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IMPROVEMENT OF SKID RESISTANCE IN COASTAL HIGHWAYS USING CRUMB RUBBER

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ABSTRACT
In Bangladesh, historical evidences show that accidents occur in the coastal areas especially in the Chittagong–Cox's Bazar highway. Raw salt is often carried by truck from Cox's Bazar to different parts of the country. But most of the salt businessman don't follow the rules and regulations of salt transportation. As a result, in winter season especially during night salts deposit on the pavement while being transported and make the surface slippery. Due to the slippery condition, the vehicles had to cover a higher stopping distance while overtaking. This results in fatal accidents in the form of head on collision between two vehicles. Bangladesh generates huge amounts of non-biodegradable waste tire annually which can be used with conventional bitumen to make flexible pavement more skid proof. After conducting physical property test on both conventional and modified bitumen, we find that crumb rubber modified bitumen (CRMB) is less ductile, has low stripping value. Further skid resistance test is conveyed on both road models by PORTABLE SKID RESISTANCE TESTER and evaluate the result as a BPN value which is directly related to frictional resistance. The reduction in stopping distance in the case of CRMB after applying brake also justifies the above statement. So modification of conventional bitumen can be a solution to improve the skid resistance of road surface.

Keywords: Coastal areas; Salt transportation; Skid resistance; Accidents; Crumb rubber.

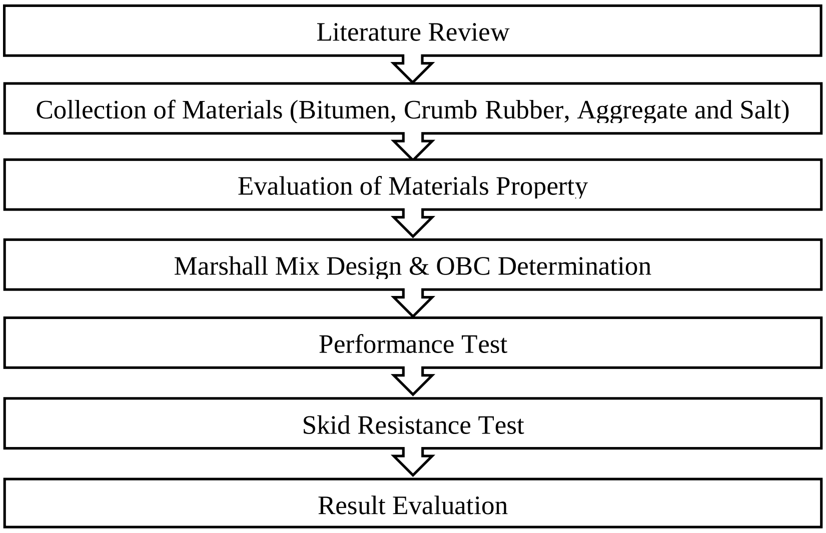
1. INTRODUCTION

Bangladesh is a country of rivers. Coastal zone of Bangladesh covers about 710 km in length. In Bangladesh, about 98% of paved roads are flexible pavement. Raw salt is often carried by truck from coastal area to different parts of the country. During transportation of salt, salt water comes in contact with the surface of the pavement. This problem adds up more in winter due to the foggy condition at night when salt deposits on the pavement surface. This phenomena makes the pavement surface slippery. As such the braking force of the vehicles decreased and the vehicles lose their control. This results in fatal accident. In Chittagong-Cox's Bazar-Teknaf highway 253 people were killed and 1,144 injured in road accidents in the last six months. The main reason of the majority of those accident is slippery condition of the pavements.

In Bangladesh, we commonly use bitumen for road construction. But is has low stability and low skid resistance under adverse condition of environment. As a result it has been necessary to go for constant maintenance and awareness works which results in huge amounts of money loss in our country. To remove this problem, we can use modifier to improve the life time, stability and skid resistance of the bitumen. Among the different types of modifier, we can use waste tire powder as this is available and cheap in our country. Today the availability of the tire wastes is enormous, as the automobiles have become the part and parcel of our daily life. They are thrown over land area. If they are not recycled, their present disposal may be by land filling or it may be by incineration. Both the processes have significant impacts on the environment. If they are incinerated, they pollute the air and if they are dumped into some place, they cause soil and water pollution. Under these circumstances, an alternate use for those tire wastes is required. By using this polymer with neat bitumen, environmental impact can also be removed.

