	1.20

Bulk Density/ Unit Weight: The bulk density of aggregate is evaluated using standard test methods- ASTM C 29/C29M-17a or BS 812-2:1995. The bulk density or unit weight is the weight per unit volume (mass per unit volume or density). Bulk density of the two fractions of RBCA (less than 1" size and less than 3/4" size) were also determined using ASTM C29 standard test method. Test results are shown below.

Table 4: Unit Weight of different RBCA fraction

Sample ID	***Remarks***	***Unit Weight (Kg/m^3)***
RBCA (Less than 1")	Mix of Stone & Brick Chips	1550
RBCA (Less than 3/4")	Mix of Stone & Brick Chips	1550

Los Angeles Abrasion (LAA) Value Test: Los Angeles abrasion test on aggregates is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration. This test is carried out by AASHTO T 96 or ASTM C 131: Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine. LAA value of RBCA for different fractions of were determined. Test results are shown below.

Table 5: Los Angeles Abrasion Value of different RBCA fraction

Sample ID	***Remarks***	***LAA Value (%)***
RBCA (Greater than 1”)	Brick Chips (Picked Jhama)	28
RBCA (Less than 1”)	Mix of Stone & Brick Chips	19

Aggregate Crushing Value (ACV) Test: Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. ACV for different fractions of RBCA were determined according to BS 812 (part3) test standard. Test results are shown below.

Table 6: Aggregate Cushing Value of different RBCA fraction

Sample ID	***Remarks***	***ACV Value (%)***
RBCA (Greater than 1”)	Brick Chips (Picked Jhama)	35*
RBCA (Less than 1”)	Mix of Stone & Brick Chips	18

*The ACV test is not appropriate for this weak aggregate sample. It is recommended to perform 10% fine value (TFV) test to know the crushing properties of the sample. The TFV test result is shown next.

Ten Percent Fines Value (TFV) Test: The Ten Percent Fines Value Test is conducted to know the load (in KN) required to produce ten percent of fine material when subjected to a gradually applied compressive load. TFV for RBCA fraction greater than 1” size (Brick Chips) was determined according to BS 812 (part3) test standard. Test results are shown below.

Table 7: Ten Percent Fine Value of RBCA (greater than 1")

Sample ID	*Remarks*	*TFV Value (KN)*
RBCA (Greater than 1")	Brick Chips (Picked Jhama)	120

Aggregate Impact Value (AIV) Test: The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load. AIV for different fractions of RBCA were determined according to BS 812 (part3) test standard. Test results are shown below.

Table 8: Aggregate Impact Value of different RBCA fraction

Sample ID	*Remarks*	*AIV Value (%)*
RBCA (Greater than 1")	Brick Chips (Picked Jhama)	34
RBCA (Less than 1")	Mix of Stone & Brick Chips	15

4.2 **California Bearing Ratio (CBR):**

The CBR test ASTM D1883 (AASHTO T193) has been performed to assess the potential strength of the RBCA under uniaxial load. Figure 8 shows typical equipment for CBR test.

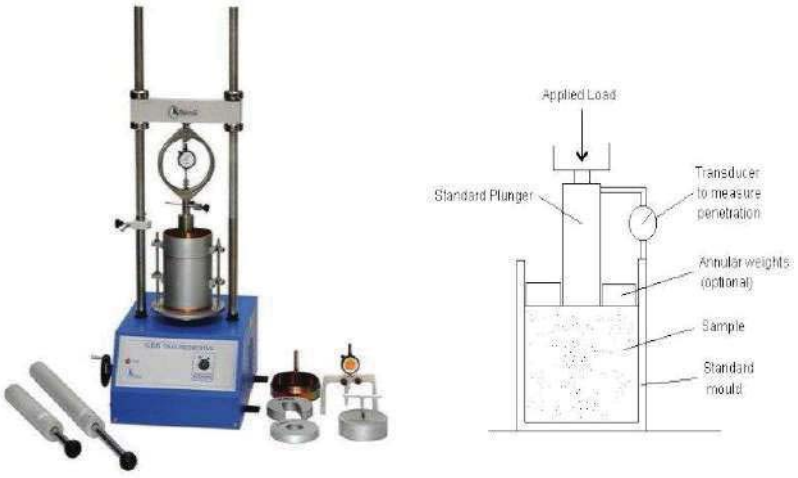


Figure 8: California Bearing Ration Test Equipment

The California Bearing Ratio (CBR) of base/ sub-base material is an indication of its bearing capacity under traffic loading and is determined as the ratio of the penetration resistance of the base material to that of a standard crushed stone.

According to ASTM D 1883, "the test method covers the determination of the CBR (California Bearing Ratio) of pavement subgrade, subbase, and base course materials from laboratory compacted specimens. The test method is primarily intended for (but not limited to) evaluating the strength of materials having maximum particle sizes less than 3⁄4 in. (19 mm)". So as a starting point to carryout Lab CBR test on RBCA sample, the sample was separated at the ¾" Size. Samples containing less than ¾" size aggregates were used for Lab CBR test. The test results of characterization tests performed on this sample (less than ¾" size) is shown below.

Table 9: Characterization of Aggregate used in CBR Test

Sample	***Parameter***	***Test Standard***	***Results***
RBCA (Less than ¾" Size)	Specific Gravity (OD)	ASTM C127	2.45
	Water Absorption	ASTM C127	2.30 (%)
	Unit Weight/ Bulk Density	ASTM C 29	1550 (kg/ m^3)
	Voids in Aggregate	ASTM C 29	37 (%)

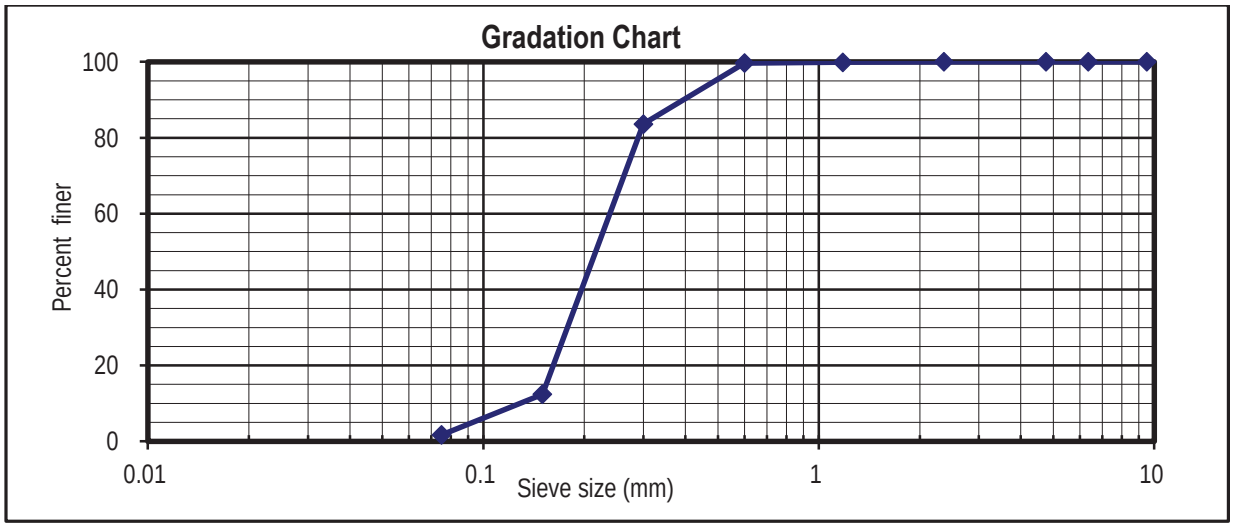
It was observed from the sieve analysis test of RBCA (shown above) that almost all fraction of the RBCA is larger than 9.5 mm size. As a result, molding of samples for CBR test using only the above reclaimed bituminous coated aggregate was not possible. Thus, for sample molding purposes, fine aggregate (local sand) was added to the RBCA in requirement amount based on voids percentage of RBCA. The properties of the sand used for molding purposes is shown below.

Table 10: Characterization of Local Sand used in CBR Test

Sample	***Parameter***	***Test Standard***	***Results***
Local Sand (used for CBR sample molding)	Specific Gravity (OD)	ASTM C127	2.61
	Water Absorption	ASTM C127	1.20 (%)
	Unit Weight/ Bulk Density	ASTM C 29	1540 (kg/ m^3)
	Fineness Modulus	ASTM C 136	1.04

Sieve analysis results along with gradation chart for local sand used in CBR sample preparation as per ASTM C 136 is shown below.

Sieve Size	Material Retained	Percent of Material Retained	Cumulative % Retained	Percent Finer	Fineness Modulus
mm	gm	%	%	%	
12.5	0.0	0	0	100	
9.5	0.0	0	0	100	
6.35	0.0	0	0	100	
4.75	0.0	0	0	100	
2.36	0.0	0	0	100	**1.04**
1.18	0.2	0	0	100	**(One point zero four)**
0.6	0.6	0	0	100	
0.3	48.2	16	16	84	
0.15	213.5	71	88	12	
0.075	32.0	11	98	2	
Pan	5.4	2			
Total	300				



Local sand of the above specification was mixed with RBCA at three different mix proportions to find the appropriate one that provides maximum unit weight and fills the target voids content in RBCA (3/4" down) which is 37 %. A volumetric mix proportion approach was used to make the process field ready. The mix proportions used along with the density achieved is shown below.

