A Study on Stripping of Coarse Aggregates of Andhra Pradesh

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Abstract: ***Stripping of the aggregates from bituminous roads is a very common problem in our country. Stripping is generally defined as the breaking of the adhesive bond between the aggregate surface and the bitumen. Stripping is a complex problem comprise of many variables, including the type and use of mix, aggregate and bitumen characteristics, construction practice and use of anti-stripping additives. External factors which mainly affect stripping are traffic and environmental conditions. To evaluate the stripping of aggregates, Indian Standard has prescribed the stripping test for which aggregates coated with bitumen are kept immersed in water for 24 hours at 40^{0}C. However, when the same aggregates are used on the road they do undergo stripping underwater. This happens probably due to the fact that lab and field conditions are different in respect of contact period of water with bitumen, prevailing field temperature and environmental conditions and various other factors. This study brings forth and discusses the results of a lab study conducted on coarse aggregates of Andhra Pradesh to evaluate their stripping value under prevailing field conditions.***

Keywords: stripping, coarse aggregates, additives on aggregate stripping, stone quarry, alkaline and acidic condition

1. Introduction

Proper adhesion between aggregate and bitumen is one of the principal fundamental properties for good performance of bituminous pavement. This adhesion can be reduced by presence of water which may cause de-bonding of bitumen from aggregate. The phenomenon is known as 'stripping'.
Contact of water with bituminous pavement is one of the main factors for stripping. The moisture affects physical properties and mechanical behavior of bitumen paving mixtures as aggregates that have a dry surface adhere better to bitumen and have a higher stripping resistance than wet aggregates. The physical and chemical characteristics of aggregates have a significant effect on the bonding between aggregate and bitumen. In addition, aggregate surface texture, aggregate porosity and pore structure are also known to affect stripping. A deficiency in properties of aggregate reduces the strength of the bond and leads bitumen-aggregate mixture towards stripping. Stripping may further cause rutting, raveling, bleeding, cracking and formation of potholes and culminate with complete failure of the pavement. Hence, to prevent pavement from these failures, we need to thoroughly investigate various factors which affect the stripping of aggregate.

1.1 Research Topic and Its Importance

The topic entitled "A Study on Stripping of Coarse Aggregates of West Godavari, Krishna and Guntur" aims at determining and analyzing various factors influencing stripping of coarse aggregates. The problem of stripping is very common in India and road network in West Godavari, Krishna and Guntur also faces this problem. Many a times it is experienced that the stripping of aggregate takes place on the road, even when laboratory tests indicate no stripping. This mainly happens because laboratory testing conditions are different from the field conditions. It is very important to control the problem of stripping as it is initiated with de-bonding and gradually leads to complete collapse of pavement. Such an acute problem may cause innumerous damage to the road. Bad condition of the road due to stripping creates various transportation problems like congestion, delay, maneuvering difficulties, increment in travel time and travel cost, socio-economic losses. Loss of lives in case of fatal accidents due to bad road condition must be taken into account because approximately 1.5% of road accidents occur due to poor condition of the road. The present study investigates the problem of stripping including various factors which show their existence in the field and may help in mitigating its ill-effects.

1.2 Objectives of the Study

The study under consideration aims to identify the factors causing stripping of coarse aggregate. It investigates the factors causing stripping of coarse aggregate including traffic and other environmental factors such as temperature, alternate wetting and drying and pH value of the water.
The main objectives of the study are:
1) To evaluate the stripping of coarse aggregate obtained from different sources of West Godavari, Krishna and Guntur under standard test conditions.
2) To vary the standard test conditions of temperature, immersion time and load to simulate the field conditions and to evaluate the stripping under these varying conditions.
3) To evaluate the stripping by subjecting the coated aggregate to a specified cycle of alternate wetting and drying.
4) To study the effect of additives on stripping.
5) To discuss the factors affecting stripping.

1.3 Scope of Research

In this study, experiments for evaluating the stripping value of road aggregate selected from different sources of West Godavari, Krishna and Guntur have been conducted under varying conditions. The aggregates have been selected from Donabanda, Koduru, Gouripatnam, Perecharla, Maaturu, Chimakurthi and I.pangidi quarries. Stripping test is performed on selected aggregate samples keeping into consideration various affecting factors like traffic load, temperature variation, wetting-drying cycles and extended immersion time in the water.

