Salt Tolerance Limit of Bituminous Pavement

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ABSTRACT

The quality of the black topped pavement is based on the quality of the bituminous materials. To increase the strength properties and quality of the bitumen several techniques are applied today throughout the world. The areas within which the bituminous pavements are constructed may be harmful to the pavements. Salt is one of the harmful agents to the bitumen and bituminous mixtures. In the coastal belt of Bangladesh, sometimes pavements are submerged under water for long time. So the pavements come in contact with the saline water and salt (Sodium Chloride). Hence Stripping is a dominative cause of destruction of the bituminous pavements. Seawater contains nearly three percent (3%) Sodium chloride and deposition of salts on the adjoining areas of the sea is predominant phenomenon. This salt intrusion reduces the bond strength of bitumen with aggregates. Thus the bituminous pavements become weaker and destructed rapidly. This investigation is to find the effect of salt on the properties of bitumen and tolerable limit of salt for the bituminous mixes. This study reveals that the stability value of bituminous mixes decreases with increase the salt content. Tolerable limit of the salt content based on strength properties is varying from 0 to 4 percent.

Keywords*: Properties of Modified Bitumen, Properties of Aggregates, Marshall Stability, Salt Tolerance Limit.*

1. Introduction

Bangladesh is a country of rivers. A large part of the country is surrounded by coastal belts like Patuakhali, Kuakata, Mongla, Barguna, Patharghata, Taltoli, Satkhira, Khulna, Cox' Bazaar, Chittagong, Feni, Bhola, Bagerhat, Perojpur, Gopalgonge, Jessore, Barisal, Jhalakathi, Narail, and Laxmipur covering areas of **47201**square kilometer [1]. Coastal zone of Bangladesh covers about 710 km in length. Salt beds covering 50 square kilometer. Sea water contains average 3.5 percent (35 grm/L) salt ranging from 3.2 -3.8 percent. During natural disasters like floods, cyclones, extremely high tides most of the pavements undergo sea water which is mostly saline. Thus the pavements come in contact with the salt and affected by the damaging action of the salt. Saline water also attack binding properties and reduce the strength of the pavement. In such a situation, it is important to study the effect of salt on the properties of bitumen for aiding design, construction and maintenance.

Salinity level in the groundwater at shallow depth (65-70 ft) are low whereas salinity level at deeper depth (840-1350ft) are very high (3000-4000 µS/cm) [2]. Salts at sufficient concentration, have been shown to accelerate deterioration of road surfacings causing damage such as blistering, cracking and debonding of thin bituminous surfacing [3]. Salinity problem causes effect like pothole in granular pavement, rutting, shape loss, crumbling concrete kerbs, subsequent spalling of concrete, and corrosion of steel reinforcement [4]. Research conducted by Austroads (Australia), the Institute for Transport and Road Research (South Africa) and the British Overseas Development Administration and Transport and Road Research Laboratory (UK, Africa and the Caribbean) has shown that concentration of soluble salts beneath bituminous surfacings can lead to debonding, cracking and blistering of the surfacing [3, 5, 6].

Bituminous mixes are most commonly used all over the world in the construction of Black topped pavement. Under normal circumstances, designing the bituminous pavement considering standard properties of bituminous materials and executed properly perform quite satisfactory. There are several agents which are responsible for increasing strength properties of bitumen like sulphur, oganic polymer, waste polyethylene, waste polyvinyle chloride etc.. Many researches show that the strength of the paving mixes can be enhanced by using a binder modified by certain additives like sulphur, neoprene, rubberand organic polymer [7, 8, 9, 10, 11]. Waste polyethylene and waste poly vinyle chloride are also good modifier increasing strength properties and showing low moisture susceptibility [12, 13, 14].

A little work has been found investigating changes in the properties of bitumen and behavior of bituminous concrete in presence of salts. In this investigation, an attempt has been taken to study the effect of salts on various properties of bitumen and bituminous mixes. The aim of this study is to analyze the salt tolerance limit of the bituminous materials containing salt.