2. METHODOLOGY

During our investigation we followed various steps. Our project work is shown below in a flow chart:



2.1 MATERIAL USED IN INVESTIGATION

Crumb rubber collected from a local tire retreading shop near New market, Chittagong was used to modify 60/70 penetration graded asphalt obtained from Bay Terminal & Distribution Company Limited located also in Chittagong. The crumb rubber was generated by scraping old tires of automobiles. Crumb rubber passing ASTM 30 sieve and retained on ASTM 50 sieve was used for bitumen modification. Stone chips collected from local quarry in Chittagong were used as aggregates. Due to local practice IRC, 81 specifications for aggregate gradation for 50-65 mm thick bituminous surface course was used in this investigation. Stone dust passing 0.075 mm sieve was taken as filler material. Apparent specific gravity of different types of aggregates were determined to use them in Marshall Mix design. Physical properties of different types of aggregate are given in Table 1. The aggregate gradation chart is given below by Table 2 and gradation curve is shown in Figure 1.

Table 1: Physical Properties of Aggregates Used

Properties	Coarse Aggregate	Fine aggregate	Filler Material
Apparent Specific Gravity	2.67	2.63	2.82
Water Absorption (%)	1	-	-
Impact value (%)	5.97	-	-
Los Angles Abrasion (%)	11.84	-	-
Elongation Index	18.35	-	-
Flakiness Index	24.32	-	-

Table 2: Gradation of Aggregates Used

Sieve Size (mm)	Individual retained (gm.)	Retained percent percentage (%)	Cumulative weight by weight of total aggregate passing	Cumulative % by weight of total aggregate passing	Passing percentage (%)
26.5	0.00	0.00	0.00	0.00	100.00
19	146.00	13.27	146.00	13.27	86.73

13.2	198.00	18.00	344.00	31.27	68.73
9.5	80.00	7.27	424.00	38.55	61.45
4.75	180.00	16.36	604.00	54.91	45.09
2.36	110.00	10.00	714.00	64.91	35.09
1.18	99.00	9.00	813.00	73.91	26.09
0.6	66.00	6.00	879.00	79.91	20.09
0.3	66.00	6.00	945.00	85.91	14.09
0.15	66.00	6.00	1011.00	91.91	8.09
0.075	44.00	4.00	1055.00	95.91	4.09
Pan	45.00	4.09	1100.00	100.00	0.00

The aggregate gradation curve of used aggregate is as below:

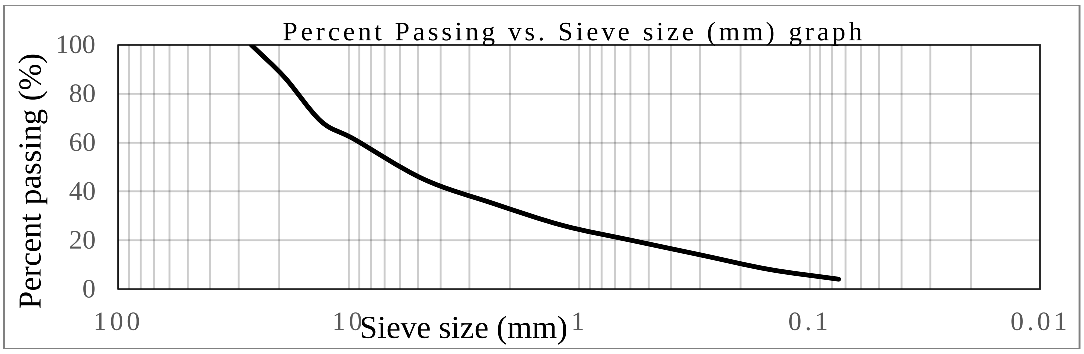


Fig. 1: Aggregate Gradation Curve

The properties of the salt are given in the Table 3.