2. Methodology of the Study

The research approach used to achieve the study objectives is detailed in Figure 2.1.

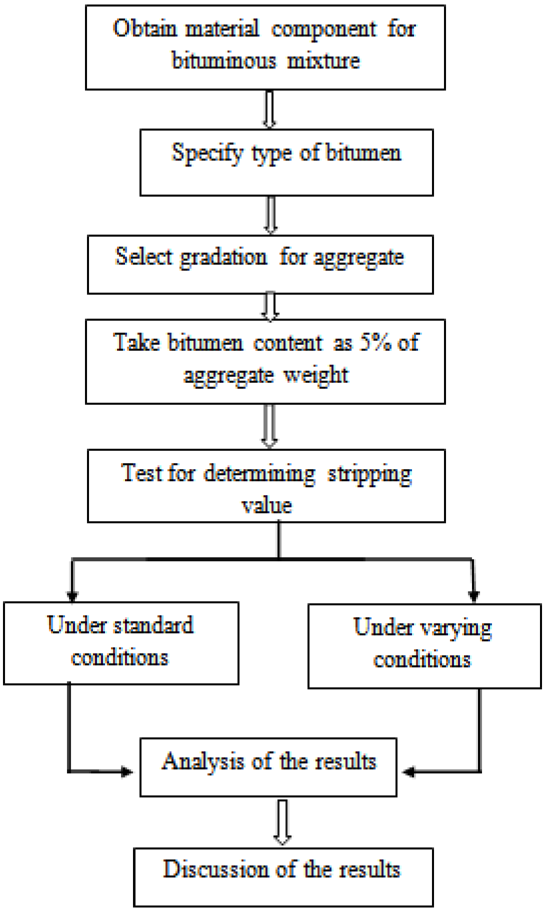

Figure 2.1: Flow Chart Illustrating the Research Steps

2.1 Tests to Determine Stripping

2.1.1 Test as per Indian Standard

'Method of Test for Determination of Stripping Value of Road Aggregates (IS: 6241-1971)' is the standard describing the stripping test for the coarse aggregate.

2.2 Tests under Varying Conditions

In this study, testing is performed on the aggregate-bitumen sample by undertaking various field conditions into consideration. Most of the times it is envisioned that the laboratory test conditions and field conditions vary a large extent leads to stripping of aggregates on the road even when laboratory tests indicate nil stripping value.

To determine the effect of these variables on stripping, experiments have been carried out in the highway engineering lab of M.V.R College of engineering and technology, Paritala. The effect of traffic load and tyre friction has been simulated by applying light pressure with finger nails of the observer.

These tests as well distinguish the result of type of bitumen grade i.e. viscosity grade 10 and 30, type of aggregates i.e. simple, dust coated and round aggregates and the presence of additives on the value of stripping of bitumen from the aggregate surface.

3. Experimental Investigation

This chapter describes the materials used, the preparation of the test samples and the test procedure. In order to achieve the stated objective, the study was carried out in stages. At the initial stage, all the materials and equipment needed were procured. Bitumen and aggregates were used in preparing samples in predefined proportions. Prepared samples were tested under standard and varying conditions. Finally, the results obtained were analyzed to draw out conclusions.

3.1 Materials Used

Materials used with their types are given in Table 3.1.

Table 3.1: Materials used in Tests

Material	Type
Crushed Aggregates	•Type 1, Source: Donabanda Quarry, Colour: Bluish-white. •Type 2, Source: Koduru Quarry, Colour: Light bluish-white •Type 3, Source: Gouripatnam Quarry, Colour: Reddish white.
Dust Coated Crushed Aggregates	•Type 1 •Type 2 •Type 3
Gravels (Rounded aggregates)	•Type 1 •Type 2
Bitumen	•VG-10 grade, Source: I.pangidi Refinery, 5% of mass of aggregate. •VG-30 grade, Source: I.pangidi Refinery, 5% of mass of aggregate.
Additive	•Quick lime •Portland cement
Water	•Potable water

3.2 Experiment results

Stripping test is carried out under standard conditions and varying conditions to determine the change in the value of stripping on different aggregates. To observe the effect of grade of bitumen on the value of stripping, the tests have been conducted with two types of bitumen of VG-10 grade and VG-30 grade respectively.