2. Materials and Methods

2.1 Bitumen

80/100 grade bitumen was used in this study from civil engineering laboratory of RUET supplied by Eastern Refinery Company, Bangladesh. This was used for all the mixes so that the type and grade of binder would be constant. The collected samples were modified with varying percentage of sodium chloride in laboratory and modified bitumen was used in the laboratory test. Test results of bitumen is presented in the article-4.

2.2 Salt

Salt, also known as table salt, or rock salt, is a crystalline mineral that is composed primarily of sodium chloride (NaCl), a chemical compound belonging to the larger class of ionic salt. It is used for highway deicing. It is normally obtained from sea salt or rock deposits. Salt is the common name of the chemical compound named as sodium chloride. It is the most important chemical compound for the human body. The chemical formula of the salt is NaCl. The properties of the salt is given in the Table1.

Table 1. Properties of salt tested in the laboratory.

Appearance	Solubility in water (g/L)	Melting Point (^{0}C)	Boiling Point (^{0}C)	Vapor Pressure	Density (g/cm^3)
Colorless, transparent crystals or white crystalline powder, odorless, hygroscopic.	360	801	1413	9.01575 (1026.85 C)	2.16

2.3 Aggregates and Filler

According to the recommendation of the Asphalt Institute (1984), particles retained on 2.36 mm sieve were regarded as coarse aggregate which is followed by this study [15]. The boulders were crushed manually and brought to the sizes of 26 mm or less. Fine aggregate portion of the aggregate blend (passes 2.36 mm and retained on 0.075 mm sieve) was taken from Domer sand. Non plastic sand finer than 0.075 mm (No. 200) sieve size was used as filler in all mixes. Specific gravity of the filler was 2.30. The properties of all ingredients were determined by following the ASTM/AASHTO standard including AASHTO T19, AASHTO T85, AASHTO T104 and BS 812 (part 3). Test results of intrinsic properties of coarse aggregates are given in Table 2.

Table 2. Properties of Aggregates and Filler

Properties	Designation	Recommended Value By AASHTO/BS	Coarse aggregate	Fine aggregate	Filler
Unit weight, dense, (kg/m^3)		…….	2640	2350	2300
Unit weight, loose, (kg/m^3)		…….	2610	2342	2260
Bulk specific gravity	C 127, T 85, C29	……	2.64	2.35	2.30
Apparent specific gravity	C 127, T 85,C29	…….	2.67	2.74	…….
Absorption of water,%	C 127, T 85,C128	…….	0.33	2.63	2.48
Los Angeles Abrasion, %	C 131, T96	40%(max)	30.86	……	……
Soundness($MgSO_{4,}$5cycle), %	T104	15%(max)	17	……	……
10% fines value, kN	T104	100(min)LGED	120	……	……
Aggregate Crushing value,%	BS 812, part IV	35 %(max)	16.59	……	……
Aggregate Impact Value,%	BS 812:1975, Part 3.	40%(max)	10.88	……	……

2.4 Preparation of Specimens

2.4.1 Bituminous Specimen

The samples are prepared by adding sodium chloride with pure bitumen. The amounts of salt are added by weight of percentage of pure bitumen separately. First of all fresh bitumen, without debris and adulterants was collected. The properties of bitumen were justified. Six bowls for preparing sample were weighted. Hot weighted bitumen was poured into those bowls. The salt was added with respect to 0%, 2%, 4%, 6%, 8% and 10% weight of bitumen separately. Thus six samples were prepared with variable salt contents. Six type of mixes are designated as mix type A, B, C, D, E and F.