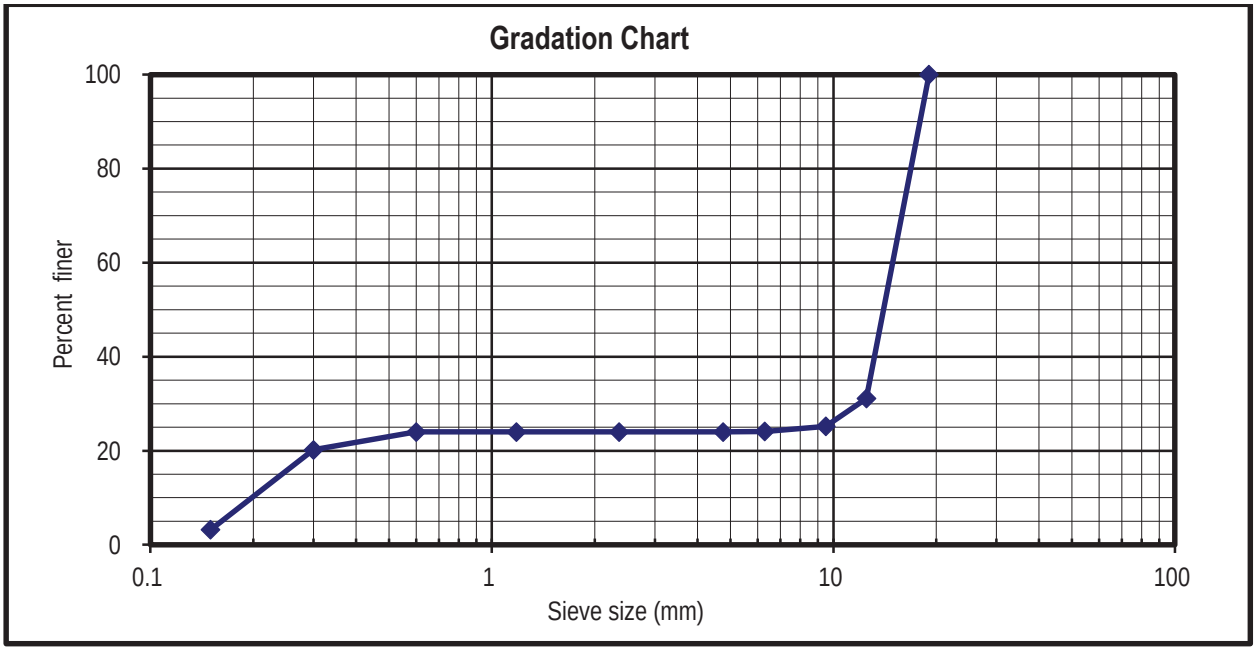
Table 11: Composition of various aggregate mixes considered for CBR Test

Mix Proportion RBCA (3/4" down) : Local Sand)	Mix Percentage RBCA (3/4" down) : Local Sand)	Unit Weight/ Bulk Density (kg/m^3)
3 : 1	75% : 25%	1990
5 : 2	71% : 29%	2010
2 : 1	67% : 33%	2010

The combined gradation of CBR samples for the different mix proportions of RBCA and local sand are shown next.

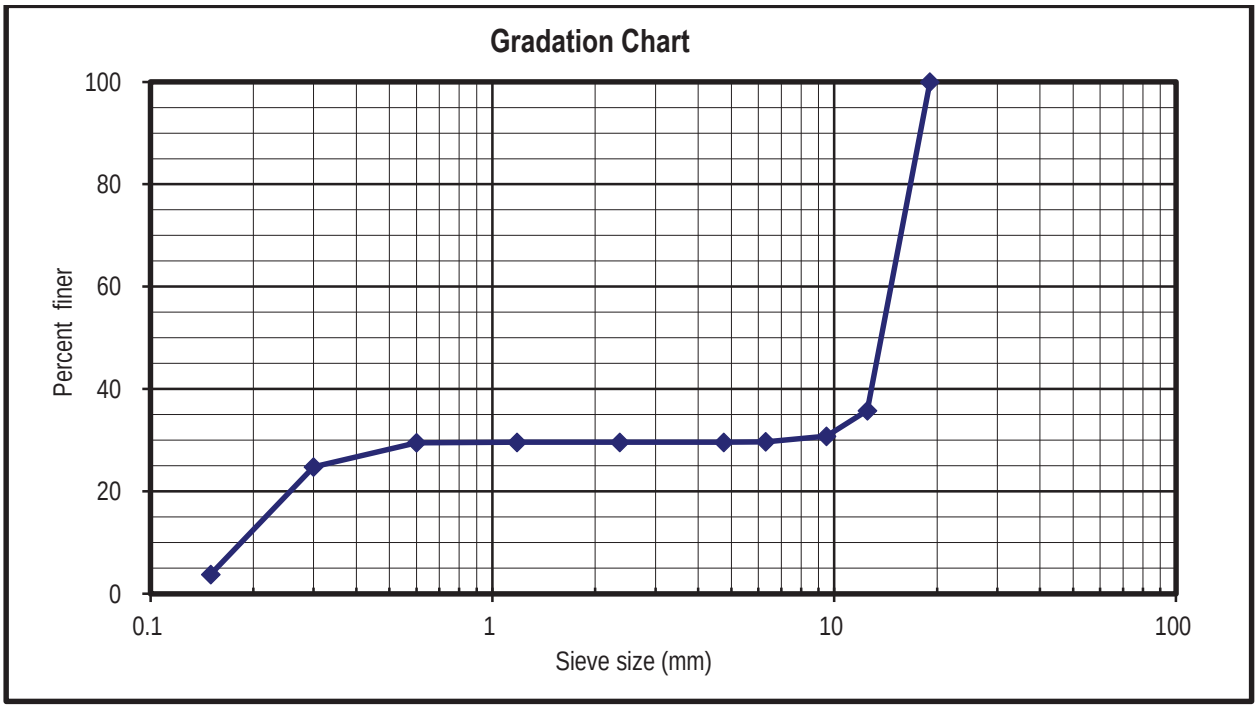
Combined gradation of CBR Sample for Mix Proportion- RBCA (3/4" down): Local Sand) = 3:1

Sieve Size	Material Retained	Percent of Material Retained	Cumulative % Retained	Percent Finer	Fineness Modulus
mm	gm	%	%	%	
19.05	0.0	0	0	100	**5.55 (Five point five five)**
12.5	4485.0	69	69	31	
9.5	387.0	6	75	25	
6.3	73.0	1	76	24	
4.75	6.0	0	76	24	
2.36	2.0	0	76	24	
1.18	1.0	0	76	24	
0.6	3.1	0	76	24	
0.3	249.6	4	80	20	
0.15	1110.0	17	97	3	
0.075	166.0	3	99	1	
Pan	28.1	0	100		
Total	6511				



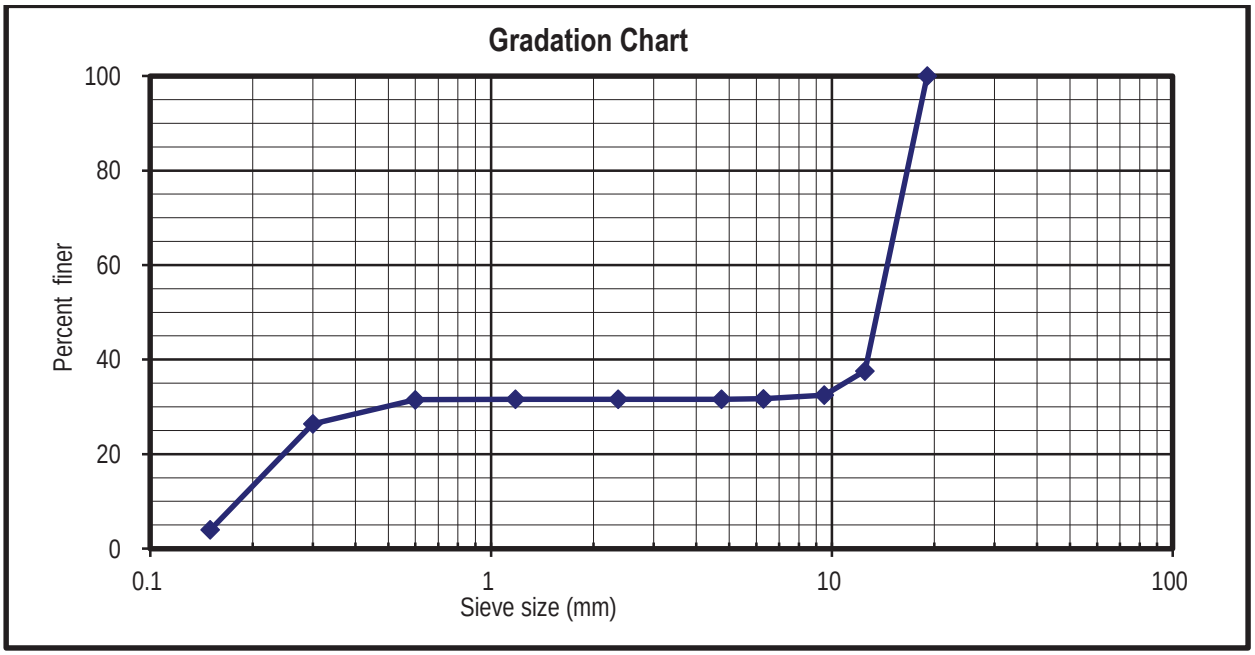
Combined gradation of CBR Sample for Mix Proportion- RBCA (3/4" down): Local Sand) = 5:2