3.3 Stripping tests on crushed aggregates general

Three types of aggregates from different sources are taken for evaluating the value of stripping under various testing conditions. These three types of aggregates from Donabanda, Koduru, Gouripatnam quarries are shown in figure 3.1.

Figure 3.1: Type 1 Aggregate from Quarries

All the tests were performed on the aggregates which are menstioned at different sections explained above. From the test results the discussion and analysis is carried out.

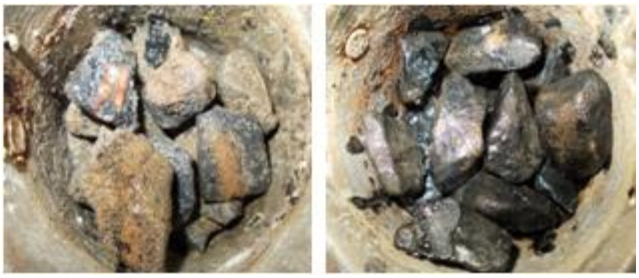

Figure 4.2: Stripping of aggregates in alkaline and acidic condition

3.4 Stripping value using bitumen of viscosity grade 3 (VG-30):

3.4.1Stripping of Aggregates at Different Temperatures

A sample of Type 2 aggregates (Koduru Quarry) are tested at 20^0C, 40^0C and 60^0C respectively and increase in water immersion time from 1 day to 7 days in order to determine the effect of temperature and extended contact time of water on the value of striping. The effect of traffic load and tyre friction has been simulated by applying light pressure with finger nail. The results obtained are mentioned in Table 3.2 and graphically presented in Fig. 3.3.

Table 3.2: Stripping at Different Temperatures (Type-2 Aggregates)

S No	Contact time of Bituminous mix with water (Days)	Stripping value in % at Temperature					
		20^0C		40^0C		60^0C	
		Without pressure	With finger pressure	Without pressure	With finger pressure	Without pressure	With finger Pressure
1	1	Nil	Nil	Nil	Nil	Nil	Nil
2	2	Nil	Nil	Nil	0-0.5	0-0.3	0-0.5
3	3	Nil	0.2-0.3	0-0.5	0.5-1	0.5	0.5-1
4	4	0-0.3	0.3-0.5	< 1	< 2	0.5-1	1-2
5	5	0.3-0.5	0.5-1.0	1.5	2	< 2	< 3
6	6	0.5-0.8	1.0-1.5	1.5-2	2-2.5	2-2.5	3-4
7	7	0.8-1.0	1.5-2.0	2.5	3	3-3.5	> 4

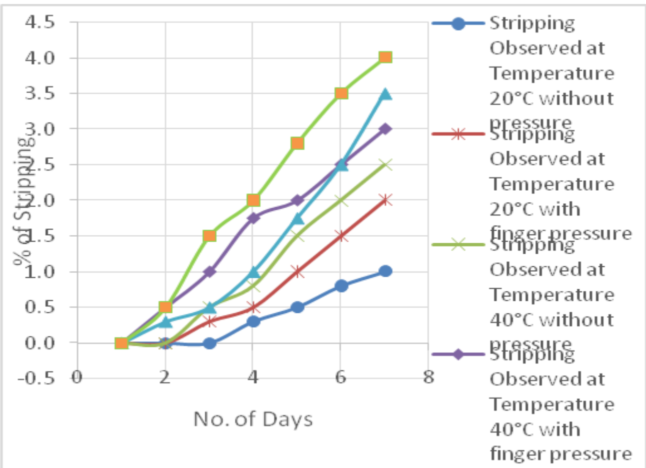

Figure 3.3: Stripping at Different Temperatures

It is observed from Fig. 3.3 that the stripping of coarse aggregate increases with increase in temperature of water, number of days the water remains in contact with coated aggregates and the applied pressure on the coated aggregates. Likewise all the tests were performed and recorded.

