Scarcity of Road Construction Materials in Bangladesh: Exploring Pavement Recycling Option as a Solution

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***Abstract*— In most of the underdeveloped and developing countries, every year considerable kilometers of new roads are constructed along with the periodical maintenance and rehabilitation of the existing road network. All these construction and maintenance programs require a great deal of construction materials. Again in many countries, limited sources of good quality materials also hinder road construction. Every year, millions of tons of mineral aggregates are imported from abroad for the purpose of special and large scale highway construction and maintenance. For general purpose road construction and maintenance work, locally occurring rocks, gravels and sands are used, but the good quality resources are decreasing but aggregate demand is increasing. Recycling of pavement has not yet been popular in most of the underdeveloped and developing countries and so they depend mostly on imported materials for road construction and maintenance though use of recycled materials have been performed in pavement constructions for many decades in the developed counties. This paper presents a brief overview of in-place recycling-repaving process of aggregates used in road reconstruction and maintenance in Bangladesh which can be an easy solution of ongoing and future material demand.**

***Index Terms*— In-place recycling-repaving, periodical maintenance, recycled materials, rehabilitation**

I. Introduction

Bangladesh, being a developing country from underdeveloped country, has increasing amount of infrastructures for ever-growing populations which results in critical highway system to meeting the mobility and economic needs of local communities, regions, and the nation. In view of geological and geomorphic features, the country lacks good qualities and adequate quantities of readily available road construction materials, especially course aggregates. The present trend of road construction in Bangladesh is almost 95% bituminous pavement [1]. The size of the major road network in Bangladesh has grown from 2,500 kms to the present network of 20,866.36 kms [2]. The upcoming projects all over the country are about 173 [3]. Therefore the scarcity of the aggregates used for pavement construction will be on demand in near future. But most of the source of aggregates in Bangladesh are being drained and emptied. So to fill this scarcity aggregates are being exported or recycled. In Bangladesh, Rocks are available in the border areas but the deposits are too scant and scattered to be economical to exploit. It's also available in river channels where the monsoon rains annually replenish the deposits with boulders and gravels washed downstream into Bangladesh.

Bangladesh has limited source of good quality aggregates. Every year million tons of mineral aggregates are imported from abroad for special and large scale highway construction and maintenance. It is costlier for small scale projects but high quality can be ensured for construction works. In place recycling of roadway materials is cost effective and environmentally friendly, resulting in reduced energy consumption, greenhouse gas emissions and waste material disposal [4]. However, the asphalt binder in recycled pavement material and fines in road surface gravel may adversely affect the strength, stiffness, and plastic deformation of recycled materials used as base course [5]. Existing deteriorated asphalt surface can be pulverized and mixed with the underlying materials to form a new recycled base layer known as recycled pavement material (RPM). The depth of pulverization typically ranges from 100 to 300mm and includes some or all of the existing base course and even part of the underlying subgrade [6]. Similarly, when upgrading unpaved gravel roads to a roadway with a paved surface, the existing road surface gravel can be recycled to form a base or sub-base.

II. Problem Statement and Objectives

A. Problem Statement

Recycling of existing pavement materials during rehabilitation and reconstruction of roads can provide more sustainable alternative to conventional methods such as full or partial removal and replacement of the pavement materials. Use of recycled materials for the

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construction of roads, pavements, footpaths is increasing all over the world due to their cost effectiveness and environmentally sustainable aspects. The most common recycled materials used in different layers of flexible pavements are Reclaimed Asphalt Pavement (RAP) [7-9], Recycled Concrete Aggregate (RCA) [10-12], recycled construction and demolition waste (RCDW) [13], recycled bricks [14, 15], recycled glass [16-21] and fly-ash [22].

B. Objectives

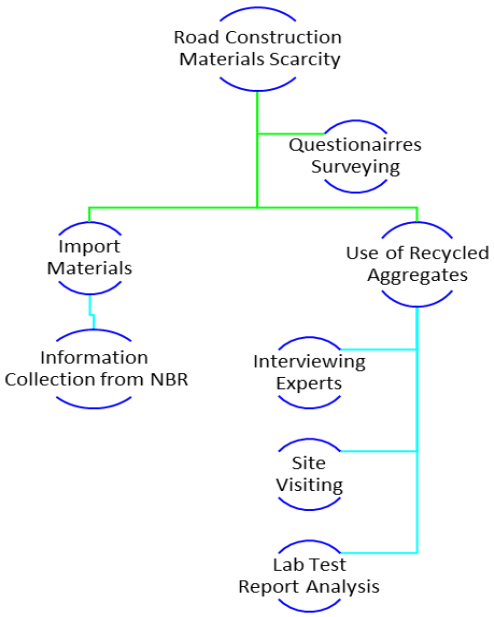
The purpose of this paper is to evaluate the feasible use of imported or RAP aggregate in pavement applications, mainly as base and sub-base material in roads. The main objectives of this research are -

1. To analysis the situation of aggregates in Bangladesh.
2. To identify the solution to meet up the scarcity of aggregates in Bangladesh.
3. To experience real life recycling projects
4. To analysis the recycling aggregates and compare with specifications.