2.4.2 Marshall Mix Design

Approximately 1100 gm. aggregates and filler are taken to prepare one specimen of 10.16 cm (4 inch) diameter and 6.35 cm (2.5 inch) thick for each mix type. Three specimens were prepared for each bitumen content and five bitumen content were used with increments of 0.5% for stone chip. The aggregates blend is heated for four hours in an electric oven maintained at a temperature of 182-188^{0}C and bitumen is heated to a steady temperature of 160^{0}C. The aggregate and bitumen are rapidly mixed to yield a mixture having a uniform distribution of bitumen throughout. Mixture is introduced in the mould heated to boiling temperature spaded with a hot trowel 15 times around the perimeter and 10 times over the interior. 50 blows are applied on each side with the standard compaction pedestal of 4.5 kg with a free fall of 45.7 cm for medium traffic condition. The sample is then cooled for about 10 minutes and extruded from the mould with the help of a hydraulic jack.

2.4.3 Optimum Bitumen Content (OBC)

$$\%\mathrm{OBC} = \frac{\%\ \mathrm{BC\ at\ maximum\ unit\ weight} + \%\ \mathrm{BC\ at\ maximum\ Marshall\ Stability} + \%\mathrm{BC\ at\ 4\ percent\ air\ void}}{3}$$

For determination of optimum bitumen content (OBC), Marshall Specimens are prepared by varying bitumen content (4.0%, 4.5%, 5.0%, 5.5% and 6.0% by weight of aggregate) with hot aggregate.

3. Test Result and Discussion

3.1 Effect of Salt on Properties of Bitumen

Test results of properties of mix type A, B, C, D, E and F are presented graphically in Fig. 1(a) to 1(g).

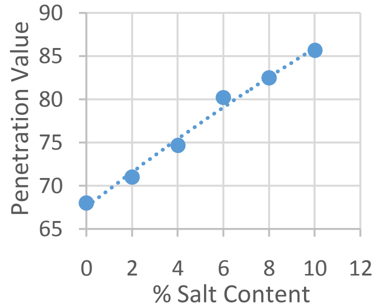

Fig. 1(a)

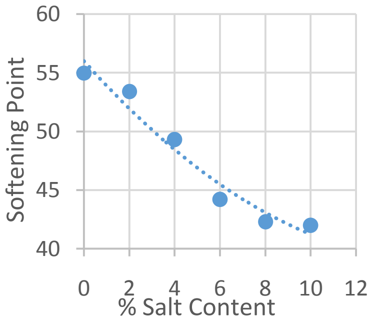

Fig. 1(b)

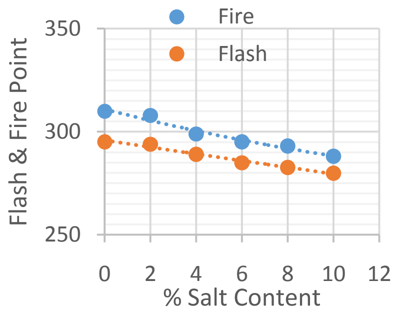

Fig. 1(c)

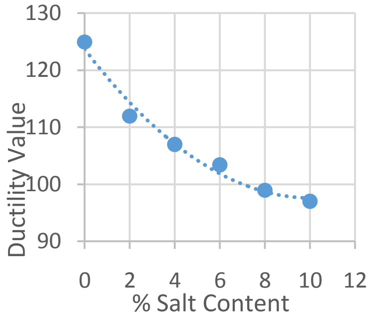

Fig. 1(d)

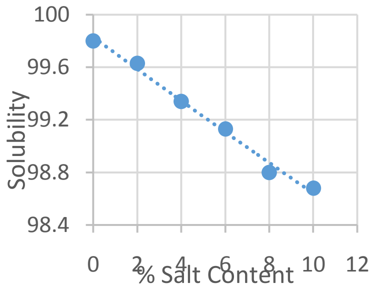

Fig. 1(e)

