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INVESTIGATING THE EFFECT OF ALTERNATE WETTING AND DRYING ON THE PERFORMANCE OF COIR REINFORCED SMA

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Abstract: ***Transport sector accounts for a share of 6.4 per cent in India's Gross Domestic Product (GDP). Road transport has emerged as the dominant segment in India's transportation sector, with a share of 5.4 percent in India's GDP. Hence taking steps to increase the life of pavements is an absolute necessity to maintain the growth of transportation in India. Owing to India's strategic location near the equator, the roads here face drastic conditions wherein they undergo phases of alternate wetting and drying which ultimately reduce the life of flexible pavements. This project investigates the effect of alternate wetting and drying on coir reinforced SMA. Optimum bitumen content and optimum fiber content were estimated using Marshal Method of Mix Design and their performance was analyzed with respect to virgin mix. To study the effect of alternate wetting and drying on the pavements' performance, the samples were conditioned with alternate wetting and drying cycles, and were tested for indirect tensile strength and wheel rut. It was observed that upon addition of coir fibre, the drain down and rutting properties improved and the tensile strength of the mix increased. A higher rate of pavement deterioration was observed with an increase in number of alternate wetting and drying cycles. Hence, when pavement design factors are considered, in addition to prolonged exposure to wetting condition, the effect of alternate wetting and drying should also be taken into account.***

*Keyword**: Road transport; pavement; wetting and drying; coir; reinforcement; SMA; rutting***

I. INTRODUCTION

In today's world of increasing traffic demand, there is a growing concern to construct long lasting pavements with minimum maintenance. Thus, the concept of perpetual pavements (long lasting pavement) is gaining momentum for the reasons of economic and environmental sustainability.

For ensuring long-term performing pavements, focus should shift towards introducing rut resistant mix in order to tackle the prime pavement distress of rutting. SMA reinforced with a fibre additive is one such mix. Both synthetic as well as natural fibres can be used as a stabilizing additive. Natural fibre outranks synthetic fiber in terms of economic and environmental concerns. Evaluation of SMA reinforced with coir is presented in this study. Apart from the widely discussed distress issues of rutting, cracking, shoving etc, moisture also plays a role in deteriorating the pavement. It manifests itself in the form of moisture caused and moisture accelerated distresses. The moisture damage is ever prominent in tropical regions which are exposed to conditions of alternate wetting and drying. This effect is investigated within this study.

II. MOISTURE SUSCEPTABILITY

Moisture damage in asphalt concrete pavements, better known as stripping, is a primary cause of distresses in the asphalt pavement layers (Hicks, 1991; Pan et al.,1999; and Epps, 2000). The frequent exposure of asphalt pavements to water is often one of the major factors affecting the durability of HMA .This is predominant in tropical regions which are prone to alternate wetting conditions throughout the year. Though the effect of freezing and thawing on pavements has been extensively studied, literature related to the effect of moisture on the durability of pavements is sparse.
The test procedures developed to capture the effect of moisture susceptibility seldom captures the effect of alternate wetting and drying conditions. An attempt has been made to study the effect of alternate wetting and drying conditions

MOISTURE DAMAGE AND ITS MECHANISMS

Moisture-induced damage is the loss of adhesion between asphalt and aggregates in a mix (stripping) and/or the loss of cohesion within the asphalt mastic (Cheng et al. 2002). Stripping is a major cause of distress in flexible pavements. Flexible pavement distresses that could be attributed partly to stripping include cracking, raveling, and rutting. Stripping due to the exposure to moisture in asphalt mixes, led to the development of quantitative and qualitative tests on asphalt pavements (Kandhal 1994, Hicks 1991).The water induced damage in HMA layers may be associated with two mechanisms: loss of adhesion and/loss of cohesion (Hicks 1991).
Moisture susceptibility test in which the sample is continuously immersed in water for a period of 24 hours is used to

capture the effect of moisture on pavement. The tensile strength of the soaked specimen is compared with that of the unconditioned specimen to yield Tensile Strength Ratio (TSR). The TSR value is used to gauge the moisture susceptibility of the mixture. Even though these test procedures capture the effect of extreme conditions of exposure to moisture .The effect of alternate wetting and drying on pavements remain unexplored.

III. METHODOLOGY

Samples are subjected to alternate wetting and drying conditions. The performance of these samples is then compared with the unconditioned specimen. Performance was evaluated using indirect tensile strength and wheel rut.