III. Methodology

The research was carried out in three parts. At first a set of questionnaires were conducted with different persons and students transport engineers to analyze the perspectives, In the second part, data were collected by field surveying, testing the samples, by interviewing the project experts and collecting import data from NBR. Finally last part includes the collected data analysis.

A. Flowchart of Whole Thesis Work



B. Data Collection Method

In this research, data had been collected in three ways: site investigation and lab test, filling questionnaires, information collection from national board of revenue.

1. Information of National Board of Revenue

Information from NBR was required to identify the import materials, quality and cost situation worldwide and to validate it. The economical perspective could also be explained with that data.

2. Questionnaire Survey

Questionnaire survey is the most common tool to investigate the people thinking. This survey was conducted with peoples with knowledge and own perception. Mainly it covered the views of road engineers and students of transportation engineering. Self-rating questionnaires were used as a data collection method in this research. This survey was directed at benchmarking current state-of-the-practice in usage and quantification of preservation and maintenance practices in terms of environmental performance utilized by the respondent's agency. Sustainability in the survey refers to promoting environmentally friendly practices that also provide technical and economic benefits.

3. Site Investigation

At Gaibandha, the reconstruction work of N5 road was on process that time. So, investigation site had been selected at three work places of Gaibandha. Site investigation covers the important information of location, type of vehicles. Detailed photographs were also taken. The existing road condition was inspected as well as some lab test was also conducted with the existing materials to know about the current properties of materials.

4. Lab Test [23]

Lab test includes Aggregate Crushing Value test (ACV), Ten Percent Fines Value Test (TFV), Absorption Test, Density Test, Crushing Strength of Brick, Gradation Test, and Fineness Modulus of Sand test.

IV. Results and Discussions

This research work is aimed to investigate the availability of road construction materials and to meet up the demand of good quality road construction materials, use of recycled aggregates are newly introduced in Bangladesh. For the first time, recycled aggregates are used in road maintenance project named "Emergency repair of N5 highway under periodic maintenance program (PMP-Major) by cutting, excavation and re-compact of bituminous layers and followed by DBS wearing course at different Km of Gaibandha portion under road division, Gaibandha during the year 2017-18" governance by the Roads and Highway Department, Bangladesh. Information about yearly imported aggregates are also collected to verify the quantity and price amount of aggregates also.

A. Information Collected from NBR

The National Board of Revenue (NBR) is the central authority for tax administration in Bangladesh. It is under the Internal Resource Division of Ministry of Finance. NBR gathers information related to value added tax (VAT) and customs duties and undertakes data collection and investigation on evasion of duties and taxes. From NBR, the data of importing quantity and price of materials of pavement were collected.

1. HS Codes of Imported Aggregates

The information about the provided HS codes for both imported aggregates and bitumen that were requested to NBR office for the thesis, was approved by the Chairman of NBR and delivered by Mr. Ruhul Amin, an officer of Central Intelligence Service (CIS) Cell, NBR, Bangladesh. The HS codes were-

TABLE I. HS CODES FOR IMPORTED AGGREGATES

HS Code	Harmonized Description
2517.10.90	Broken or crushed stone
2516.90.10	Boulder stone
2516.90.90	Other than Boulder stone
2516.20.00	Sandstone

2. Quantity of aggregates imported from 2015 to 2017

TABLE II. QUANTITY OF IMPORTED AGGREGATES (METRIC TONS)

HS Code	2015-16	2016-17	2017-17
2517.10.90	1,296,648	7,264,835	9,163,223.5
2516.90.10	1,187,125	2,100,670.5	3,520,375
2516.90.90	143,343	917.5	5.6
2516.20.00	15,956	18,053	554

3. Price of aggregates imported from 2015 to 2017

TABLE III. TOTAL PRICE VALUE OF IMPORTED AGGREGATES

HS Code	2015-16	2016-17	2017-17
2517.10.90	1,545.1	9,588.9	13,367.5
2516.90.10	1,102.9	2,147.3	3,802.6
2516.90.90	196	9.985	0.23
2516.20.00	53.2	60.9	4

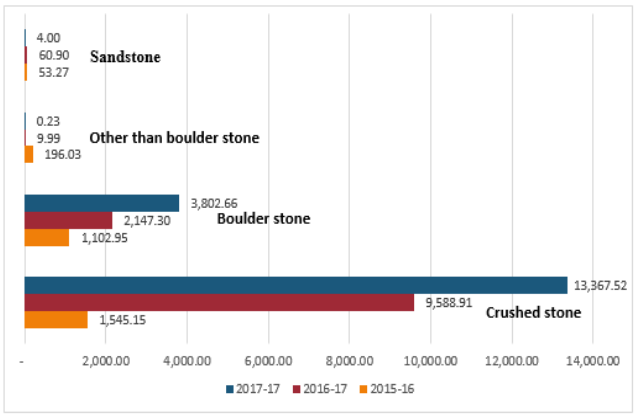


Figure 1. Aggregate price in graphical presentation

4. Findings from NBR

The scarcity and demand of good quality road construction materials are present and this can be validated by the import information of National Board of Revenue, Bangladesh. In these recent years, it has been seen that, crushed and boulder stones are imported in significant amounts and the rate has been increased. But Import of sandstones and other stones drastically decreased (Fig. 1).