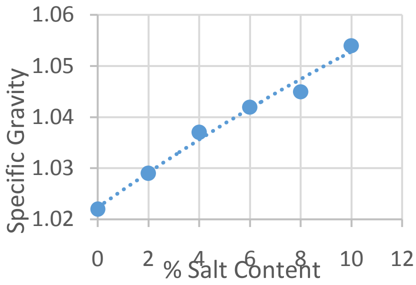

Fig. 1(f)

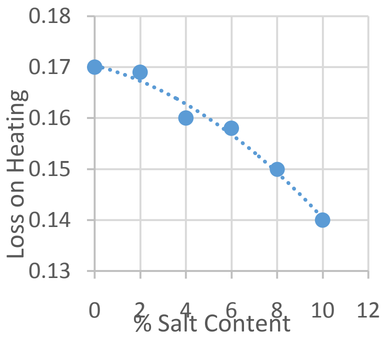

Fig. 1(g)

Fig. 1. Variation of properties of bitumen modified with percentage of salt content

There have been a variations in the properties of salted bitumen from the standard values. The increasing penetration value and decreasing softening point refer that this modified bitumen is suited for the colder regions shown in Fig. 1(a) & Fig. 2(b) respectively. Bitumen with lower ductility value may cause crack especially in cold weather. The ductility value may vary from 15 to 100^+, generally greater than 95. Fig. 1(d) shows that ductility value of bitumen decreases with increasing the percentage of Salt content. Generally bitumen should be soluble in carbon disulfide (CS_2) at least 99.5%. But Fig. 1(e) shows that solubility value decreases with the increase in Salt content. Fig. 1(g) indicates that specific gravity of bitumen increases gradually with increase percentage of Salt content. This is due to the higher value of specific gravity of salt whereas specific gravity of fresh bitumen varying from 1.022-1.06.

3.2 Effect of Salt on the Behavior of Bitumen

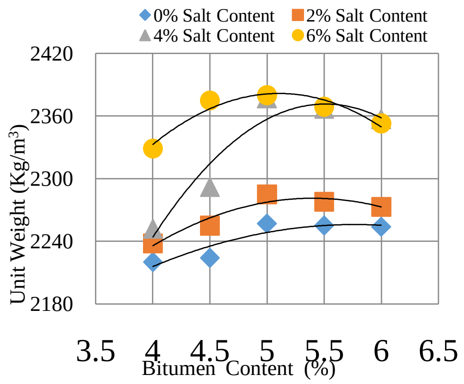

Fig. 2(a)

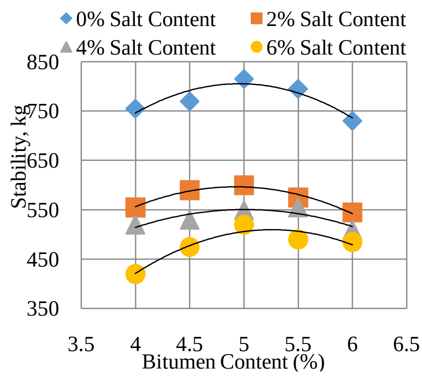

Fig. 2(b)

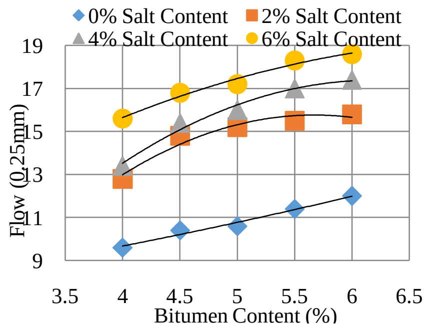

Fig. 2(c)

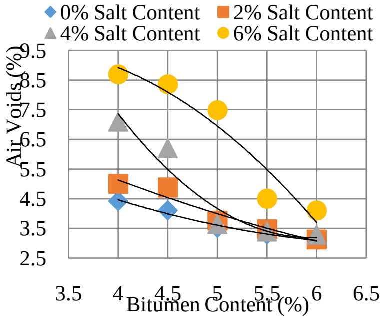

Fig. 2(d)