Sieve Size	Material Retained	Percent of Material Retained	Cumulative % Retained	Percent Finer	Fineness Modulus
mm	gm	%	%	%	
19.05	0.0	0	0	100	**5.22 (Five point two two)**
12.5	4510.0	64	64	36	
9.5	354.0	5	69	31	
6.3	80.0	1	70	30	
4.75	6.0	0	70	30	
2.36	1.0	0	70	30	
1.18	1.4	0	70	30	
0.6	4.1	0	71	30	
0.3	331.9	5	75	25	
0.15	1473.0	21	96	4	
0.075	221.0	3	99	1	
Pan	37.3	1	100		
Total	7020				



Combined gradation of CBR Sample for Mix Proportion- RBCA (3/4" down): Local Sand) = 2:1

Sieve Size	Material Retained	Percent of Material Retained	Cumulative % Retained	Percent Finer	Fineness Modulus
mm	gm	%	%	%	
19.05	0.0	0	0	100	**5.11 (Five point one one)**
12.5	4515.0	62	62	38	
9.5	368.0	5	68	33	
6.3	60.0	1	68	32	
4.75	7.0	0	68	32	
2.36	1.0	0	68	32	
1.18	1.5	0	68	32	
0.6	4.6	0	69	32	
0.3	366.0	5	74	26	
0.15	1622.6	22	96	4	
0.075	243.2	3	99	1	
Pan	41.0	1	100		
Total	7230				



Although, the highest density was achieved for 5:2 ration, due to rounding both 5:2 and 2:1 ration appear to give same density. Based on this finding, CBR molds were prepared using 5:2 ration for test purposes. Two types of compaction were performed i.e. manual compaction and vibration (vibrating table) for sample preparation to find out the effects of compacting efforts on CBR. Figure 9 below shows the prepared samples for Laboratory CBR test.

(a) (b)

Figure 9: Prepared samples for CBR Test.

Next, Soaked CBR tests were performed on the prepared samples and results are shown below.

Soaked CBR test on samples prepared from vibrating for 10 minutes and 15 minutes on the vibrating table and 56 blows manually compacted sample are shown below. Figure 10 and Figure 11 Shows the corresponding graphs.

Table 12: Summary of CBR Test Results (Using Vibrating Table, and Manual Compaction)

SUMMARY OF RESULTS (SOAKED CBR)

Specimen	Moisture Content (%)	Dry Unit Wt. (pcf)	Surcharge Weight, lbf	Pen. Stress (psi) at 0.1" **	Pen. Stress (psi) at 0.2" ***	Bearing Ratio at 0.1" **	Bearing Ratio at 0.2" ***	CBR Value (%)
10 min Vib.	10.79	120.93	10	735	1373	74	92	**74 / 92**
15 min Vib.	10.24	134.85	10	881	1901	88	127	**88 / 127**
56 blows	11.63	136.17	10	1120	2324	112	155	**112 / 155**

**Corrected, ***Corrected/ Uncorrected (for 0.2" or Maximum Penetration or Maximum Stress), Vib. Means Vibration on Vibrating Table.

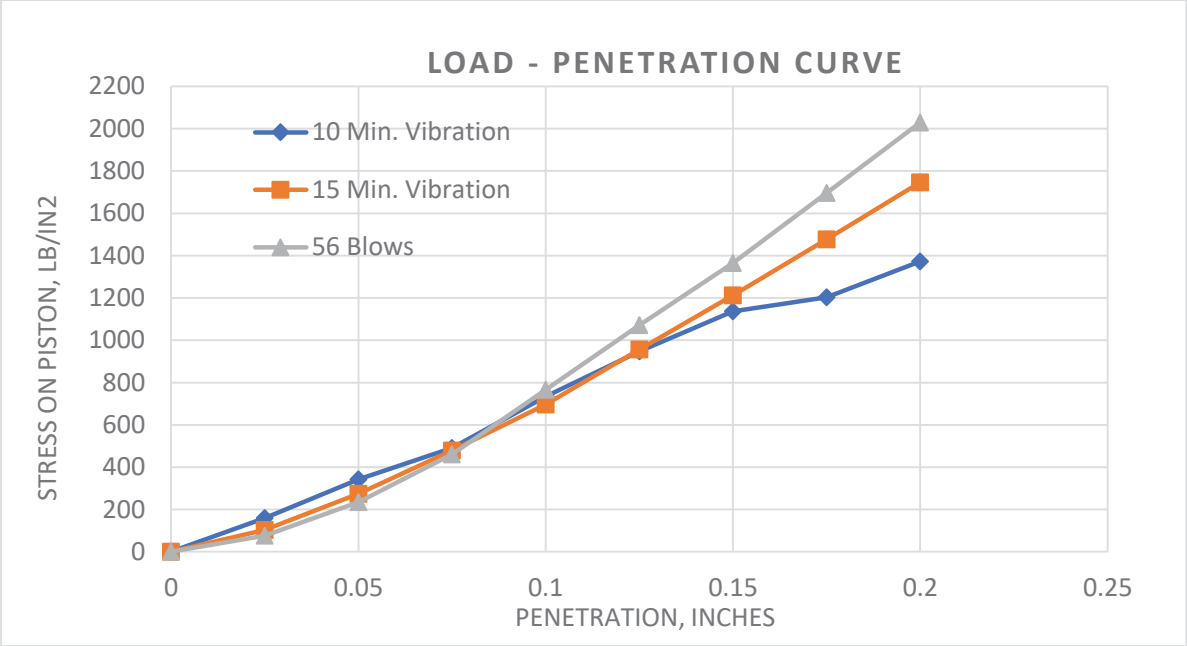


Figure 10: Stress-penetration Graph for soaked CBR test to identify effects of compacting force on density and CBR

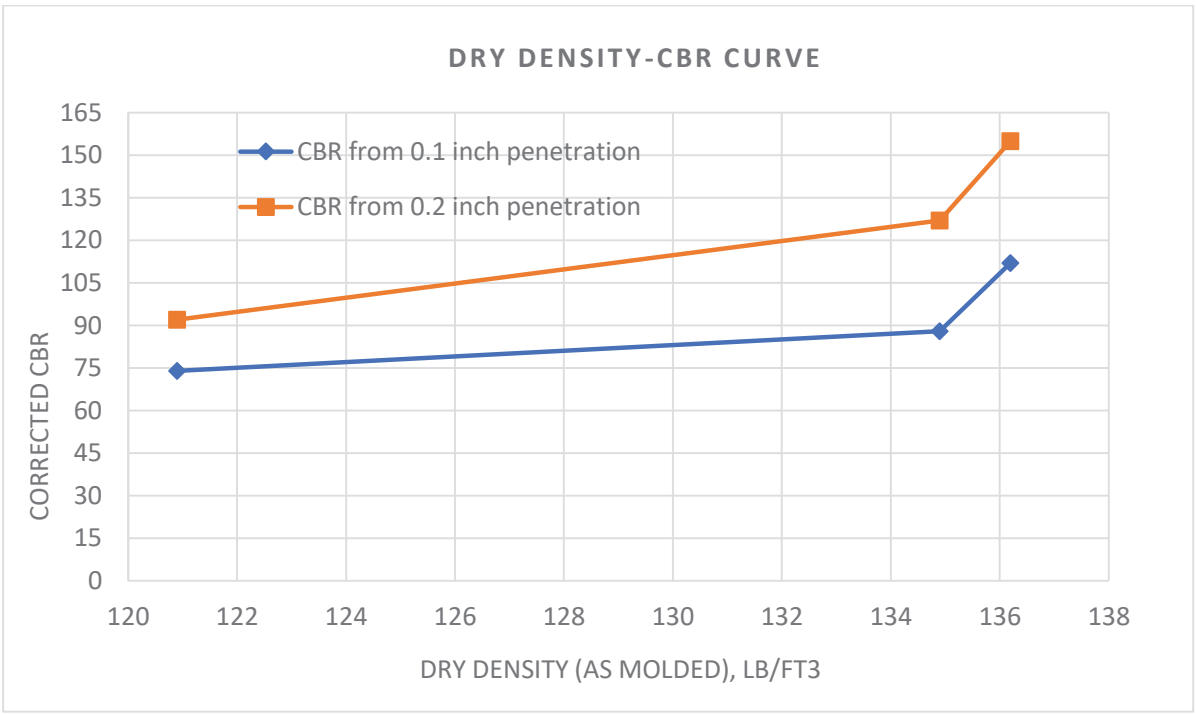


Figure 11: CBR- Density Graph for soaked CBR test to identify effects of compacting force on density and CBR

From the above results, it was evident that manual compaction produced denser sample compared to 10 minutes of vibration and slightly better compaction compared to 15 minutes of vibration. Based on this, samples were prepared using manual compacting effort at 10, 25 and 56 blows. Soaked CBR tests were performed on the prepared samples and the results are shown below. For 56 blows, a CBR value of 109% was found at 0.1" penetration and 147 % was found at 0.2" penetration. Figure 12 and Figure 13 Shows the corresponding graphs.

