DETERMINATION OF OPTIMUM POTENTIAL APPLICABILITY FOR PREVENTION OF MOISTURE DAMAGE IN PAVEMENT BY USING ZYCOTHERMS

[1]M.Varun Kumar, [2]H.N. Kishan, [3]B.Naveen Kumar, [4]E.Anjaneyulu
[1,2,3]Assistant Professor, [4]UG Student, [1,2,3,4]Department of Civil Engineering, Brilliant Grammar School Educational Society Group of Institutions Integrated Campus, Hyderabad, India

ABSTRACT
The causes of flexible pavement failure have been studied by a number of researchers over the years, and they have provided a range of solutions for issues like rutting, fatigue, and low temperature cracking, which are caused by the susceptibility to moisture as well as the temperature sensitivity of either asphalt, aggregate, or the asphalt mixture as a whole. In order to address potential failure issues in flexible pavements, this study is being conducted to determine the ideal amount and potential applicability of zycotherm nanomaterial in asphalt and asphalt concrete mixtures with two different systems: directly applying to bitumen and dilution and applying to aggregate. The study is carried out experimentally by conducting tests on bitumen and bituminous mixtures.

Seepage through soil sub bases in most commonly facing problem in sub base of pavements in order to avoid this problem researchers found a revolutionary technologies in the form of waterproofing chemicals for soil. Due to reduction in the water seepage, the soil bases can be compacted better and they act as structural layers to offer better strength and durability for the pavements.

Zycotherms are the nano materials when sprayed, it offers waterproofing basement for different soils. Zycotherms changes the surface of an aggregate from hydrophilic (water- loving) to hydrophobic (oil-loving) its particles capture and isolate the asphalts in bitumen and drag them to the surface of the aggregate.

INTRODUCTION

Warm temperatures are ideally suited for producing asphalt mixture, which has been shown to increase energy savings and reduce CO2 emissions. The warm mix method has been extensively employed for road construction and restoration due to its performance being equivalent to that of hot mix asphalt (HMA). When compared to other innovations in the history of the asphalt business, the technique is widely acknowledged as the most successful invention, claim Crew et al. From a few thousand in 2005 to an estimated 46 million metric tonnes in 2010 and 55 million metric tonnes in 2011, the United States alone produced a lot more of it. According to global field observations, the majority of the warm mix trial portions exhibit satisfactory performance or performance as good as HMA control sections.

Based on previous studies and field experiences elsewhere, this technology should be adapted for implementation in Malaysia. In this regards, extensive laboratory studies have been conducted to evaluate the applicability of a surfactant-based silane additive, ZycoTherm. Use of this additive enables asphalt mixtures to be produced and compacted at lower temperatures by enhancing mixture workability, and to allow construction processes to be performed at lower temperatures. Besides that, pavement distresses due to moisture damage are among the main concerns in the durability of asphalt pavements. A thorough coating is essential to lower the possibility of premature failure by moisture and bonding between materials. Applications of this advance generation silane additive could potentially improve the performance of asphalt mixture through a better coating and bonding between materials. Based on a study conducted by Mirzababaei, ZycoTherm chemically modified the aggregate surface to create a molecular level hydrophobic zone that gives a strong bonding of bitumen on aggregates. These could thus enhance the asphalt mixture performance, prolong the pavement service life, as well as help to support sustainable infrastructure development in Malaysia. This study involved both asphalt binder and mixture performance tests to assess the compatibility and applicability of ZycoTherm with typical road making materials used in Malaysia. The basic and rheological properties of the control or conventional binders (60/70 and 80/100 Penetration Grade) and the asphalt binders incorporating 0.1% ZycoTherm were evaluated in terms of its penetration, softening point, rotational viscosity and complex modulus.

On the other hand, there has also been a great impetus to use recycled asphalt pavement (RAP) with WMA technologies to decrease the environmental impacts and save natural resources using less virgin material and reducing CO2 emissions. Since RAP particles have aged binder, reducing mixing temperature using WMA technology can prevent excessive aging. Moreover, the use of RAP at high percentages in WMA can compensate for the less resistance of WMA against moisture susceptibility. In spite of having many advantages, less rutting resistance and moisture susceptibility have been reported for WMA asphalt concrete in different studies, showed that the WMA mixtures without RAP performed better in terms of moisture susceptibility and low-temperature cracking resistance. In this study, the usability of different percentages of RAP in WMA produced with two different WMA additives was investigated and compared to control HMA mixtures in terms of moisture susceptibility tensile strength, and resilient modulus. For this aim, a laboratory study was conducted on asphalt mixtures containing 0%, 25%, 50%, and 75% of RAP aggregates by the weight of total aggregates. Finally, a statistical analysis was performed on the laboratory testing results.

During the past years different researchers have studied the causes of failure of flexible pavements and they offered variety of alternatives for solving these failure problems such as rutting, fatigue and low temperature cracking which are sourced from moisture susceptibility and also temperature sensitivity of either asphalt, aggregate or the asphalt mixture as a whole. This study is conducted to determine the optimum amount and potential applicability of zycotherm nanomaterial in asphalt and asphalt concrete mixtures with two different systems: directly applying to bitumen and diluting and applying to aggregate in order to address the solution of potential failure problems in flexible pavements. The study is carried out experimentally by conducting tests on bitumen and bituminous mixtures. Tensile strength test and retained stability tests were performed on bituminous mixture in order to measure the tensile strength ratio (TSR) and the retained stability index (RSI), which are both the indexed parameters to determine the mixture resistance to de-bonding anddisintegration in the presence of water.