4. Analysis and Discussion of Results

To find out stripping of coarse aggregate obtained from different sources of Krishna, stripping tests are conducted under standard and varying conditions. Several trials have been performed in accordance with the methods identified in chapter-3. The test results are discussed here in this chapter. The discussion is divided into seven sections according to the objectives stated in the earlier part of the thesis. The seven sections mentioned are:

1. Effect of temperature and immersion time on stripping.
2. Effect of bitumen grade on stripping.
3. Effect of wet-dry cycles and altered temperature on stripping.
4. Effect of surface moisture on stripping.
5. Effect of type of aggregates on stripping.
6. Effect of alkaline and acidic water on stripping.
7. Effect of additives on stripping.

3.1 Effect of temperature and immersion time on stripping

It is experienced that the friction between aggregates is retained at high temperature but bitumen-fines viscosity and stability reduces at high temperature thus resulting in strength loss, which eventually increases the value of stripping (International Symposium, 1985).

Various lab experiments show that with the increase in temperature the stripping value increases as viscosity of bitumen decreases which reduces the bonding of bitumen with aggregate.

Stripping test conducted on bitumen coated aggregates at 20^{0}C, 40^{0}C and 60^{0}C and it is observed from the Fig. 4.1and 4.2 that stripping value increases with increase in contact time, test temperature and applied pressure on the aggregates. The stripping value increases from zero to about 5% with increase in temp from 20 to 40^{0}C, contact time from one to seven days and pressure condition from 'No pressure' to slight pressure of finger nails.

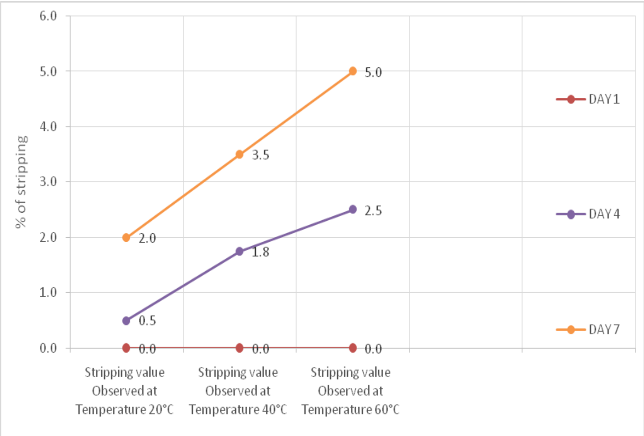

Figure 4.1: Striping Value at Different Temperature and Days (without Pressure)

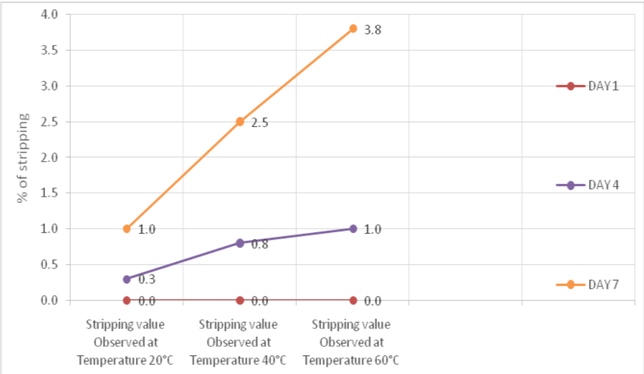

Figure 4.2: Striping Value at Different Temperature and Days (under Applied Pressure)

3.2 Effect of bitumen grade on stripping

Bitumen must adhere to the aggregate for providing proper adhesive binding between bitumen and aggregate. Bitumen-aggregate interaction is important to resist stripping and maintain stability in mix against various other factors. The properties of the bitumen that influence the bitumen-aggregate bond are viscosity, film thickness and surface energy.

The viscosity of the bitumen does play a role in the propensity of the bitumen mixture to strip. It has been reported that bitumen with high viscosity resists displacement by moisture better than those that have low viscosity. Bitumen with high viscosity usually carry high concentrations of polar functionalities that provide more resistance to stripping and provide a better coating (Bahia, H. U., et al 2007). It has likewise been reported that the bond strength is immediately associated to film thickness. Samples with thicker bitumen film tend to have cohesive failure after moisture conditioning. On the other hand, specimens with thinner asphalt film have an adhesive failure. A thin asphalt film makes the mix more susceptible to stress and weathering (Kanitpong, K. and Bahia, H. U. 2003).