Table 3: Properties of salt tested in the laboratory

Appearance	Chemical formula	Solubility in water (g/L)	Melting Point (℃)	Boiling Point (℃)	Density (g/cm^3)
Colorless, transparent crystals or white crystalline powder, odorless and hygroscopic.	NaCl	360	801	1413	2.16

2.2 PREPARATION OF CRUMB RUBBER MODIFIED BITUMEN

In preparing the modified binders, about 4500 g of the bitumen was heated to fluid condition in a 8 liter capacity metal container. For blending of crumb rubber with bitumen, it was heated to a temperature of 180°C and then crumb rubber was added. For each mixture sample 10% of crumb rubber by weight fine (300µm-150µm). The blend is mixed manually for about 3-4 minutes. The mixture is then heated to 160°C and the whole mass was stirred using a mechanical stirrer for about 50 minutes maintaining rotation at 1200 rpm. Care is taken to maintain the temperature between 160°C to 170°C. The contents are gradually stirred for about 55 minutes. The modified bitumen is cooled to room temperature and suitably stored for testing.

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2.3 SKID RESISTANCE TEST BY BRITISH PENDULUM TESTER

Two road models which are at the optimum asphalt content and design gradation are prepared.

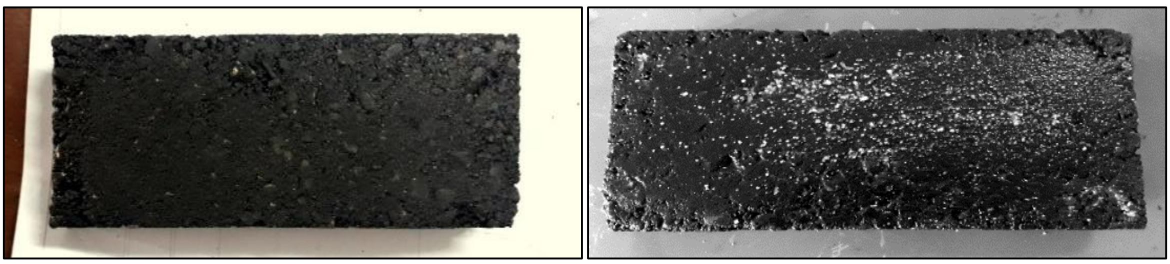

Fig 2: Road models

Apply sufficient water to cover the test area thoroughly. Execute one test swing to check whether the pendulum makes enough contact with the road model surface. Make four more swings and record the results. Report the individual values as BPN also note down the temperature and condition of test surface. The measurement obtained from the scale represents the skid resistance of the material tested such that higher values indicate greater skid resistance.

2.4 DETERMINATION OF STOPPING DISTANCE

If a driver puts on the brakes of a vehicle, the vehicle will not come to a stop immediately. The stopping distance is the distance the vehicle travels before it comes to a rest. It depends on the speed of the vehicle and the coefficient of friction (*f*) between the wheels and the road. This stopping distance formula does not include the effect of anti-lock brakes or brake pumping.

Stopping Distance at level, SD = (lag distance + braking distance)

$$= \mathbf{Vt} + \frac{\mathbf{v^2}}{\mathbf{30f}} \quad (1)$$

Where,

v = speed of vehicle (mile/hour)
f = **coefficient of friction**
t = reaction time (sec)

3. RESULTS

The different physical properties tests of both the neat and modified bitumen were conducted according to ASTM specifications. The property test results of both neat and modified bitumen are shown below by table 4

Table 4: Physical Properties of Bitumen Used

Name of Property Test	Neat Bitumen	CRMB
Specific Gravity	1.037	1.048
Penetration (1/10th of mm)	68	48
Flash Point (℃)	262	239
Fire Point (℃)	280	260
Softening Point (℃)	52	58
Ductility (cm)	100	42
Loss on Heating (%)	0.1	0.4
Solubility (%)	95.3	82.69
Stripping Value (%)	0	0

The Marshall Mix design test results at OBC for both neat and modified bitumen are shown below by table 5

Table 5: Comparison of Marshall Test Result at OBC

Bitumen Type	OBC	Stability (KN)	Bulk Density (gm./cm^3)	Air void (%)	Flow value (in 0.25 mm)	Volume of Bitumen (%)	Void in mineral agg. (%)	Void filled with asphalt (%)
Neat	5.28 %	13.33	2.34	5.38	1.32	11.83	16.83	68.38
CRMB	5.00 %	16.68	2.337	5.56	1.57	11.37	16.92	67.17

The measured value, or British Pendulum Number (BPN) is approximately 100 times the coefficient of friction (Williams, 2008). So it is possible to find out the coefficient of friction from the tested value. The coefficient of friction values are listed in the table 6.