So it can be state that, large quantity of road construction materials are imported at increasing rate. This proves the necessity of foreign country aggregates in terms of quality and scarcity-fulfillment in road construction.

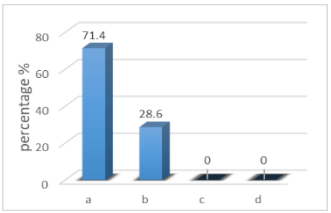
B. Questionnaires Surveying

A survey was conducted to know about the perceptions of peoples related to transportation engineering about the knowledge of recycling and efficiency of it in Bangladesh. There, few questions were asked with some multiple choices. The question answers and peoples thinking were shown in graphical representation.

a) Questionnaires surveying on aggregates of bituminous pavement

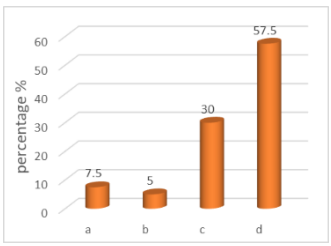
1. What is the present situation of transport sector in Bangladesh?

Answer
a. poor
b. fair
c. good
d. excellent



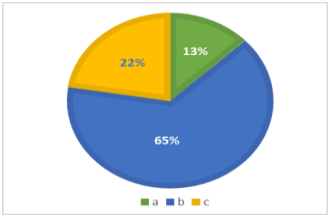
2. Why road/bridge construction is expensive in Bangladesh?

Answer
a. terrain ruggedness and proximity to markets
b. inadequate tender competition
c. delays in project implementation
d. conflict and higher level of corruption



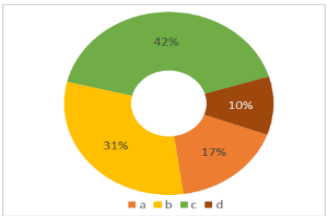
3. What do you think about aggregates, are they collected from inside the country or aggregates are imported?

Answer
a. inside the country only
b. sometimes imported from outside
c. regularly imported from outside



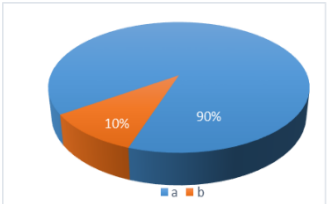
4. If the aggregates are imported, what do you think about the percentage of the aggregates are imported?

Answer
a. below 10%
b. 10% to 25 %
c. 25% to 50%
d. over 50%



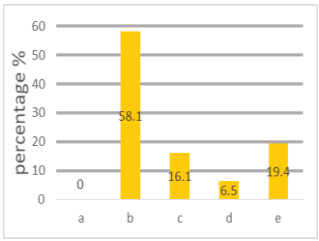
5. What do u think about pavement recycling, Can recycled aggregate be a tool of road construction?

Answer
a. yes
b. no



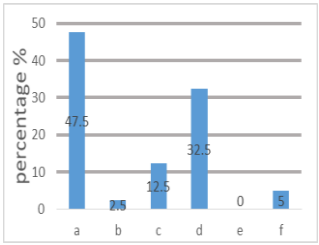
6. What do you think about imported aggregate, why it is necessary?

Answer
a. cost effective
b. better quality
c. scarcity of virgin aggregates
d. environment friendly
e. technical assurance



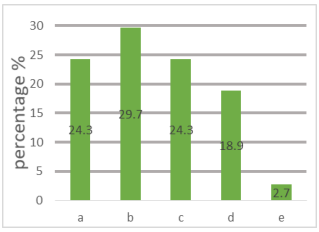
7. What do you think about recycled aggregate, why it is necessary?

Answer
a. cost effective
b. better quality
c. technical assurance
d. scarcity of virgin aggregates
e. environment friendly
f. easy maintenance work



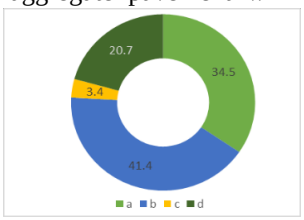
8. Which of the following recycled materials do you think, can be used in pavement maintenance specifications in Bangladesh?