The 24 hour time window was dividing into equal time intervals. Cycles of 4 hour, 6 hour, 8 hour, 12 hour and 24 hour duration were selected. The specimen was then subjected to alternate wetting and drying conditions for the above mentioned time intervals. For a 4 hour cycle, the sample is initially soaked in water for a period of 4 hours and performance tests are then carried out. For the next test point (performed at the end of 8 hours), the sample is initially soaked in water for 4 hours and then dried in air for another 4 hours and tested at the end of this period.

The process is extended for 24 hour duration. The values at the end of 24 hours for each of these different cycles (4, 6, 8, 12 and24 hours) are compared with the sample that is soaked in water continuously for 24 hours. Another set of samples were subjected to dry conditions initially and then subjected to wet conditions. Performance tests were then carried out at the end of each cycle. The same procedure of alternate wetting and drying was applied for conditioning the specimens for Wheel Rut Test. The rut depth obtained from this test was used to evaluate the performance of the pavements when subjected to alternate wetting and drying conditions.

IV. INDIRECT TENSILE STRENGTH

Using the indirect tensile strength, the cracking resistance and properties of the mixture is found out. The same procedure when applied by conditioning the specimens yields in the tests for moisture susceptibility. Hence to ascertain the effect of alternate wetting and drying the same procedure was followed by conditioning the specimen by subjecting it to alternate conditions. The Indirect Tensile Strength Test (ITS) was carried out as per ASTM D6931-12 The samples were casted as in the case of Marshall testing, but for the optimum binder and fibre length condition which was selected according to its performance.

IDT strength= 2000p/πdt

St = IDT strength, kPa

P = maximum load, N

T = specimen height immediately before test, mm

d = specimen diameter, mm

Figure 4-1 shows the strength tested at the end of 24 hours when subjected to multiple cycle changes according to the cycle duration i.e. 4 hour duration cycle undergoes 6 changes within 24 hours whereas 6 hour cycle experiences 4 changes and the like. . 4 hour cycle experiences more number of changes compared to 6,8,12 hour cycles and strength value

Table 4-1. Strength results of wetting and drying cycle

CYCLE DURATION (HR)	TESTING TIME(HR)	WET POINT/ DRY POINT	ITS (KPA)
4	**4**	**W**	**135.673**
	8	**D**	**937.005**
	12	**W**	**147.674**
	16	**D**	**766.712**
	20	**W**	**161.009**
	24	**D**	**636.465**
6	**6**	**W**	**171.652**
	12	**D**	**989.932**
	18	**W**	**177.389**
	24	**D**	**822.497**
8	**8**	**W**	**173.224**
	16	**D**	**906.96**
	24	**W**	**184.485**
12	**12**	**W**	**195.168**
	24	**D**	**837.228**
24	**24**	**W**	**222.889**
	48	**D**	**849.074**
26	**6**	**D**	**837.73**
	12	**W**	**115.693**
	18	**D**	**589.724**
	24	**W**	**134.406**

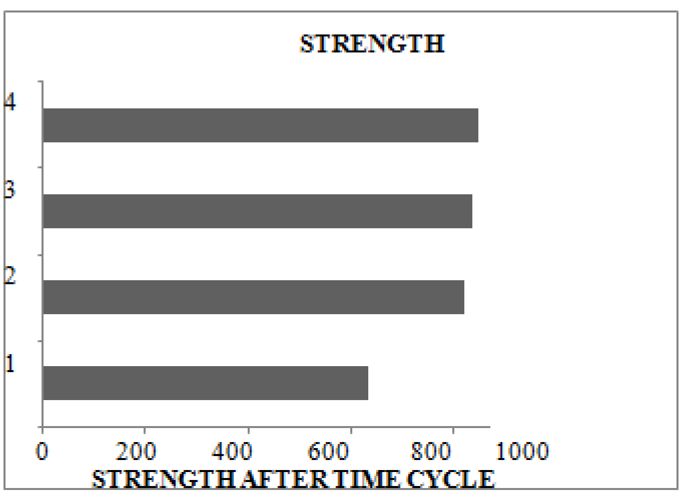


Figure 4-1. Graph showing the effect of cycle change

at the end of 24 hours is also least for the same. Whereas 12 hour cycle undergoes least number of cycle change and has higher strength decreases with increased number of fluctuations. Another evident point is that all values tested at dry conditions display a very high value compared to the ones that are tested at wet conditions. This trait is seen in all cases.