Table 13: Summary of CBR Test Results (Using Manual Compaction)

SUMMARY OF RESULTS (SOAKED CBR)								
Specimen	Moisture	Dry Unit	Surcharge	Pen. Stress (psi)	Pen. Stress (psi)	Bearing Ratio	Bearing Ratio	CBR
No. of Blows	Content (%)	Wt. (pcf)	Weight, lbf	at 0.1" **	at 0.2" ***	at 0.1" **	at 0.2" ***	Value (%)
10	9.80	128.59	10	482	1080	48	72	**48 / 72**
25	9.08	134.65	10	988	1841	99	123	**99 / 123**
56	9.19	137.82	10	1085	2212	109	147	**109 / 147**

**Corrected, ***Corrected/ Uncorrected (for 0.2" or Maximum Penetration or Maximum Stress)

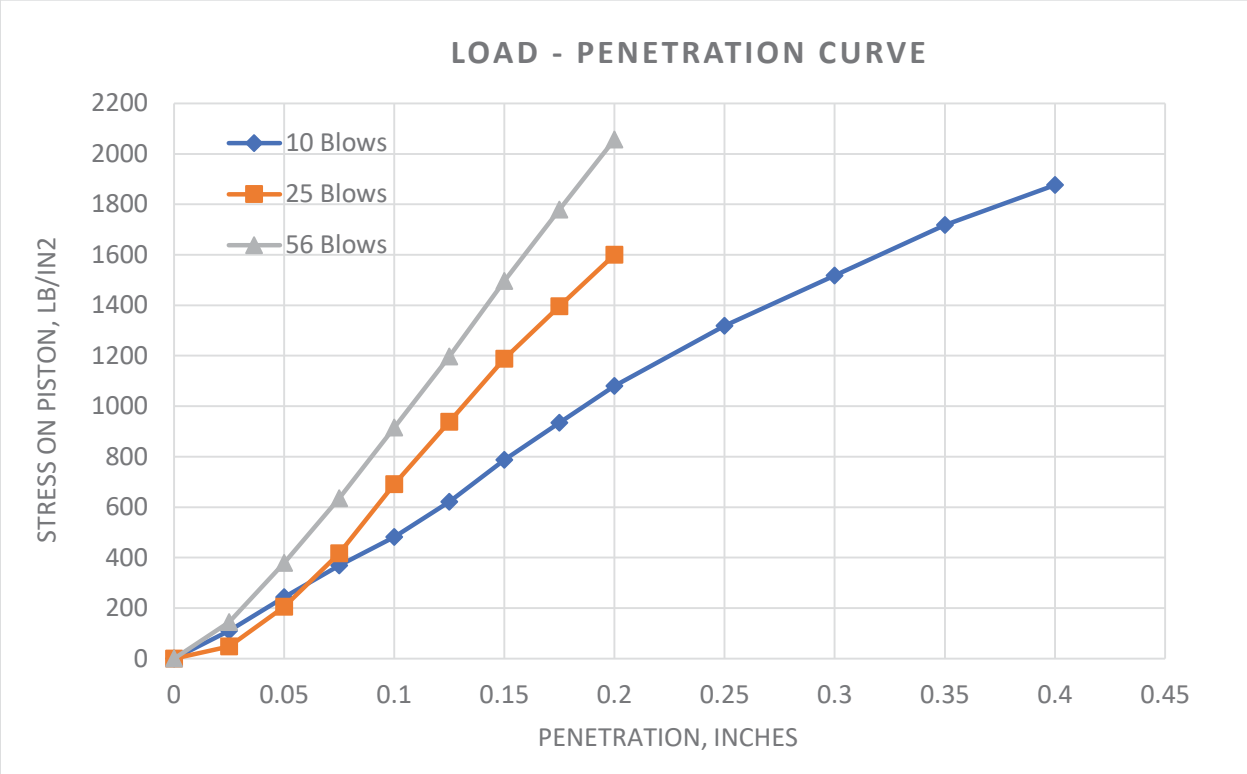


Figure 12: Stress-penetration Graph for soaked CBR test

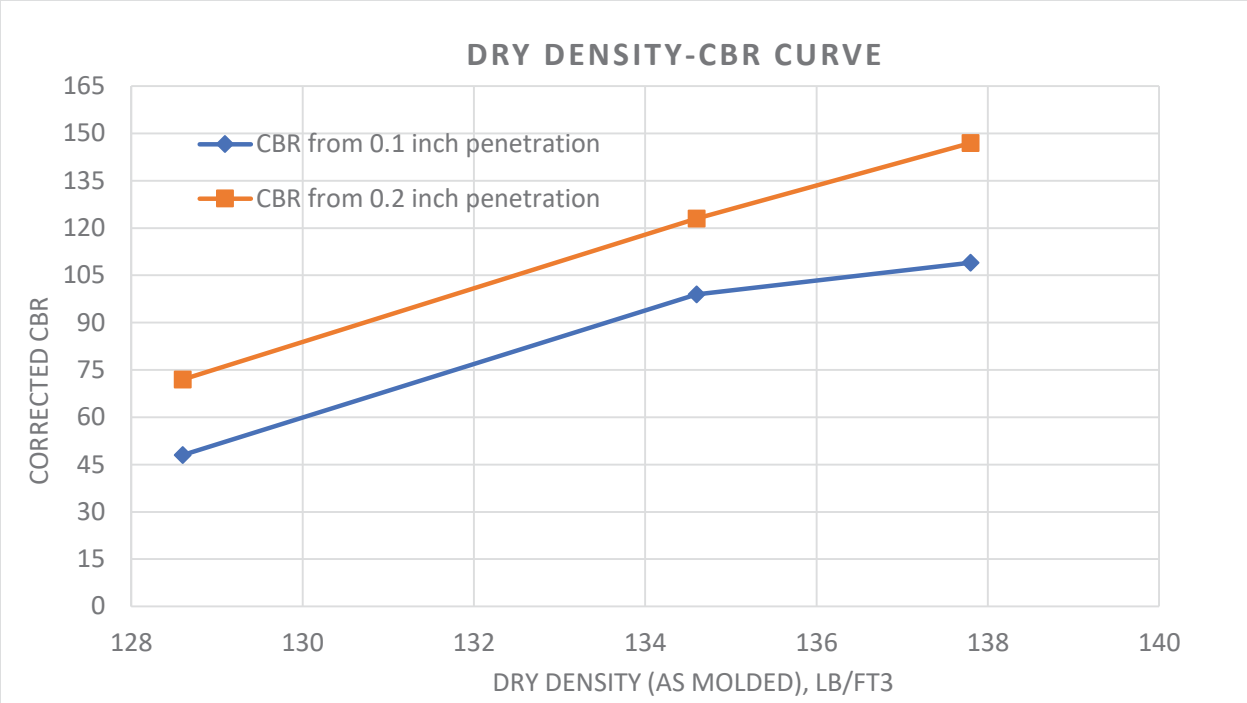


Figure 13: CBR- Density Graph for soaked CBR test

In order to correlate the laboratory CBR test results with field conditions, maximum density of RBCA was determined using ASTM D 4253 (Maximum Index Density/ Unit Weight of Soil). The modified proctor test (ASTM D 1557) is allowed for material having 30% or less by mass of their particle retained on the ¾" sieve, and in our case 79 % of the particles retained on ¾" sieve, thus ASTM D 4253 was used instead. In ASTM D4253, vibratory table is used to obtain maximum index density which is applicable to soils where 100 %, by dry mass, of soil particles pass a 3-in. (75-mm) sieve. Figure 14 shows the (a) vibrating table, (b) RBCA filled mold, (c) compaction in progress, and (d) the compacted RBCA sample.

(a)

(b)

(c)

(d)

Figure 14: Maximum Index Density test of RBCA- (a) vibrating table, (b) RBCA filled mold, (c) compaction in progress, and (d) the compacted RBCA sample.

The results of the Maximum Density test using only RBCA is shown below.

Table 14: Summary of Maximum Index Density of RBCA

Maximum Index Density/Unit Weight of Whole Rap aggregate (RBCA)		
Maximum Dry Density / Unit Weight	1.37	g/cm^3
	13.46	kN/m^3
	85.6	lb/ft^3

Also, in correlation with CBR test, maximum index density of RBCA mixed with local sand in the proportion of 5:2 was determined. The results are shown below.

Table 15: Summary of Maximum Index Density of RBCA and Sand Mix

Maximum Index Density/Unit Weight of (RBCA : Local Sand = **5 : 2**)		
Maximum Dry Density / Unit Weight	1.63	g/cm^3
	16.03	kN/m^3
	102	lb/ft^3

The maximum dry density achieved for only RBCA sample using ASTM D 4253 was 85.6 lb/ft^3 whereas the maximum dry density achieved for RBCA mixed with local sand in the ration (5:2) was 102 lb/ft^3. Both of them are quite below the density achieved in the laboratory CBR tests (136.17 ~137.82 lb/ft^3). The reason behind this is the mixture of two different aggregates i.e. stone chips and brick chips of two predominantly different sizes. Brick chips are lighter in weight compared to stone chips and comparatively larger sizes are brick chips in the mix. As a result, when CBR test sample is prepares using ¾" down size aggregates, larger proportion of stone chips are incorporated compared to when the whole RBCA sample is taken. For this reason, direct relationship between laboratory CBR and field density could not be established at this point. In order to overcome this difficulty, Field CBR tests were performed at the site of sample collection to get actual in-situ CBR values.

4.3 Field CBR Test

In order to evaluate the field CBR value where RAP (RBCA) material have been used to prepare sub-base/base, BUET Consultant Team visited LGED's road construction site at Manikganj on 19th February 2023. A field CBR test has been performed on that site. Figure 15 shows the pictures of BUET team performing filed CBR test at site.