Answer
a. Recycled Asphalt Pavement (RAP) in base or Subbase Layers
b. Recycled Asphalt Pavemen (RAP) in Flexible Layer
c. Recycled Concrete Aggregate in Base or Subbase Pavement Layers
d. Recycled Concrete Aggregate in Concrete Pavement Layers
e. Any



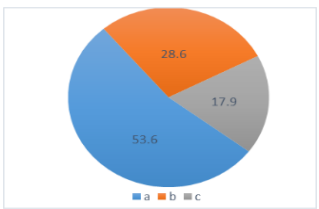
9. How long the recycled aggregate pavement will sustain, what do you think?

Answer
a. less than new pavement
b. equal to new pavement
c. more than new pavement
d. any



10. Do you think recycling pavement can rectify the faults of previous constructions?

Answer
a. yes
b. no
c. any



b) Findings from surveying

According to questionnaires surveying, most of the people has thought that the condition of transportation sector is poor and road construction is expensive. For better quality aggregates, import is necessary. Again most of people think that to meet up the scarcity of virgin aggregates, recycled aggregate should be used and it is a cost effective method of construction. Virgin aggregates and recycled aggregate mix materials are more preferable for all. From the data analysis, it is clear that, the highway materials were imported and the import rate is increasing significantly. Scarcity of aggregates as well as the quality and economic efficiency are the main reasons of importing road materials.

C. Site Investigation and Observation

To investigate the main reason of pavement failure of N5 highway, the portion of Slippage Failure is excavated. The findings are given below-

1. Geographical Properties Investigation

a) Total Asphalt Layer Thickness of pavement is found 200mm (8 in) which is the integrated thickness due to Overlay work at different times. (Figure 2)

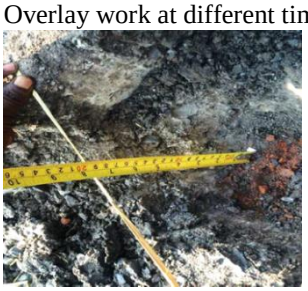


Figure 2. Asphalt Layer Thickness

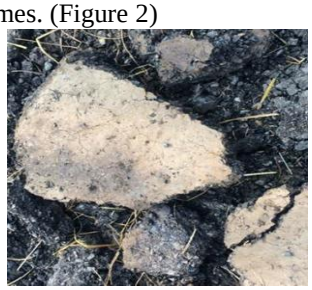


Figure 3. Thin Muddy Clay layer 200mm

b) Top 100mm Asphalt Layer (2 times Overlay) is not sufficiently bonded with Bottom 100mm Asphalt Layer I Top 100mm Asphalt Layer's Opposite Face is Thin Muddy Clay Layer (Fig. 3). Mainly this thin Muddy Clay Layer prevents to create sufficient bonding between Top 100mm Asphalt Layer and Bottom 100 mm Asphalt Layer and acts as separation layer between these layers.

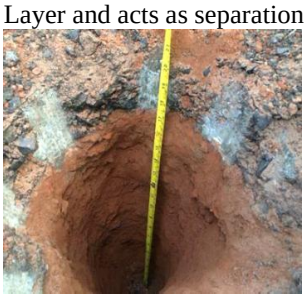


Figure 4. WBM Layer Thickness 450mm.

Figure 5. WBM contains moist fine particles.

c) Base Layer Excavation is also done this pavement which is laid on WBM base. WBM Layer Thickness is 450 mm (Fig. 4). For several years Heavy vehicular movements, the particle size of WBM has been changed. More Fine Particles are observed at WBM and the Fine Particles has moistures (Fig. 5). Moreover WBM Layer is acting like Clay Layer (Fig. 3). Therefore cracks are occurred at bottom asphalt layer (Fig. 6) and also heaving is created in Asphalt Surface at mid or side portion of pavement (Fig. 7).

Figure 6. Cracks at Bottom 100mm Asphalt Layer Surface.

Figure 7. Heaving of pavement surface

2. Probable Damage Hypothesis

There are several cracks in Bottom 100mm Asphalt Layer. While raining, rainwater infiltrates through the Crack Surface and reaches at WBM Layer and water remains entrapped (Fig. 8).

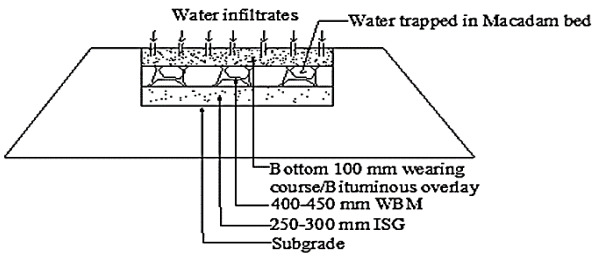


Figure 8. Water entrance at bottom 100mm layer

Then again when next Overlay Layer is laid, then these entrapped Water at WBM Layer shows Capillary Rise and reaches at 100mm Bottom Layer Surface. The soil in this area is generally Stiff Clay. So Stiff Clay Particle lasts at Asphalt Surface, which can't be cleaned out by Blower Machine. This Surface Attached Clay Particle, Capillary Rise and Pumping Action of WBM Layer creates a Thin Layer, which is the reason of interface Bond Failure of Asphalt Layer, which results in Surface Crack and Heaving (Fig. 9).