Table 6: Coefficient of friction values of different conditions and temperatures for both Conventional Bitumen and CRMB model roads

Temperature	Coefficient of Friction Values					
	Conventional Bitumen			Crumb Rubber Modified Bitumen		
	Dry Condition	Wet Condition	Salt affected Surface	Dry Condition	Wet Condition	Salt affected Surface
25℃	0.60	0.55	0.39	0.65	0.63	0.48
12℃	0.48	0.45	0.34	0.55	0.53	0.40
8℃	0.41	0.39	0.31	0.46	0.43	0.37

So, the stopping distance can be computed for the above coefficient of friction values at level by assuming vehicle speed of 50 km/hr. and reaction time of 2.5 sec using equation (1).

Table 7: Stopping distance of different conditions and temperatures for both Conventional Bitumen and CRMB at level for vehicle speed of 50km/hr.

Temperature	Stopping Distance (ft.)					
	Conventional Bitumen			Crumb Rubber Modified Bitumen		
	Dry Condition	Wet Condition	Salt affected Surface	Dry Condition	Wet Condition	Salt affected Surface
25℃	167.65	172.54	196.63	163.52	165.09	181.10
12℃	181.10	185.59	208.76	172.54	174.77	194.55
8℃	192.59	196.62	217.95	184.02	188.91	201.08

By using Crumb Rubber Modified Bitumen stopping distance can be reduced. The Reduction of stopping distance of different conditions and temperatures for using CRMB at level for heavy vehicles are listed in the Table - 8

Table 8: Reduction of stopping distance of different conditions and temperatures for using CRMB at level for vehicle speed of 50 km/hr.

Temperature	Reduction of stopping distance (ft.)		
	Dry Condition	Wet Condition	Salt affected Surface
25℃	4.13	7.45	15.51
12℃	8.56	10.83	14.21
8℃	8.56	7.71	16.86

The Reduction of stopping distance for crumb rubber modified bituminous on road models in various temperatures and conditions are represented graphically as below:

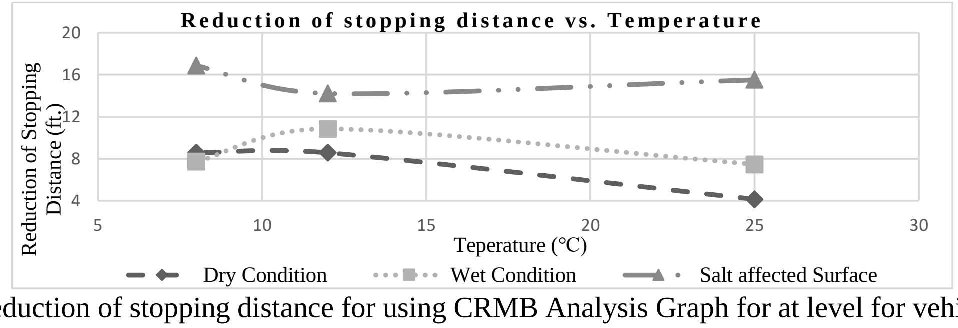

Fig 3: Reduction of stopping distance for using CRMB Analysis Graph for at level for vehicle speed of 50 km/hr.

4. CONCLUSION

The experimental results and related information presented in this research leads to the following conclusions:

CRMB increases the strength and lifetime of pavements. It also helps the pavement to withstand with heavy traffic as well as reducing the maintenance and repairing cost. From the physical perspective, CRMB shows 6℃ more softening point than the conventional 60/70 penetration graded bitumen and possess zero percent stripping value. After performing the skid resistance test on both CRMB and conventional bituminous road model, we can say that BPN value which is a Skid resistance parameter of pavement related to braking force is 22.30%, 17.04% and 16.80% more for CRMB sample than the CB sample conducted respectively in 25℃, 12℃ and 8℃ temperature for salt affected surface. For the vehicle speed of 50 km/hr. stopping distance in winter season reduced by 16.86 ft. in coastal highway by using CRMB.

So, it can be suggested that Crumb Rubber Modified (CRM) Asphaltic road can carry heavier traffic than the conventional bituminous road. Besides CRMB roads possesses higher skid resistance than the conventional bituminous roads in the case of salt affected surface. As a result, the probability of occurring accidents get reduced especially in winter season. Such incident happens because of the reduction of the stopping distance covered by the heavy vehicle in the salt affected CRMB roads after applying brake.

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