Figure 15: Field CBR Test by BUET Team

However, due to limitation of testing arrangement at the site (unavailability of heavy truck to perform as support of CBR test equipment), the field CBR test could be performed up to 0.1 inch penetration only. Results of the field CBR test is shown below. The observed CBR value was 109 for 0.1 inch penetration as shown in Figure 16.

Table 16: Summary of Field CBR Test

SUMMARY OF TEST RESULTS								
Spot ID	Water Content (%)*	Dry Unit Wt.* pcf	Surcharge kg	Pen. Stress (psi) at 0.1 inch **	Pen. Stress (psi) at 0.2 inch ***	Bearing Ratio at 0.1 inch **	Bearing Ratio at 0.2 inch ***	CBR Value (%)
1	6.0	N/A	13.5	1087	--	109	--	**109 / --**
* Field Condition ** Corrected *** Corrected/Uncorrected (for 0.2" or Maximum Penetration or Maximum Stress)								

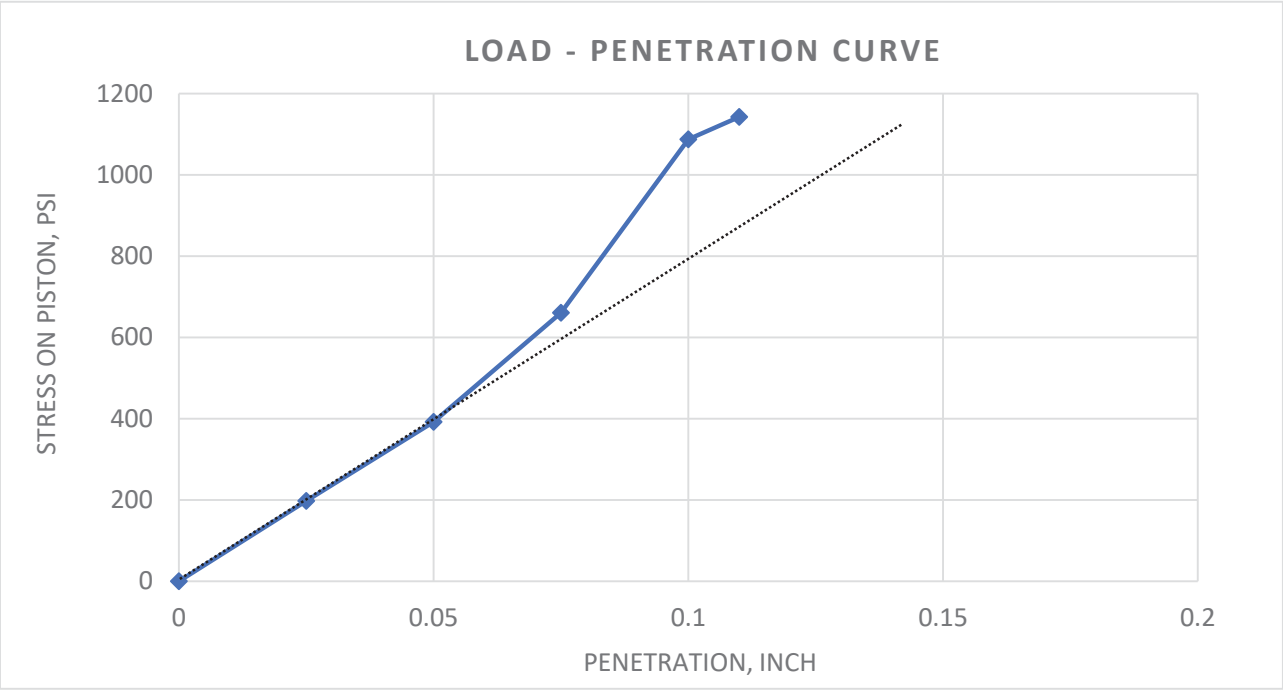


Figure 16: Stress-penetration Graph for Field CBR test.

5. FINDINGS AND RECOMMENDATION

The major findings of this research on the use of reclaimed bituminous coated aggregate (RBCA) obtained from reclaimed asphalt pavement are as follows-

- From laboratory CBR test, the soaked CBR value of RBCA (for 3/4" down portion) obtained was 109% at 0.1" penetration and 147 % at 0.2" penetration.
- Field CBR tests were performed for field verification of laboratory findings. Similar to lab results, a high CBR value of 109% was obtained for field compacted reclaimed bituminous coated aggregate at the test site in Manikganj. However, the field CBR test was performed in dry condition unlike the soaked condition used for laboratory CBR test.
- The field CBR test could not be performed beyond 0.1" penetration due to proper arrangement at the test site. In line with the findings from lab CBR test, it is expected that the CBR value corresponding to 0.2" penetration in field condition would also be higher than 0.1" penetration.
- Although it was intended to perform field density test along with field CBR tests, it wasn't possible to carry out due to the smaller thickness (less than 3 inch) of the compacted layer.

Limitation

Although high CBR values were obtained at laboratory soaked CBR tests (109% at 0.1" penetration & 147% at 0.2" penetration) as well as in field CBR test (109% at 0.1" penetration, which are quite higher than LGED's required CBR value for base (80%) as well as sub-base (30%), there still remains some concern for their use in flexible pavement layers-

- RBCA is not virgin/fresh material, rather it is a reclaimed material that has been under actions of environmental and man-made forces during their service life. Durability i.e. long term performance of such reclaimed material will remain a concern and needs to be evaluated further. Hence, it is necessary to perform Soundness Test, Durability Test and other relevant test as necessary to evaluate their long term performance.
- Another major issue is the hydraulic conductivity of such reclaimed materials which is important for sub-surface drainage of flexible pavement layers such as base and sub-base. Since certain portion of bitumen is mixed with the aggregate, it may hamper hydraulic conductivity of the compacted RBCA layer. During field conditions, it may not be possible to control uniform mixing of the bituminous portion throughout the layer, rather there is high probability of concentration of bituminous rich portion at certain parts of the compacted RBCA layer. This may lead to poor drainage at those locations. Hence Hydraulic Conductivity Test/Permeability Tests (and/or other relevant tests and practices) on aggregate would give invaluable insight regarding their hydraulic performance.

Recommendation

Considering satisfactory CBR value from laboratory and from field test, it can be recommended that recycled material from LGED's Road can be used as Sub-Base material as well as Base material. However, necessary durability tests and hydraulic conductivity tests are needed to be done to further assess the long term performance of these recycled materials.

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APPENDIX

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

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TRANSPORTATION ENGINEERING LABORATORY

BRTC Bureau of Research Testing & Consultation

BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

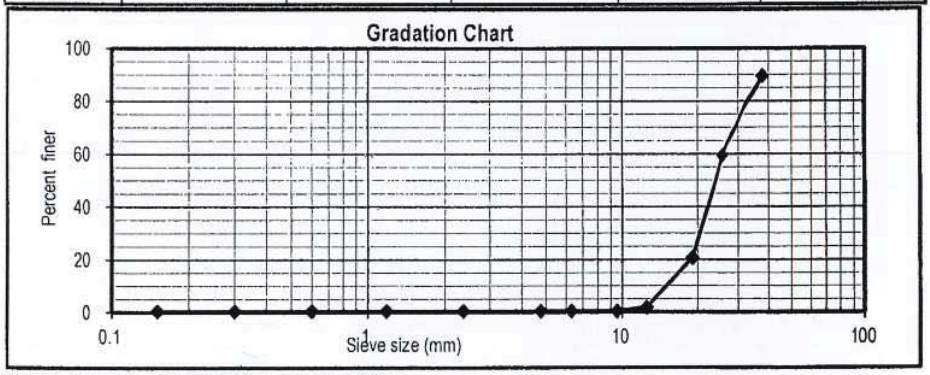
Sample : Mix of Stone & Brick Chips Sample ID: (Combined aggregate)

Test : Gradation of Aggregates [ASTM C136]

Date of Test : 22/6/2022

TEST REPORT

Sieve Size	Material Retained	Percent of Material Retained	Cumulative % Retained	Percent Finer	Fineness Modulus
mm	gm	%	%	%	
37.5	1581.0	11	11	90	
25.4	4510.0	30	41	59	
19.05	5816.0	39	79	21	
12.5	2820.0	19	98	2	
9.5	216.0	1	100	0	
6.3	0.0	0	100	0	
4.75	0.0	0	100	0	
2.36	0.0	0	100	0	**7.87 (Seven point eight seven)**
1.18	0.0	0	100	0	
0.6	0.0	0	100	0	
0.3	0.0	0	100	0	
0.15	0.0	0	100	0	
0.075	0.0	0	100	0	
Pan	57.0	0	100		
Total	15000				



Notes: Samples were received in sealed condition.