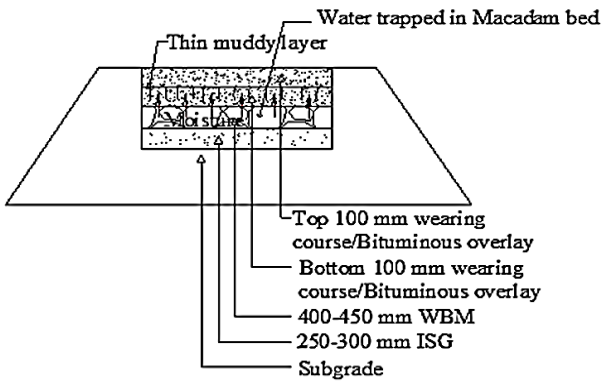


Figure 9. Thin Layer between Top 100mm and Bottom 100mm

3. Temporary Measures

To keep traffic movement stable and normal, the heaving parts of the pavements are cut off and resurfaced by carpeting and seal coating. But the quantity of affected portion quite a lot, so reconstruction of asphalt is needed. As it is one of the busiest national highways, the vehicular movement need to be usable at emergency basis.

4. Permanent Measures

To solve the problem of cracking at bottom 100mm layer, a project has been taken named "Emergency repair of N5 highway under periodic maintenance program (PMP-Major) by cutting, excavation and re-compact of bituminous layers and followed by DBS wearing course at different Km of Gaibandha portion under road division, Gaibandha during the year 2017-18."

5. Reconstruction work site observation

Three sites were visited and observed. The locations were -

Location 1: N5 (palashbari) - (latitude 25.287, longitude 89.35)

Location 2: N5 (gobindapur) - (latitude 25.1469, longitude 89.388)

Location 3: N5 (gobindoganj) - (latitude 25.129, longitude 89.3877)

The observation of the sites are described briefly below-

a) Location 1:

The 1st location was at palashbari, dhaka-bogura-Rangpur N5 highway. The latitude and longitude was 25.287 and 89.35. There, Asphalt milling machine (model 1300D) was used for excavation and crushing wearing surface (Fig. 10), then immediately after filling and leveling the surface, Dynapac soil compactor was used to compact the surface (Fig. 11).

Figure 10. Using of asphalt milling machine.

Figure 11. Levelling and compacting road surface

b) Location 2

The 2nd location was at gobindapur, dhaka-bogura-Rangpur highway of N5. The latitude and longitude was 25.14689 and 89.388.there, at first, CAT excavator E200 was used to excavate pavement surface (Fig. 12) and then Local crusher machine was used to make finer aggregate. Then aggregates were used to fill the surface and after that, Dynapac soil compactor was used to compact pavement (Fig. 13).

Figure 12. Using of excavator to excavate road surface.

Figure 13. Levelling and compacting road surface

c) Location 3

The 3rd location was at gobindoganj, dhaka-bogura-Rangpur highway of N5. The latitude and longitude was 25.129 and 89.3877.there, at first, CAT excavator E200 was used to excavate pavement surface and then Local crusher machine was used to make finer aggregate. Then aggregates were used to fill the surface and after that, Dynapac soil compactor was used to compact pavement (Fig. 14).

Figure 14. Excavate, crush and re-compact road surface

D. Sample Testing in Laboratory

Different lab tests had been done for aggregates and bitumen and compared with the specifications of Roads and Highways, Bangladesh.

1. Aggregate crushing value test of aggregates

TABLE IV. ACV TEST OF STONE CHIPS

sample: Base type 1, Bitumenous binder and wearing coarse material		
Aggregate Crushing Value		
test sample	Base type 1 (stone chips)	Binder course and wearing course (stone chips)
wt of sample (surface dry) A gm	2800	2800
wt passing (through #8 sieve) B gm	703	647
Aggregate Crushing Value =(B/A)*100%	25.17	23.1
Mean Value (ACV)%	**25%**	**23%**

2. TFV test of aggregates

TABLE V. TEN PERCENT FINER VALUE (TFV) TEST OF STONE CHIPS

Ten Percent Fines Value		
test sample 1	Base type 1 (stone chips)	Binder course and wearing course (stone chips)
wt of sample (surface dry) A gm	2800	2800
wt passing (through #8 sieve) B gm	316	314
Aggregate Crushing Value y =(B/A)*100%	11.28%	11.21%
Maximum Load x KN	155	174
TFV = $\frac{14 * x\ KN}{y+4}$	**142 KN**	**160 KN**

3. Crushing strength test of aggregates

TABLE VI. CRUSHING STRENGTH TEST OF BRICKS

Crushing Strength Test						
Sample: Bricks						
sample	length	width	Net area mm2	Load KN	Strength	average Strength
1	120.9	120.8	14604.72	266	1.821329	1.915525
2	121	120.9	14628.9	294	2.00972	