Various tests are conducted taking bitumen of viscosity grade 10 and 30 to determine their effect on the value of stripping. It is observed from the Fig. 4.3 that the bitumen of grade 10 (VG-10) shows higher value of stripping as compared to bitumen of grade 30 (VG-30).

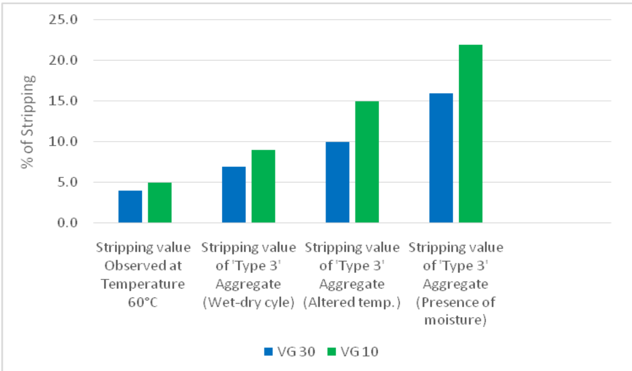

Figure 4.3: Stripping Value due to the Different Bitumen Grade (under Applied Pressure)

3.3 Effect of wet-dry cycle and altered temperature on stripping

Variations in temperature, freeze–thaw cycles, and wetting–drying cycles increase the stripping potential of bituminous pavements (Roberts F.L. el at 1991).

To simulate field conditions of temperature variation during the day and night (in summer season) and water contact during rainy season, tests are conducted on an aggregate-bitumen, mixture under the condition of wetting-drying cycles and altered temperature. The effects reported in previous chapter shows that the value of stripping increases radically as these variations affect stability of the mixture.

The value of stripping increased to about 5% when aggregate-bitumen sample is tested under wetting-drying cycles as compared to its values under standard conditions with applied finger pressure.

The value of stripping increased to about 10% when aggregate-bitumen sample is tested under altered temperature condition as compared to its values under standard conditions with applied finger pressure.

Comparison of the stripping values under different test conditions is presented graphically in Figure 5.4.

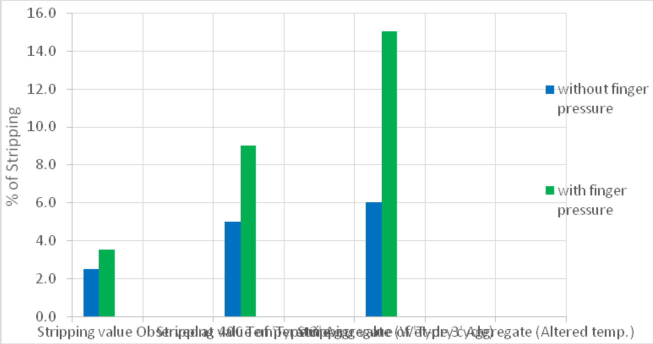

Figure 4.4: Stripping Value under Varying Conditions (under Applied Pressure)

4.4 Effect of surface moisture on stripping

Moisture damage can be defined as the loss of strength and durability in bitumen mixtures caused by the presence of water. The level and the extent of moisture damage, also called moisture susceptibility, depend on environmental, construction, and pavement design factors.

Moisture damage is induced by the loss of bond between the bitumen or the mastic (bitumen, the mineral filler and small aggregates) and the fine and coarse aggregate. Moisture damage accelerates as moisture permeates and weakens the mastic, making it more susceptible to moisture during cyclic loading and ultimately leads towards stripping.

There are various factors which affect the process of stripping, but contact of water with bituminous pavement is one of the main factors for stripping. Presence of moisture on the surface of aggregate reduces the potency of bond with bitumen, such mixture under cyclic load and high tyre pressure shows stripping. Aggregates that have a dry surface adhere better to bitumen and have higher stripping resistance than do damp or wet aggregates (Majidzadra, K. and Brovold, F.N., 1968).