Countersigned by:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed by:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Brick Chips Sample ID: (RAP aggregate greater than 1" Size)

Test : Specific Gravity and Water Absorption (ASTM C127)

Date of Test : 4/7/2022

TEST REPORT

Sample Designation	Weight of oven dry sample (gm)	Weight of SSD sample (gm)	Weight of saturated sample in water (gm)	Bulk Specific Gravity (OD) (Relative Density)	Absorption Capacity (%)
Brick Chips	2047.4	2221.2	1168.3	1.94	**8.50**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 1 inch Size)

Test : Specific Gravity and Water Absorption (ASTM C127)

Date of Test : 25/10/2022

TEST REPORT

Sample Designation	Weight of oven dry sample (gm)	Weight of SSD sample (gm)	Weight of saturated sample in water (gm)	Bulk Specific Gravity (OD) (Relative Density)	Absorption Capacity (%)
Mix of Stone & Brick Chips	3017.3	3090.8	1854.2	2.44	**2.40**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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DEPARTMENT OF CIVIL ENGINEERING

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 3/4 inch Size)

Test : Specific Gravity and Water Absorption (ASTM C127)

Date of Test : 1/11/2022

TEST REPORT

Sample Designation	Weight of oven dry sample (gm)	Weight of SSD sample (gm)	Weight of saturated sample in water (gm)	Bulk Specific Gravity (OD) (Relative Density)	Absorption Capacity (%)
Mix of Stone & Brick Chips	3013.3	3081.8	1850.2	2.45	**2.30**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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DEPARTMENT OF CIVIL ENGINEERING

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Brick Chips Sample ID: (Greater than 1 inch Size)

Test : Moisture Content Test [ASTM C 566]

Date of Test : 22/6/2022

TEST REPORT

MOISTURE CONTENT IN AGGREGATE (%) =	3.8 Percent

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

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TRANSPORTATION ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 1 inch Size)

Test : Moisture Content Test [ASTM C 566]

Date of Test : 22/6/2022

TEST REPORT

MOISTURE CONTENT IN AGGREGATE (%) =	1.2 Percent

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

for **Dr. A. B. M. Badruzzaman**
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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TRANSPORTATION ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD.
Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 1 inch Size)

Test : Unit Weight/Bulk Density & Voids in Aggregate [ASTM C 29]

Date of Test : 22/10/2022

TEST REPORT

Unit weight/Bulk Density (kg/m3) =	**1550 kg/ m3**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD.
Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 3/4 inch Size)

Test : Unit Weight/Bulk Density & Voids in Aggregate [ASTM C 29]

Date of Test : 6/11/2022

TEST REPORT

Unit weight/Bulk Density (kg/m3) =	**1550 kg/ m3**

Voids in Aggregate (%) =	**37**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**
Sent by : Upazila Engineer, Saturia, Manikganj.
Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022
Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.
Sample : Brick Chips Sample ID: (Greater than 1 inch Size)
Test : Los Angeles Abrasion Value [ASTM C-535-03]
Date of Test : 22/6/2022

TEST REPORT

Type of Aggregate	Grading Type	Total Weight of Aggregate	Aggregate Passing 1.70 mm Sieve	Los Angeles Abrasion Value
		gm	gm	%
Brick Chips	2	10055	2857	**28**

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 1 inch Size)

Test : Los Angeles Abrasion Value [ASTM C-131]

Date of Test : 22/6/2022

TEST REPORT

Type of Aggregate	Grading Type	Total Weight of Aggregate	Aggregate Passing 1.70 mm Sieve	Los Angeles Abrasion Value
		gm	gm	%
Mix of Stone & Brick Chips	B	5000	952	**19**

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

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BRTC Bureau of Research Testing & Consultation

TRANSPORTATION ENGINEERING LABORATORY

BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Brick Chips Sample ID: (Greater than 1 inch Size)

Test : Aggregate Crushing Value [BS 812 (part 3) 1975]

Date of Test : 22/6/2022

TEST REPORT

Type of Aggregate	Sample Size	Weight of sample (Surface Dry)	Weight of material passing 5.0 mm sieve	Aggregate Crushing Value (ACV)
		(gm)	(gm)	%
Brick Chips	28 mm to 20 mm	2017	697	**35**

Notes: Samples were received in sealed condition.

The ACV test is not appropriate for this weak aggregate sample. It is recommended to perform 10% fine value (TFV) test to know the crushing properties of the sample.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28/06/22
28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 1 inch Size)

Test : Aggregate Crushing Value [BS 812 (part 3) 1975]

Date of Test : 22/6/2022

TEST REPORT

Type of Aggregate	Sample Size	Weight of sample (Surface Dry)	Weight of material passing 5.0 mm sieve	Aggregate Crushing Value (ACV)
		(gm)	(gm)	%
Mix of Stone & Brick Chips	28 mm to 20 mm	2789	507	**18**

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Brick Chips Sample ID: (Greater than 1 inch Size)

Test : Aggregate Impact Value [BS 812 (part 3) 1975]

Date of Test : 22/6/2022

TEST REPORT

Type of Aggregate	Sample Size	Weight of sample (Surface Dry)	Weight of material passing 5.0 mm sieve	Aggregate Impact Value (AIV)
		(gm)	(gm)	%
Brick Chips	28 mm to 20 mm	252	85	**34**

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone & Brick Chips Sample ID: (Less than 1 inch Size)

Test : Aggregate Impact Value [BS 812 (part 3) 1975]

Date of Test : 22/6/2022

TEST REPORT

Type of Aggregate	Sample Size	Weight of sample (Surface Dry) (gm)	Weight of material passing 2.36 mm sieve (gm)	Aggregate Impact Value (AIV) %
Mix of Stone & Brick Chips	14 mm to 10 mm	359	54	15

Notes: Samples were received in sealed condition.

Countersigned *by*:

28/6/22

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

28 June 2022

Dr. Md. Mizanur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Local Sand Sample ID: Local Sand used for CBR Test

Test : Specific Gravity and Water Absorption (ASTM C128-01)

Date of Test : 23/11/2022

TEST REPORT

Sample Designation	Weight of oven dry sample (gm)	Weight of SSD sample (gm)	Weight of saturated sample in water (gm)	Bulk Specific Gravity (OD) (Relative Density)	Absorption Capacity (%)
Local Sand	494.1	500.0	310.5	**2.61**	**1.20**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22-Jan-23

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD.
Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Local Sand Sample ID: Local Sand used for CBR Test

Test : Unit Weight/Bulk Density & Voids in Aggregate [ASTM C 29]

Date of Test : 24/11/2022

TEST REPORT

Unit weight/Bulk Density (kg/m3) =	**1540 kg/ m3**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023
Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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BRTC No.	:	**1102-64766 /21-22/CE ; Dt: 22/6/2022**
Sent by	:	Upazila Engineer, Saturia, Manikganj.
Ref. No.	:	CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022
Project	:	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.
Sample	:	Mix of Stone, Brick Chips and Local Sand — Sample ID: Mix of 75% RAP Aggregate (3/4" down) & 25% Local Sand
Test	:	Unit Weight/Bulk Density & Voids in Aggregate [ASTM C 29]
Date of Test	:	6/12/2022

TEST REPORT

Unit weight/Bulk Density (kg/m3) =	**1990 kg/ m3**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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BRTC Bureau of Research, Testing & Consultation

BRTC No.	:	**1102-64766 /21-22/CE ; Dt: 22/6/2022**
Sent by	:	Upazila Engineer, Saturia, Manikganj.
Ref. No.	:	CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022
Project	:	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.
Sample	:	Mix of Stone, Brick Chips and Local Sand — Sample ID: Mix of 67 % RAP Aggregate (3/4" down) & 33 % Local Sand
Test	:	Unit Weight/Bulk Density & Voids in Aggregate [ASTM C 29]
Date of Test	:	6/12/2022

TEST REPORT

Unit weight/Bulk Density (kg/m3) =	**2010 kg/ m3**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023
Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

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TRANSPORTATION ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

BRTC No. : **1102-64766 /21-22/CE ; Dt: 22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22.; Dt: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone, Brick Chips and Local Sand

Sample ID: Mix of 71 % RAP Aggregate (All Size) and 29 % Local Sand (Ratio = 5:2).

Test : Unit Weight/Bulk Density & Voids in Aggregate [ASTM C 29]

Date of Test : 6/12/2022

TEST REPORT

Unit weight/Bulk Density (kg/m3) =	**2010 kg/ m3**

Notes: Samples were received in sealed condition.

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

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TRANSPORTATION ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