4. Water absorption test of aggregates

TABLE VII. DENSITY TEST OF WEARING AND BINDER COURSE

DENSITY OF WEARING AND BINDER COURSE						
sample	Weight of Mould					Remarks
	Wt in air (gm)	Wt in water (gm)	SSD (gm)	Vol CC	Density (gm/cc)	
1	820.4	463.7	828	356.7	2.3	Wearing Course 1
2	800	452.62	812.4	347.4	2.303	Wearing Course 2
3	1040	586.04	1048	454	2.291	Binder Course 1
4	980.4	552.1	988.9	428.3	2.289	Binder Course 2

5. Gradation analysis of aggregates

TABLE VIII. GRADATION OF WEARING COURSE SAMPLE 1

location: chainage 252+750 km (Left side)					
thickness= $\frac{54+52+52}{3}$ = 52.66					
sample: Wearing course 1					
astm sieve	retained	passing	passing%	specification	
				upper	lower
1"			100	100	100
3/4"	0	770	100	100	100
0.56"	81.62	688.38	89.4	100	85
3/8"	95.48	592.9	77	90	70
#4	135.52	457.38	59.4	75	52
#8	103.18	354.2	46	58	40
#16	86.24	267.96	34.8	48	30
#30	75.46	192.5	25	38	20
#50	56.21	136.29	17.7	28	14
#100	58.52	77.77	10.1	20	8
#200	26.18	51.59	6.7	10	6
pan	40.6				
loss	10				
total wt	770				

TABLE IX. GRADATION OF WEARING COURSE SAMPLE 2

location: chainage 254+550 km (Right side)					
thickness= $\frac{41+40+41}{3}$ = 40.55					
sample: Wearing course 2					
astm sieve	retained	passing	passing%	specification	
				upper	lower
1"			100	100	100
3/4"	0	720	100	100	100
0.56"	86.4	633.6	88	100	85
3/8"	80.64	552.96	76.8	90	70
#4	120.96	432	60	75	52
#8	107.28	324.72	45.1	58	40
#16	81.36	243.36	33.8	48	30
#30	64.8	178.56	24.8	38	20
#50	48.96	129.6	18	28	14
#100	43.2	86.4	12	20	8
#200	36	50.4	7	10	6
pan	42.4				
loss	8				
total wt	720				

TABLE X. GRADATION OF BINDER COURSE SAMPLE 1

location: chainage 254+550 km (Right side)					
thickness= $\frac{61+61+62}{3}$ = 61.33					
sample: Binder course 1					
astm sieve	retained	passing	passing%	specification	
				upper	lower
1"			100	100	100
3/4"	0	980	100	100	100
0.56"	127.4	852.6	87	100	85
3/8"	176.4	676.2	69	90	65
#4	205.8	470.4	48	65	45
#8	185.22	285.18	29.1	45	25
#16	118.58	166.6	17	35	15
#30	37.73	128.87	13.15	30	12
#50	15.2	113.67	11.59898	20	9
#100	54.88	58.79	5.99898	15	5
#200	21.56	37.23	3.79898	7	3
pan	17.23				
loss	20				
total wt	980				

TABLE XI. GRADATION OF BINDER COURSE SAMPLE 2

location: chainage 254+850 km (Left side)					
thickness= $\frac{60+62+60}{3}$ = 60.33					
sample: Binder course 2					
astm sieve	retained	passing	passing%	specification	
				upper	lower
1"			100	100	100
3/4"	0	900	100	100	100
0.56"	100.8	799.2	88.8	100	85
3/8"	169.2	630	70	90	65
#4	184.5	445.5	49.5	65	45
#8	175.5	270	30	45	25
#16	108.9	161.1	17.9	35	15
#30	35.1	126	14	30	12
#50	28.8	97.2	10.8	20	9
#100	36	61.2	6.8	15	5
#200	25.2	36	4	7	3
pan	28				
loss	8				
total wt	900				