When bituminous mixtures are exposed to water, bitumen can be displaced from the aggregate because water breaks interfacial adhesive bonds between the two materials. When water enters the interface, it tends to wet aggregate surfaces and removes bitumen from it. Although, the process of bitumen removal is dependent characteristics of both the bitumen and aggregate.

The effect of the presence of moisture on stripping value is evaluated by conducting a stripping test on moist aggregates with an increasing immersion time of sample of water from one day to seven days. It is observed from the Fig. 4.5 that the value of stripping is continuously increasing and raised up to 15% under this condition with application of finger pressure as compared to standard test condition.

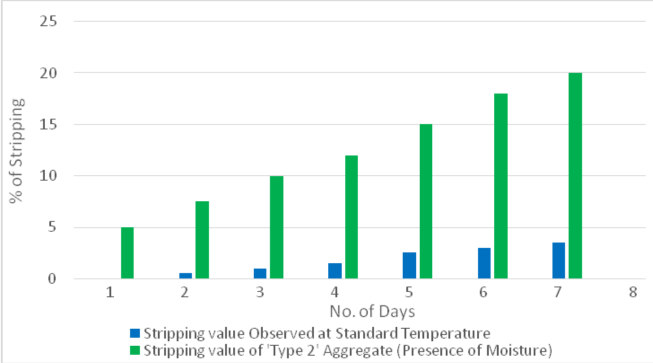

Figure 4.5: Stripping Value under Moist Condition (under Applied Pressure)

3.4 Effect of type of aggregates on stripping

Aggregate type and their physical properties have confounding effect on the value of stripping. Bitumen-aggregate interactions are strongly influenced by the composition and surface chemistry of the aggregate. Some literature considers that aggregate property is much more influential in determining adsorption and stripping behavior than are bitumen properties. The nature of aggregate surface to which bitumen is to adhere is the first item to be considered in determining the formation and permanence of a bitumen-aggregate bond (Thelen,E., 1958).

Lab tests indicate that rounded aggregates are more prone towards stripping as a bituminous mixture derives its strength from the cohesion resistance of the binder and grain interlock and frictional resistance of the aggregate and the rounded aggregates have a smooth surface with the negligible frictional value.

If good bond exists, failure of the mixture occurs within the binder. If the bond is poor, the failure may occur at the binder-aggregate interface and may result in premature failure of the mix (Majidzadra, K. and Brovold, F.N., 1968). Lab tests specifythat susceptibility of dust coated aggregates towards stripping is lower than rounded aggregates, but higher as compared to crushed aggregates. Dust on aggregate surfaces have a tendency to trap air when the road oils or cutbacks are applied.

This weakens the bitumen/aggregate bonding, or joint, by preventing intimate contact between the aggregate and the bitumen. It also promotes stripping by creating channels at the interface, through which water can penetrate.

It is observed from the Fig. 4.6 that the value of stripping is highest for gravel (round aggregate) and least for crushed aggregates. Dust coated aggregates show slightly higher value of stripping as compare to crushed aggregates.

Comparison of stripping value of different aggregates is presented graphically in Figure 4.6.

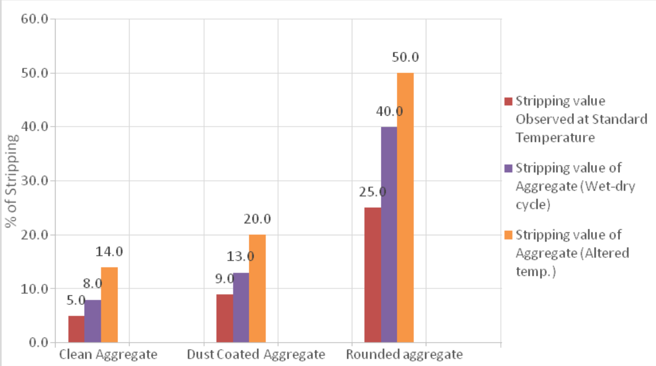

Figure 4.6: Stripping Value of Different Aggregates (under Applied Pressure)

3.5 Effect of alkaline and acidic condition on stripping

PH value of water is a dominating factor which involve in the process of stripping as instability in pH value cause stripping of bitumen mix. Change in pH of water, which is in contact with bituminous pavement influences the adhesion property of aggregate-bitumen bond. It is seen that the water susceptibility of the hydrogen bonds and salt links at the interface would increase with pH of the water at the aggregate surface.