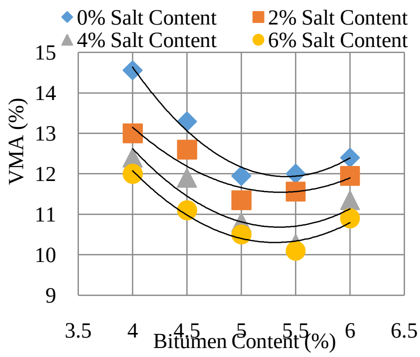

Fig. 2(e)

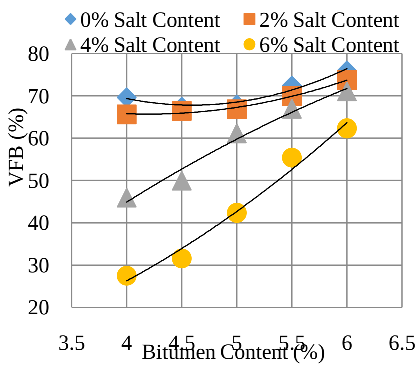

Fig. 2(f)

Fig. 2. Change in behavior of the bitumen modified with percent salt content.

Unit weight, Marshall Stability, flow, percent voids in total mix, percent voids in mineral aggregates and percent voids filled with bitumen 6 curves are drawn showing the relationship with percentage of bitumen content. Fig. 2(a) indicates that the unit weight of compacted specimens for all the mixes increase initially with an increase in bitumen content, reach a maximum value and then decrease. Fig. 2(b) shows that the variation of Marshall Stability with bitumen content is similar in nature to that of unit weight. Fig. 2(c) indicates that the flow values of the specimen increase with increase in bitumen content. Fig. 2(d) shows that the percentage air voids decreases with increase in bitumen content. The voids records of the mixes show that the percentage of voids in mineral aggregates decreases initially with an increase in bitumen content, reach a minimum value and then increases. Fig. 2(f) indicates that the percent voids filled with bitumen of the specimen increase in bitumen content. The rate of increase is being higher for higher proportions of bitumen.

For the flexible pavement, stability and air voids are two important factors for durability of the pavement. According to Marshall Mix design criteria the minimum stability value should be 544 Kg. The maximum Marshall stabilities are 815, 600, 555 and 520 kg respectively. The maximum stability of mix type A, B, C and D are very close to each other. When 6% salt is added with the bitumen then stability value is lower than the standard. Hence Marshall Mix design was not held for further salt content. At 0% salt content meaning fresh bitumen having highest stability value that decrease with increase in salt content gradually and at 6% of salt exceeds the limiting value. Hence we find that the salt content upto 4% satisfy the limiting value of strength specified by [18]. The optimum bitumen content for the mix types are given in the Table 3.

Table 3. Optimum Bitumen Content of the mix types.

Salt Content (%)	0	2	4	6
Optimum Bitumen Content (%)	5.08	5.26	5.55	5.42

4. CONCLUSION

Sodium chloride has played an important role in improvement of the different properties of the bitumen. Otherwise salt is also used for deicing of roads. But sometimes it has negative effects as reducing the strength of the bituminous mixes. From the test results, we conclude that the stability value of the bituminous mixes decreases gradually with increase in salt content in bitumen. When 4% salt is mixed with fresh bitumen then the stability value reaches very near to the minimum standard value for medium traffic is 544 Kg specified by marshal mix design criteria. Hence the allowable limit of salt content is 4% in fresh bitumen to be incorporated. Otherwise 4% salt content in fresh bitumen can't be highly safe for bituminous road pavement. So, the presence of salt is harmful for bituminous binder. Sea water contains about 3.5 percent (35 grm/L) salt which is less than the tolerable limit but at 4% salt content the stability value is very close to minimum standard. In every cases, salt content should be less than the acceptable limit. After all the salt tolerable limit of the bituminous pavement is varying from 0 to 4 %.

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