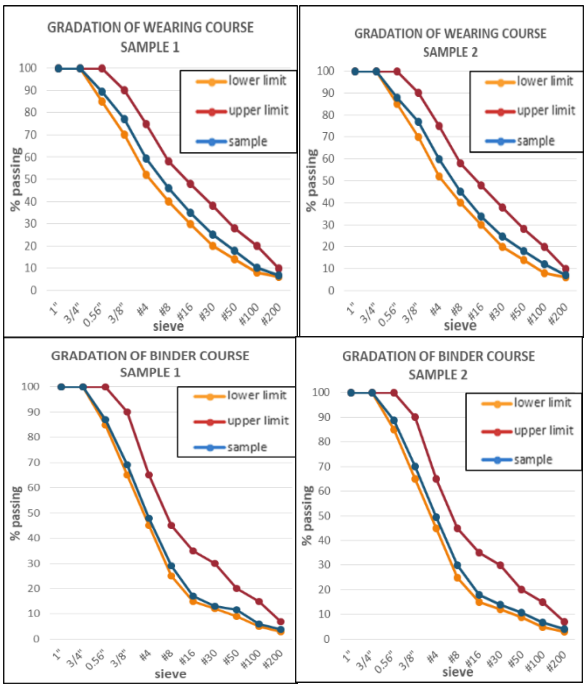


Figure 15. Gradation curves of samples

TABLE XII. GRADATION OF STONE CHIPS

SIEVE ANALYSIS				
Sample: Stone Chips				
Weight of Dry sample= 10,000 gm				
Standard Opening (mm)	Weight Retained (gm)	% Retained	Cumulative % Retained	% Passing
25	0	0	0	100
20	0	0	0	100
12.5	6960	69.6	69.6	30.4
10	2340	23.4	93	7
5	590	5.9	98.9	1.1
pan	92			
loss	18			
Total	10000			

TABLE XIII. GRADATION OF SAND

SIEVE ANALYSIS				
Sample: Sand				
Weight of Dry sample= 150 gm				
Standard Opening (mm)	Weight Retained (gm)	% Retained	Cumulative % Retained	% Passing
2.4	0	0	0	100
1.2	3.4	2.27	2.27	97.73
0.6	29.4	19.60	21.87	78.13
0.3	57	38.00	59.87	40.13
0.15	55.8	37.20	97.07	2.93
pan	4.1			
loss	0.3			
Total	150			

FM= 1.81

6. Discussion on lab test of the properties of aggregate

According to specification of roads and highway, the ACV value of aggregates should be less than 30% for base type 1 and if the value is greater than 30%, then it is considered as base type 2. The average ACV value is found out 23% for wearing and binding course and 25% for existing base 1 stone chips. So, binder and wearing course as well as base aggregate satisfies this specification. Again TFV value should be greater than 125 KN. There, binder, wearing and base aggregate satisfies the specifications. All aggregate gradation and sieve analysis are also satisfied by the specification limitations (Fig. 15). That's why wearing surface and base materials are used as reconstruction recycling materials. Improved subgrade layer is present and the fineness modulus of sand is greater than 1. So the improved subgrade is in good condition.

E. Interviewing Experts

At Gaibandha, Reconstruction of N5 highway by recycling had been taken place. After visiting the worksites, Mr Rubel, SO of palashbari, Gaibandha division of RHD explained the construction procedures. According to him, approximate 200 mm base and wearing course, as well as 400mm brick chips as sub base were at that pavement. At first, the surface pavement had been cut and excavated by excavator and then crushed by crushing machine or directly excavate and crushed by milling machines. After that, the crushed mixtures were overlaid on pavement and levelled. Then the pavement were compacted by roller machine. No new materials were added there.

Mr. Asaduzzaman, The executive engineer of Gaibandha road division, briefly explained the reconstruction works in an interview. The existing surface layer was almost 200mm, then 450 mm macadam and 100 mm sand layer of improved subgrade. There, the reasons of recycling was explained by him. Firstly, that highway was constructed by concrete cement before 1960s. Then around 1990s flexible pavements were introduced. So up to present time, during periodic maintenance bituminous overlay had been placed years after years. Thus the wearing surface became almost 200mm. Again the inter bonding of the upper and lower wearing surface layer was not good. That's why due to slippage, crack developed. Also the surface cracked due to overload or many technical reasons and base was damage because of entering water through surface. So new overlay would not be effective. Secondly, as 200 mm wearing surface dismantle work is difficult, so it had been decided that the wearing surface would be reuse again by recycling. Thirdly, 200 mm fill by virgin material was also very costly, fourthly, the scarcity of virgin material was also one of the reason. Lastly, the budget of periodic maintenance had a limit that would be exceed for new pavement.

V. Conclusion

This research work is aimed to investigate the availability of road construction materials and to introduce a new method of road construction practice the based on the quality, economic efficiency and specification. Based on this research work, conclusions are drawn on the competence of recycled aggregates based on two considerations. One is availability and other is quality.

Recycled aggregate is a new concept for our country. Therefore specified guidelines are not yet published. That's why it's not practiced in large scale. But as the existing aggregate properties are in range of specification of new aggregates, some projects are taken which proves cost efficiency as well as longevity.

VI. Recommendation

The recycled aggregate can be partial or full replacement of virgin aggregates. Based on the research it is clearly seen that recycled materials have a bright future to meet up the scarcity of aggregates for the construction in Bangladesh.

The performance of full depth recycling pavement of N5 and the analysis of that highway can bring good opportunity for future study. This highway can be used to build up the specifications for recycling aggregates by testing and mixing with virgin materials in future.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Md. Obaidur Rahaman conducted this research work with the help of Tabassum Mostafa. Md. Obaidur Rahaman collected the data from research sites and NBR. In the meantime Tabassum Mostafa formatted a general structure of the research paper. Both Md. Obaidur Rahaman and Tabassum Mostafa conducted tests, analyzed the test results, restructured the paper and modified according to the template. Md. Abdullah Al Mamun supervised Md.Obaidur Rahaman and Tabassum Mostafa through the whole research with proper guidance. All authors had approved the final version.