The chemical and electro-chemical properties between water and aggregate surface play a greater role in striping than the physical characteristics of aggregates.

The zeta potential of aggregate surface in water and/or the pH value of water imparted by aggregate could be used to measure stripping potential. In general, higher zeta potential and/or the pH value, higher the probability of stripping (Russell G. Hicks, 1991).

The nature of the water to which the mix is exposed (salt content, pH) affects stripping. The pH causes a shift in angle of contact and significantly affects the wetting properties of bitumen. The higher the pH value of water higher will be the chances of stripping.

Experiments conducted at lab under acidic and alkaline conditions show that the value of stripping is very high under alkaline condition as compared to acidic conditions. Stripping value of aggregates increase up to 15 percent under applied pressure in alkaline condition as compared to the normal condition. On the other hand, there was not much difference in the value of stripping under acidic condition as compare to the normal value of stripping.

Comparison of the stripping values is presented graphically in Figure 4.7.

3.6 Effect of additives on stripping

Additives are used to reduce moisture susceptibility of bitumen mix. Reduction in inclination of bitumen mix towards moisture decreases the chances of stripping of the mix. Anti-stripping agents are used as additives as these are chemically designed to improve the adhesion between the binder and the aggregate. Hydrated lime is widely used as ASA for reducing the moisture susceptibility of bitumen mix. Some other solid ASAs used are Portland cement, fly-ash, flue dust, etc. The liquid ASAs used include liquid amines and di-amines, liquid polymers, etc.

The mechanism by which liquid anti-stripping agents work is by reducing the surface tension between bitumen binder and aggregate surface, thus improving the aggregate coating and reducing the moisture damage of bituminous pavements (Dybalski, 1982). The addition of lime is the most accepted way to reduce the moisture susceptibility. The general practice is to add 1 to 1.5 percent of lime by the dry weight of the aggregate to the mix. If the aggregate contains more fines, more lime may be required to be added to the mix due to the increased surface area of the aggregate. Generally, three forms of lime are used in HMA: Hydrated Lime ($Ca(OH)_2$), Quick Lime (CaO), and Dolomitic Lime.

It is assumed that the mechanism by which hydrated lime improves the moisture susceptibility of the HMA involves a chemical interaction between the calcium in the lime with the silicates in the aggregate (Selim, 1997). Hydrated lime has proven to work effectively in a wide variety of aggregate sources.

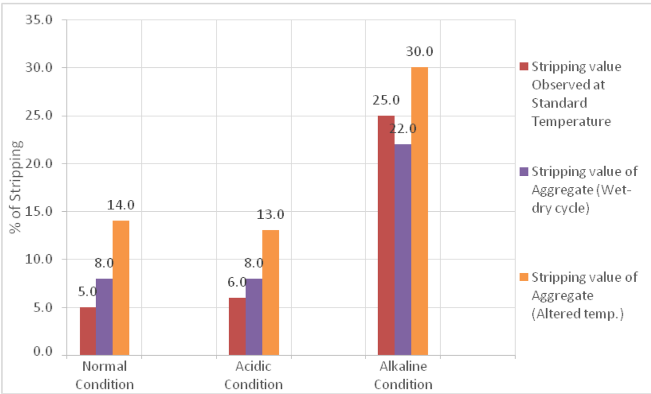

Figure 4.7: Stripping Value at varying pH Values (under Applied Pressure)

Hydrated lime and Portland cement are used as anti-stripping agents in lab experimentation to determine their effect on the value of stripping on various aggregates. It is observed from the Fig. 4.8 that in case of crushed aggregates value of stripping reduced to an average of 10 % and resides to about 2%. Fig. 4.9 and 4.10 shows that the value of stripping reduced to an average of 12% and 30% in case of dust coated and rounded aggregates and resides to about 2.5% and 4% respectively.

Fig. 4.8, 4.9 and 4.10 present stripping value of different aggregates with use of additive (hydrated lime) under applied finger pressure.