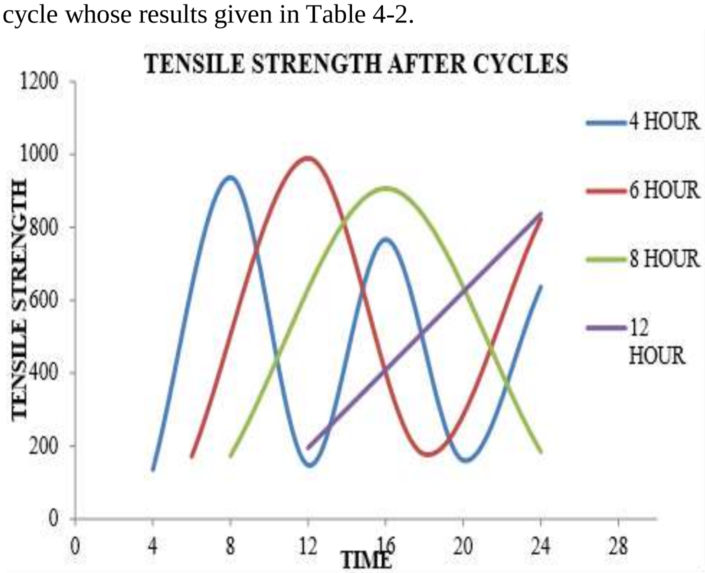
Testing time	Wet point/Dry point	ITS (kPa)
6	**D**	**837.730193**
12	**W**	**115.6934009**
18	**D**	**589.7242827**
24	**W**	**134.4057469**

Table 4-2.Strength results of dry wet cycle

This may be due to the fact that ageing plays a more prominent role when exposed to dry conditions. The same is the reason that 4, 6 and 12 hour cycle end points offer a very high strength which is even greater than the existing worst case check for moisture susceptibility(continuous soaking for 24 hours).Hence these values cannot be compared with the worst condition.

Thus, dry wet cycle provides the answer to this problem, wherein the cycle terminates at wet conditions for the above durations. Dry wet of 6 hour cycle is used for this purpose.

By comparing the end point strength value of 8 hours cycle (which terminates at wet condition) with the moisture check of 24 hours soaking, it can be seen that the 8 hour cycle of alternative wetting and drying gives a lower strength than the current check for moisture susceptibility. The repeatability of this result is sought in conducting the 6 hour dry wet cycle whose results given in Table 4-2.



Strength variation with time

V. WHEEL RUT

Rut is the second performance parameter chosen in this study to test the influence of alternate wetting and drying on the mixture characteristics. This test was adopted since it combines both effect of loading as well as repetition of loads, and hence is in a better position to capture the real time scenario of loading.
Using the Wheel Rut Tester, the conditioned specimen is subjected to a definite number of laod passes after which the rut depth is measured

A .PROCEDURE

The Wheel Rut test procedure, first the specimens are prepared as per the Marshall mix design for 2cm fibre length with 0.4% binder content combination, which was selected based on its performance.

Cycle duration	W/D	Rut depth(mm)
4	**D**	**4.265**
6	**D**	**2.281**
8	**W**	**3.655**
12	**D**	**1.993**

Table 5.1.Alternative wetting and drying for 6hour cycle

After casting the specimens they are allowed overnight cooling after which they are extruded and conditioned by subjecting it to alternate cycles of wetting and drying. The specimens are exposed to alternate cycles of wetting and drying of 6 hour duration wherein the specimen is first put in water bath for 6hours followed by a dry period when it is kept in open for the next 6 hours,; the same pattern is repeated till the end of 24 hours. Thus the complete 6 hour cycle is tested, both at intermediate and end points. The other cycle durations of 4,8 and12 hours are tested only at the end points.

The results for the Wheel rut test is provided in Table 5-1 and Table 5-2.These tables presents both the end point and intermediate rut depths for the 6 hour cycle, and the end point values for the other cycles. From Table 5-3 the variation in the rut depth across the 6 hour cycle is observed. It displays a similar trend as in the case of tensile strength of conditioned specimens, wherein testing at dry conditions yielded a far higher strength value when compared to strength tested at wet conditions.