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REFERENCES

[1] RHD road network database annual report, 2006
[2] Overview of RHD. [Online]. Available: Retrieved November 10, 2018, from www.rhd.gov.bd/OverviewOfRHD/Default.asp
[3] ActiveTenders. Retrieved November 10, 2018, [Online]. Available: www.rhd.gov.bd/ActiveTenders/Default.asp
[4] L. Edil, Tinjum, Benson, 2010; Wen, Edil, "Engineering properties of recycled materials for unbound applications," Recycled Materials Resource Center University of Wisconsin-Madison, 2009.
[5] A. Ebrahimi, B. R. Kootstra, T. B. Edil, C. H. Benson, "Practical approach for designing flexible pavements using recycled roadway materials as base course," *Road Materials and Pavement Design*, vol. 13, no. 4, pp. 731-748, 2012.
[6] J. A. Epps, "Cold-recycled bituminous concrete using bituminous materials," *NCHRP Synthesis of Highway Practice*, vol. 160. Washington DC: NCHRP, 1990.
[7] R. Taha, A. Al-Harthy, K. Al-Shamsi, et al. "Cement stabilization of reclaimed asphalt pavement aggregate for road bases and subbases," *J. Mater. Civ. Eng*., vol. 14, pp. 239–245, 2002.
[8] L. R. Hoyos, A. J. Puppala, C. A. Ordonez, "Characterization of cement-fiber-treated reclaimed asphalt pavement aggregates: preliminary investigation," *J. Mater. Civ. Eng*. vol. 23, pp. 977–989, 2011.
[9] A. J. Puppala, L. R. Hoyos, A. K. Potturi, "Resilient moduli response of moderately cement-treated reclaimed asphalt pavement aggregates," *J. Mater. Civ. Eng*., vol. 23, pp. 990–998, 2011.
[10] C. S. Poon, D. Chan, "Feasible use of recycled concrete aggregates and crushed clay brick as unbound road sub-base," *Constr. Build. Mater.* vol. 20, pp. 578–585, 2006.
[11] A. Azam, D. Cameron, "Geotechnical properties of blends of recycled clay masonry and recycled concrete aggregates in unbound pavement construction," *J. Mater. Civ. Eng.*, vol. 25, pp. 788–798, 2012.
[12] A. Gabor, D. Cameron, "Properties of recycled concrete aggregate for unbound pavement construction," *J. Mater. Civ. Eng.*, vol. 24, 2012.
[13] F. C. Leite, R. S. Motta, K. L. Vasconcelos, et al. "Laboratory evaluation of recycled construction and demolition waste for pavements," *Constr. Build. Mater*. vol.25, pp. 2972–2979, 2011.
[14] A. Arulrajah, M. Ali, M. Disfani, et al. "Geotechnical performance of recycled glass-waste rock blends in footpath bases," *J. Mater. Civ. Eng.* vol. 25, 2012, pp. 653– 661.
[15] A. Arulrajah, J. Piratheepan, M. Disfani, et al. "Geotechnical and geoenvironmental properties of recycled construction and demolition materials in pavement subbase applications," *J. Mater. Civ. Eng*. vol. 25, 2012, pp. 1077–1088.
[16] J. Wartman, D. G. Grubb, A. Nasim, "Select engineering characteristics of crushed glass," *J. Mater. Civ. Eng.*, vol. 16, pp. 526–539, 2004.
[17] L. T. Lee Jr. *Recycled Glass and Dredged Materials*, DTIC Document, 2007.
[18] M. Ali, A. Arulrajah, M. Disfani, "Suitability of using recycled glass-crushed rock blends for pavement subbase applications," in Geo-Frontiers, et al., Advances, Geotechnical Engineering, pp. 1325–1334, 2011.
[19] M. Disfani, A. Arulrajah, M. Bo, et al. "Environmental risks of using recycled crushed glass in road applications," *J. Clean. Prod*. vol. 20, pp. 170–179, 2012.
[20] M. A. Imteaz, M. Y. Ali, A. Arulrajah, "Possible environmental impacts of recycled glass used as a pavement base material," *Waste Manage. Res.* vol. 30, pp. 917– 921, 2012.
[21] A. Arulrajah, J. Piratheepan, M. Disfani, et al. "Geotechnical and geoenvironmental properties of recycled construction and demolition materials in pavement subbase applications," *J. Mater. Civ. Eng.* vol. 25, pp. 1077–1088, 2013.
[22] W. Kim, J. Labuz, "Resilient modulus and strength of base course with recycled bituminous material," Final report for the Minnesota Department of Transportation project, 2007.
[23] Standard test procedures manual. Roads and Highway Department, May 2001.

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