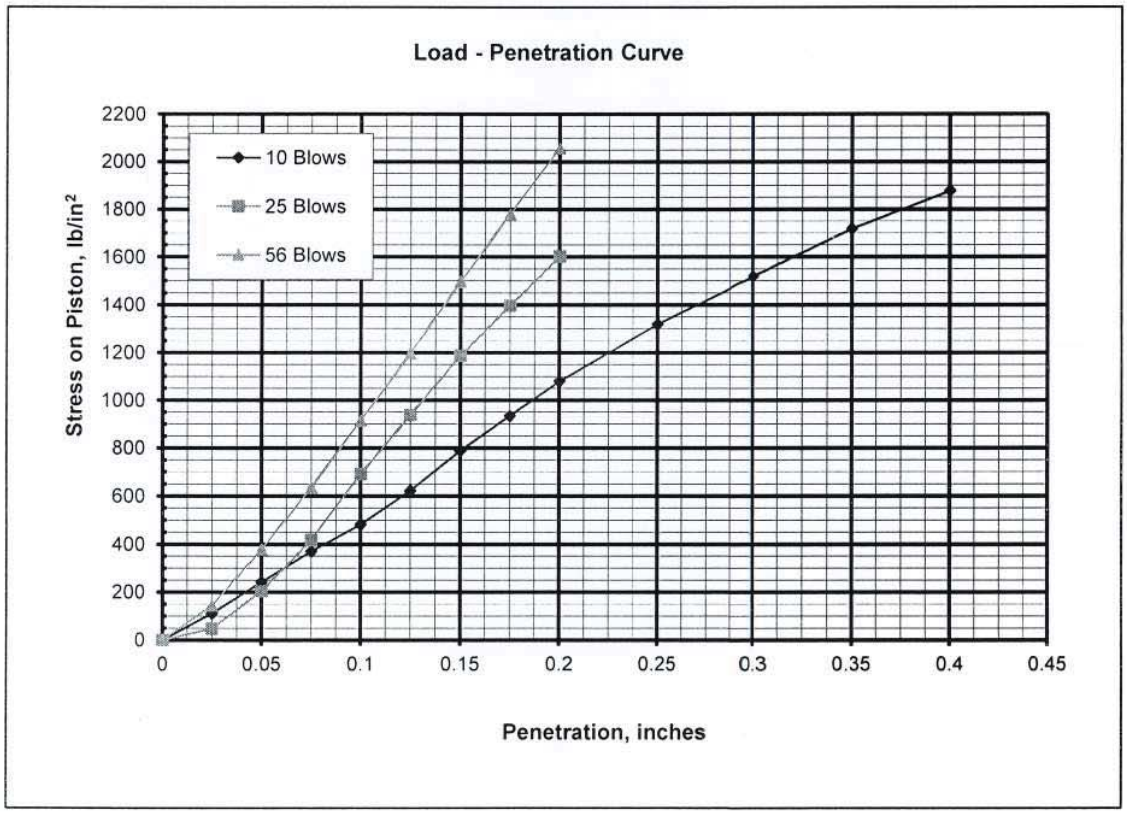
Laboratory California Bearing Ratio (CBR) Test

BRTC No :	**1102-64766/21-22/CE**	**Date:**	22/06/2022
Client :	Upazila Engineer, Saturia, Manikganj.		
Reference:	CE File No. 5410; Contract Date 10.05.22.	**Date:**	23/03/2022
Project :	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.	**Sample No:**	**RAP Aggregate (3/4" down) : Local Sand = 5 : 2**
Sample Description :	Mix of Stone, Brick Chips and Local Sand	**Depth:**	---
CBR Test Method:	ASTM D1883, AASHTO T 193	**Date of Test:**	Start: 11/12/2022

SUMMARY OF RESULTS (SOAKED CBR)

Specimen No. of Blows	Moisture Content (%)	Dry Unit Wt. (pcf)	Surcharge Weight, lbf	Pen. Stress (psi) at 0.1 inch **	Pen. Stress (psi) at 0.2 inch ***	Bearing Ratio at 0.1 inch **	Bearing Ratio at 0.2 inch ***	CBR Value (%)
10	9.80	128.59	10	482	1080	48	72	**48 / 72**
25	9.08	134.65	10	988	1841	99	123	**99 / 123**
56	9.19	137.82	10	1085	2212	109	147	**109 / 147**

**Corrected, ***Corrected/ Uncorrected (for 0.2" or Maximum Penetration or Maximum Stress)



Countersigned *by* :

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by* :

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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TRANSPORTATION ENGINEERING LABORATORY

BRTC Bureau of Research Testing & Consultation

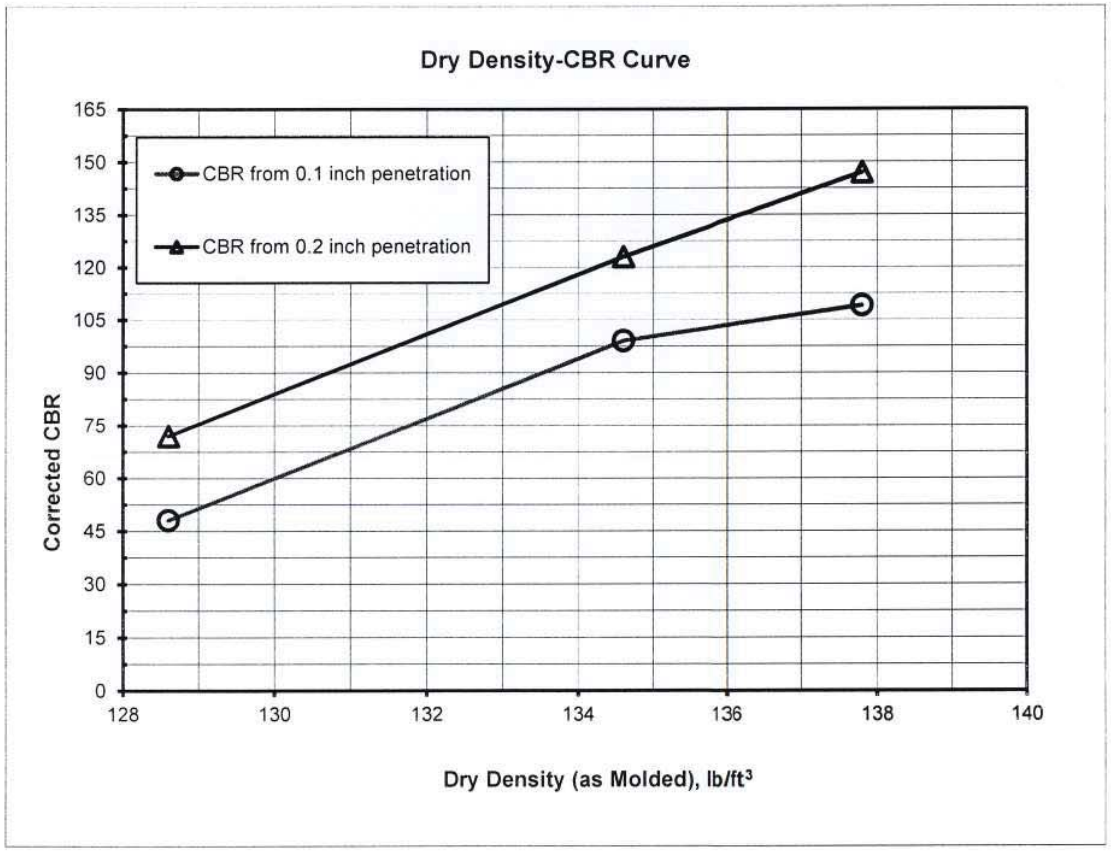
Laboratory California Bearing Ratio (CBR) Test

BRTC No :	**1102-64766/21-22/CE**	**Date:**	22/06/2022
Client :	Upazila Engineer, Saturia, Manikganj.		
Reference:	CE File No. 5410; Contract Date 10.05.22.	**Date:**	23/03/2022
Project :	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.	**Sample No:**	**RAP Aggregate (3/4" down) : Local Sand = 5 : 2**
Sample Description :	Mix of Stone, Brick Chips and Local Sand	**Depth:**	---
CBR Test Method:	ASTM D1883, AASHTO T 193	**Date of Test:**	Start: 11/12/2022

SUMMARY OF RESULTS (SOAKED CBR)

Specimen No. of Blows	Moisture Content (%)	Dry Unit Wt. (pcf)	Surcharge Weight, lbf	Pen. Stress (psi) at 0.1 inch **	Pen. Stress (psi) at 0.2 inch ***	Bearing Ratio at 0.1 inch **	Bearing Ratio at 0.2 inch ***	CBR Value (%)
10	9.80	128.59	10	482	1080	48	72	**48 / 72**
25	9.08	134.65	10	988	1841	99	123	**99 / 123**
56	9.19	137.82	10	1085	2212	109	147	**109 / 147**

**Corrected, ***Corrected/ Uncorrected (for 0.2" or Maximum Penetration or Maximum Stress)



Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

Mobile 01819557964; PABX: 55167100 Ext: 7226
http://brtc/ce.buet.ac.bd/#/home

BRTC Bureau of Research, Testing & Consultation

TRANSPORTATION ENGINEERING LABORATORY

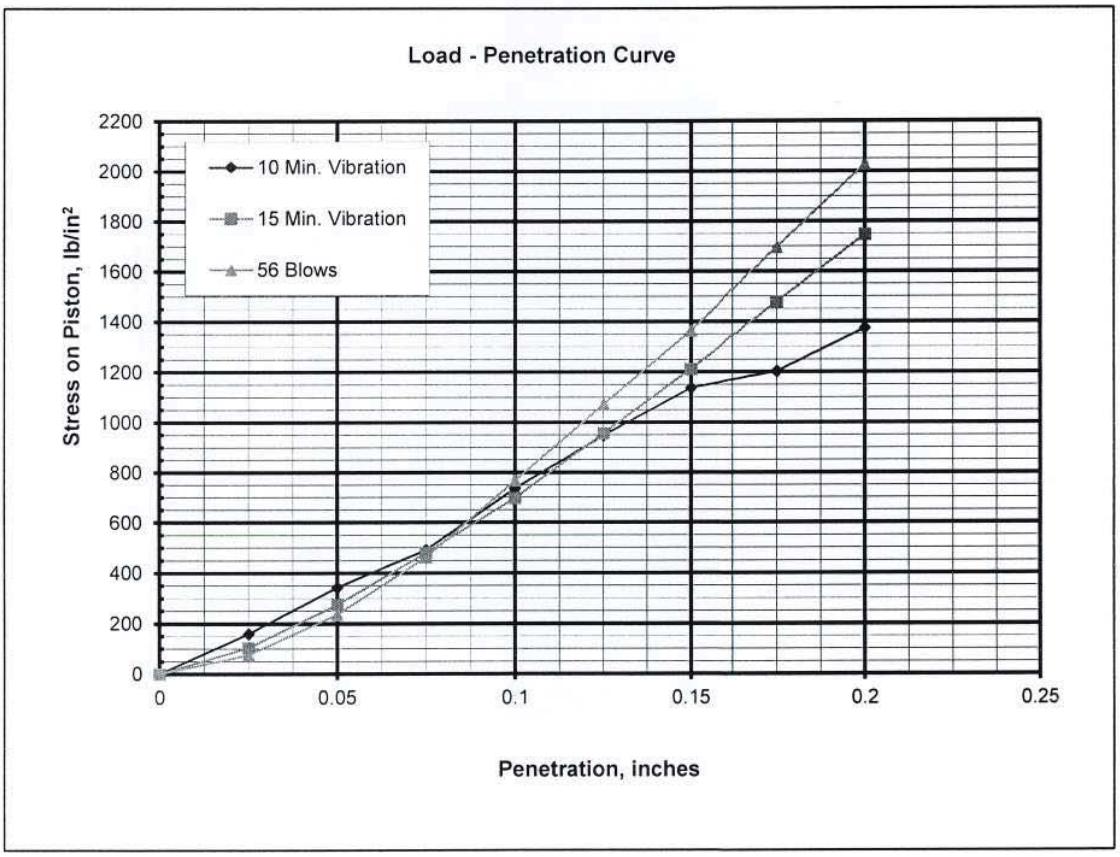
Laboratory California Bearing Ratio (CBR) Test