Table 5-2. End point values of Rut test

CYCLE DURATION	*TESTING TIME(HR)*	*W/D*	*RUT DEPTH(MM)*
6	***6***	***W***	***2.541***
	12	***D***	***2.042***
	18	***W***	***3.052***
	24	***D***	***2.281***

This same pattern is etched throughout rut results for 6 hour cycle duration since a distinctive drop in rut depth is observed at dry conditions.

Another similar trend that crept in from tensile strength variations is the effect of number of fluctuations. In section 5.3, it is seen that the tensile strength within the same time period(24 hours)decreases with the increase in number of fluctuations between wetting and drying. More the change points, lesser the strength at the same end point. This is reflected in the end point rut values of 4,8 and 12 hours, where the rut depth is higher for 4hour cycle than for 8 hour which is higher than for 12 hour(4.265>3.655>1.993).Hence, rut echoes similar observations as in the case of tensile strength. This study on the effect of alternate wetting and drying by examination of the two parameters, Tensile Strength and Rut points that the alternating conditions does play a performance deteriorating role By looking at the primary parameter, strength, it seen that the strength values of an alternate conditioned specimen is higher when tested in dry condition than in wet conditions. This may be due to the prominent role that ageing plays when exposed to dry conditions than in water.

Moreover the number of cycle change or alternations is found to play a deciding role in the tensile values. Higher the number of shifts between exposure conditions, lesser is the final end point strength within a fixed time interval.

The second parameter, rut depth supports the above two observations since it displays similar behavior.

Another observation from the tensile strength values is that the alternately conditioned specimen yields a lesser strength than the current check for moisture susceptibility. The adopted check for moisture sensitivity involves soaking the specimen in water for a period of 24 hours. The strength achieved at the end of 24 hours is greater than the strength achieved by subjecting it to cycle changes for the same period of 24 hours. This suggests that the effect of alternate wetting and drying should also be considered while capturing the worst case scenario for design purpose. This effect might be most prominent in tropical countries faced with spells of wetting and drying and also intermittent rain falls.

VI. CONCLUSION

The following conclusions were drawn after series of laboratory tests:

The optimum binder content for various combinations of lengths and percentage of coir were determined using the peak stability value, peak unit weight and median of percentage air voids and checked against MoRTH specification.

The optimum binder content is as follows

- Virgin mix – 5.95%
- 1cm, 0.3% - 6.1917%
- 2cm, 0.3% - 5.967%
- 2cm, 0.4% - 6.05%
- 2cm, 0.5% - 6.008%

Performance tests such as IT, drain down and Wheel rut were conducted on these combinations and virgin mix.

FOR ITS,

- Maximum improvement was 61.42% for 2cm 0.5% (144.96 kPa to 234 kPa)
- Minimum improvement was 6.3% for 2cm 0.3% (145.45kPa to 154.73kPa

For Draindown

- Maximum improvement was 64.24% for 2cm 0.4% (0.58 to 0.208)
- Minimum improvement was 29.85% for 2cm 0.3% (0.58 to 0.407)

For Rut

- Maximum improvement was 24.308% for 2cm 0.4% (5.06 to 3.83)
- Minimum improvement was 17.19% for 2cm 0.5% (5.06 to 4.19)

Based on the performance tests 2cm, 0.4% yielded better results.Therefore this combination was subjected to further testing with cycles of varying temperatures using ITS and wheel rut.

After subjecting the samples to alternate cycles of wetting and drying for time cycles of 4hr, 6hr, 8hr, 12hr and 24hr and testing for tensile strength and wheel rut at every point and end point, it was observed that when the number of cycles increases the performance deterioration was more. Also samples being tested at dry condition have more tensile strength than that at wet condition which may be due the effect of ageing. With the passage of time and increase in cycles the pavement deterioration is seen to be more.

Samples being subjected to alternate cycles of wetting and drying were observed to have lesser tensile strength than when exposed to continuous soaking for 24hrs. Wheel rut test also showed a similar trend to tensile strength.

VII.LIMITATIONS OF STUDY

- The study is limited to inclusion of coir fibre toSMA
- Percentage addition and length of fibre was limited
- Alternate wetting and drying was studied for limited number of cycles

SCOPE FOR FURTHER STUDIES

- Different fibres can be included and their performance can be compared.
- Different types of mixes such as BC can be studied with inclusion of fibre.
- Percentage of fibre and length of fibre can be varied.
- The study can be increased by the inclusion of more number of cycles and for a larger time interval.
- Aging effect can be studied in detail.

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