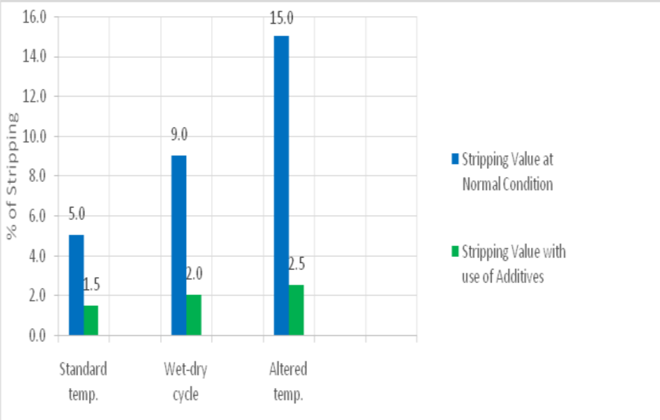

Figure 4.8: Stripping of Crushed Aggregate Type 3 (under Applied Pressure)

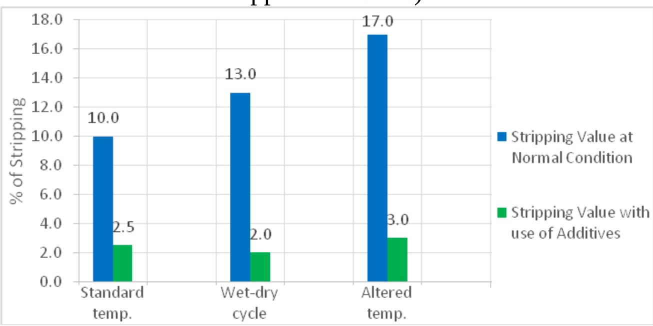

Figure 4.9: Stripping of Dust Coated Crushed Aggregate Type 3 (under Applied Pressure)

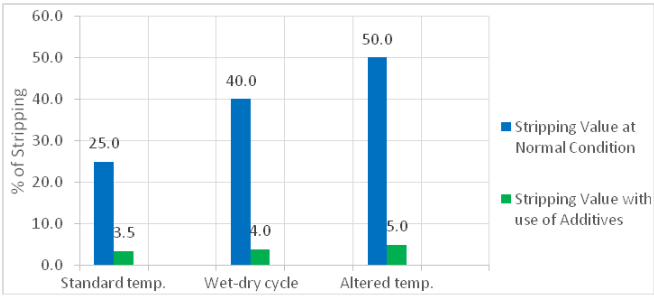

Figure 4.10: Stripping of (Gravel) Rounded Aggregate Type 2 (under Applied Pressure)

5. Conclusions

The present study on the topic "A Study on Stripping of Coarse Aggregates of West Godavari, Krishna and Guntur" has been carried out with a perspective to determining and analyzing various factors influencing stripping of coarse aggregates. Tests are conducted to investigate the effect of traffic load, tyre friction and other field conditions on the value of stripping. Effect of type of bitumen and various types of aggregates on the value of stripping is also taken into consideration. This study also involves the variation in the standard laboratory testing procedure recommended for determining the value of stripping for aggregates.

The main conclusions drawn from the study are:

1. Stripping of aggregates is caused on the roads when they are subjected to inundated conditions due to poor drainage and improper construction of the roads. The test conditions to determine stripping value in the lab do not properly simulate the field conditions. The difference in test and field conditions leads to stripping in the field many a times whereas lab test results indicate no stripping.
2. The lab test results indicate that stripping increases with increase in contact time, test temperature and applied pressure on the aggregates at the time of stripping.
3. Higher viscosity grade bitumen shows higher resistance to stripping than low viscosity bitumen.
4. Altered temperature cycles and wetting-drying cycles increase the stripping of aggregates.
5. Rounded aggregates have the highest value of stripping because of their smooth surface which does not offer any frictional resistance and grain interlock.
6. Dust coated aggregates have higher stripping value than simple aggregates as presence of dust on aggregate surface reduces aggregate-bitumen bond potency.
7. pH value of water also affects the stripping. It is seen that the mix exposed to water with a high pH value undergoes more stripping.
8. Use of additives reduces the value of stripping and limit it to approximately 2%, which is acceptable as per IS 6241:1971.
9. Lab test conditions need to be modified to take into consideration the field conditions that affect the stripping.

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