BRTC No :	**1102-64766/21-22/CE**	**Date:**	22/06/2022
Client :	Upazila Engineer, Saturia, Manikganj.		
Reference:	CE File No. 5410; Contract Date 10.05.22.	**Date:**	23/03/2022
Project :	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.	**Sample No:**	**RAP Aggregate (3/4" down) : Local Sand = 5 : 2**
Sample Description :	Mix of Stone, Brick Chips and Local Sand	**Depth:**	---
CBR Test Method:	ASTM D1883, AASHTO T 193	**Date of Test:**	Start: 15/12/2022

SUMMARY OF RESULTS (SOAKED CBR)

Specimen No. of Blows	Moisture Content (%)	Dry Unit Wt. (pcf)	Surcharge Weight, lbf	Pen. Stress (psi) at 0.1 inch **	Pen. Stress (psi) at 0.2 inch ***	Bearing Ratio at 0.1 inch **	Bearing Ratio at 0.2 inch ***	CBR Value (%)
10 min Vib.	10.79	120.93	10	735	1373	74	92	**74 / 92**
15 min Vib.	10.24	134.85	10	881	1901	88	127	**88 / 127**
56	11.63	136.17	10	1120	2324	112	155	**112 / 155**

**Corrected, ***Corrected/ Uncorrected (for 0.2" or Maximum Penetration or Maximum Stress), Vib. means Vibration on Vibrating Table.



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Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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Laboratory California Bearing Ratio (CBR) Test

BRTC No :	**1102-64766/21-22/CE**	**Date:**	22/06/2022
Client :	Upazila Engineer, Saturia, Manikganj.		
Reference:	CE File No. 5410; Contract Date 10.05.22.	**Date:**	23/03/2022
Project :	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.	**Sample No:**	**RAP Aggregate (3/4" down) : Local Sand = 5 : 2**
Sample Description :	Mix of Stone, Brick Chips and Local Sand	**Depth:**	---
CBR Test Method:	ASTM D1883, AASHTO T 193	**Date of Test:**	Start: 15/12/2022

SUMMARY OF RESULTS (SOAKED CBR)

Specimen No. of Blows	Moisture Content (%)	Dry Unit Wt. (pcf)	Surcharge Weight, lbf	Pen. Stress (psi) at 0.1 inch **	Pen. Stress (psi) at 0.2 inch ***	Bearing Ratio at 0.1 inch **	Bearing Ratio at 0.2 inch ***	CBR Value (%)
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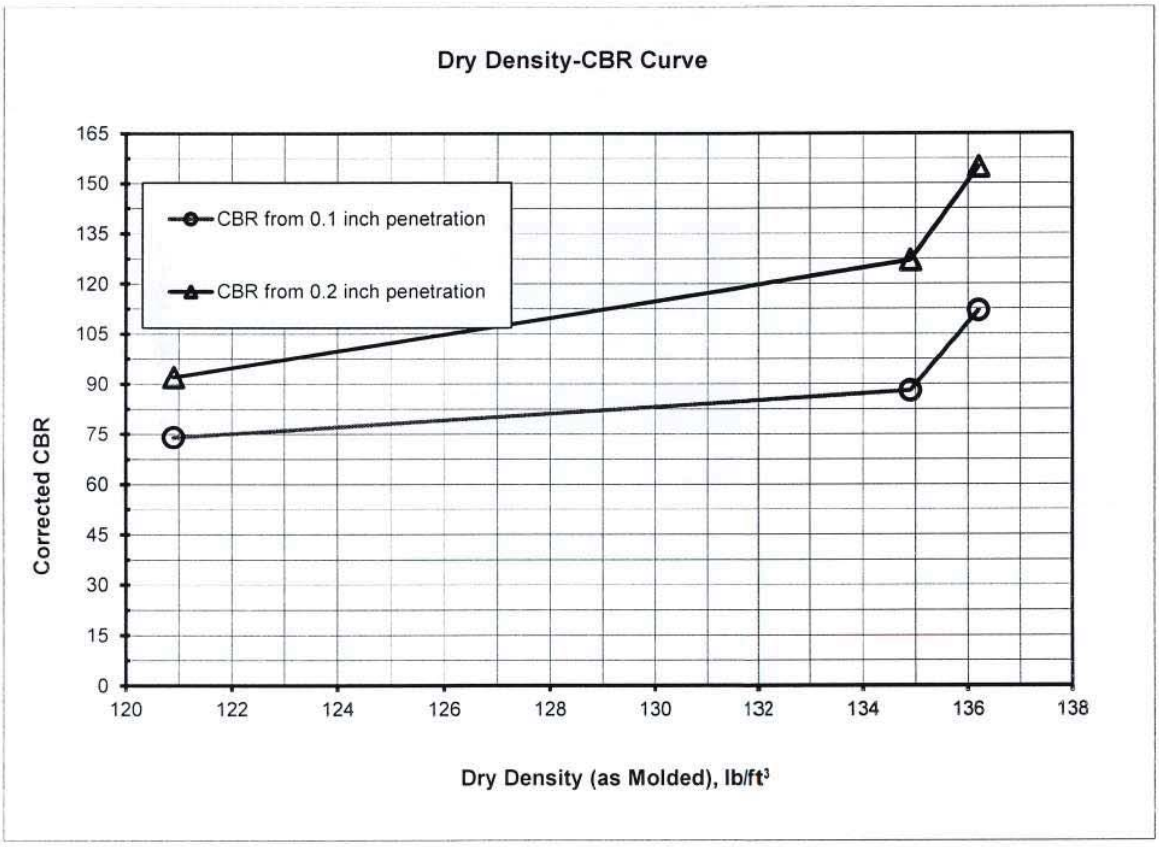

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Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by* :

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

Mobile: 01819557964; PABX: 55167228-57 Ext. 7226; http://brtc.ce.buet.ac.bd/#/home

GEOTECHNICAL ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

MAXIMUM INDEX DENSITY/UNIT WEIGHT OF SOIL

BRTC No.	:	**1102-64766/21-22/CE**	Date:	**22/6/2022**
Sent by	:	Upazila Engineer, Saturia, Manikganj.		
Ref. No.	:	CE File No. 5410; Contract Date 10.05.22.	Date:	23/3/2022
Project	:	RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.		
Sample	:	Mix of Stone & Brick Chips	Sample ID :	Whole RAP Aggregate.
Standard	:	**ASTM D4253**		
Test Date	:	**14/11/2022**		

TEST REPORT

Maximum Dry Density / Unit Weight	1.37	g/cm^3
	13.46	kN/m^3
	85.6	lb/ft^3

Countersigned *by*:

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by*:

22 January 2023

Dr. M. Neaz Murshed
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

Mobile: 01819557964; PABX: 55167228-57 Ext. 7226; http://brtc.ce.buet.ac.bd/#/home

GEOTECHNICAL ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

MAXIMUM INDEX DENSITY/UNIT WEIGHT OF SOIL

BRTC No. : **1102-64766/21-22/CE** Date: **22/6/2022**

Sent by : Upazila Engineer, Saturia, Manikganj.

Ref. No. : CE File No. 5410; Contract Date 10.05.22. Date: 23/3/2022

Project : RESEARCH ON THE REUSE OF RECLAIMED CONSTRUCTION MATERIALS IN LGED'S ROAD. Location of Sample: Daragram GC to Bangladesh Hat GC via Hargoj & Chartilli Bazar. ID: 356702004.

Sample : Mix of Stone, Brick Chips and Local Sand Sample ID : Mix of 71 % RAP Aggregate (All Size) and 29 % Local Sand (Ratio = 5:2).

Standard : **ASTM D4253**

Test Date : **1/1/2023**

TEST REPORT

Maximum Dry Density / Unit Weight	1.63	g/cm^3
	16.03	kN/m^3
	102	lb/ft^3

Countersigned *by* :

Dr. A. B. M. Badruzzaman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Test Performed *by* :

22 January 2023

Dr. M. Neaz Murshed
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Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

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