Highway flexible pavements constitute more than 90% of the national pavements of most of the countries. It is produced from hot mix asphalt (which is a mixture of well graded aggregate combined with a bituminous binder to provide a stable structure for passing vehicles), and continually faces different failure problems. These problems may be sourced from hot mix asphalt or from underlying layers either base, subbase or subgrade failures. Hot mix asphalt concrete would have a long life even under heavy traffic, severe conditions like moisture; high and low temperature, when designed and laid properly.

It is believed that moisture or water is one of the greatest factors which will have an inverse effect on the performance of hot mix asphalt. It manifests itself as a reduction in overall strength and it will increase rutting potential, decrease fatigue life and accelerate stripping potential of the mixture.

ZYCOTHERM

Zychotherm as Antistripping Agents The chemical affinity between bitumen and aggregate can be improved by the addition of very small quantities of chemicals which change the nature of the bitumen or the aggregate to have more affinity for the other. These chemicals are known as "Anti- stripping Agents" or "adhesion promoters". I since the stability of bituminous pavement largely depend on adhesion between bitumen and aggregates, the ionic nature of aggregate is an important factor explaining the problem of stripping that varies for different type of aggregates. This also explains non- formation of stable bond in bituminous pavement construction. The widely used class of Anti-stripping agents belong to Fatty Polyamine group of chemicals where even in a very small dose they serve to provide Active and passive adhesion between Bitumen and the aggregates. A new class of Nano technology- Organo-silicon based anti-stripping additives is now popular which utilizes the chemistry of Silicon-Silicon bonding [which is nature's strongest chemical bond. Being surface active agents Antistripping Agents improve bituminous wetting of aggregates, thereby reducing the requirement of Bitumen. They also prolong the pavement life by slowing the ageing process. The main goal of anti- stripping additives, is to increase the strength and durability of the adhesion between aggregate and bituminous binders. Here we use Zychotherm as antistripping agent which is help the Bituminous Concrete from water damage.

Zycotherm:

Zycotherm is an organosilane odour free, chemical warm-mix additive. Additives are added to materials to enhance their properties. They are mostly added to improve either workability or durability. However, there are also certain targeted additives that work on improving a particular aspect of a material, like lowering softening point of bitumen. In this study the Nanomaterial used is Zycotherm.

OBJECTIVES

The main objective of this study is

- To evaluate the mix design properties as per the MORTH specification.
- To Compare between WMA properties to that of HMA for the bituminous concrete mix as per the MORTH specification.
- To evaluate the properties of the bituminous concrete (BC) mix using Zycotherm additive of varying percentage of 0.05%to 0.1% by weight of binder.

LITERATURE WORKS

Flexibility of the road surface is retained during the cold weather enabling it to withstand repeated loading on warm weather condition resulting in its long life. If cracks development was minimized, the rate of water seepage through the pavement surface is greatly reduced eliminating the effect of water to the underlying layers. In the long run, the serviceability of the road surface is maintained. The environment is improvement by finding a disposal route for plastic bags and job creation (Shirish N. Nemade, 2014). The strength of bituminous mix is improved (Kadam, 2014). The SWPB particles sizes were limited to only those particles that were retained in sieve size 2.36mm (Verma, 2008). Based on ASTM 2002, where particles size of crumb rubber used in modification of bitumen were limited to particle sizes retained in sieve size 1.18mm and passing through sieve size 4.75mm. In line with, the waste particle sizes to be used in this study will be limited to particle sizes passing through sieve 2.36mm.This will assist in blending the binder homogeneously. Though SWPB had been used in the past for the modification of bitumen in other countries, the same has not be done locally. This study will aim at testing the locally generated SWPB and further compare its results with those obtained when WSCA is used as a modifier. These among many other studies, clearly indicate that modified bitumen has been usedin the construction of bituminous roads to improve road performance by enhancing bitumen mechanical properties. The studies carried out are not exhaustive and more studies can be done depending on the additives being used in line withsustainable development. According to (Gro Harlem Brundtland, Mansour Khalid, Susanna Agnelli, 1987) in their Brundtland Commission, they defined sustainable development as that development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs. When bitumen is modified, their properties are improved; the rate of extraction will be minimized thus taking care of the future generation.

Waste Sugar Cane Ash (WSCA) Researchers have focused their studies on the utilization of industrial and agricultural waste produced by industrial processes focusing on economic, environmental, and technical reasons so as to minimize their effect on the environment. Waste material such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash(referred here as Waste Sugar Cane Ash) are used as construction material for the development of concrete due to their pozzalanic properties (Ganesan K, Rajagopal K, 2007).

Sugarcane is a major crop grown in many countries in the world for the production of sugar through processing it in sugar mills that generates millions of tonnes of sugar cane ash as a waste material. About 40-45% of fibrous residue is obtained after extraction of all economical sugar fromsugarcane, and later reused as fuel in boilers for heat generation leaving behind approximately 8 -10 % of ash as waste (H. Otuoze, Y.Amartey, B. Sada, H.Ahmed, 2012). The WSCA has no other economic value and can only be dumped in the open field and this poses a serious threat of polluting air and water bodies and landfills (R, B, & Pradeep T, 2012). In Kenya, Mumias Sugar Company have boilers that have a capacity of burning 70 tonnes of bagasse per hour with a weekly ash output of approximately 120 tonnes when running at full capacity (Mwero et al, 2011). This waste product is non-biodegradable solid material currently being disposed as soil fertilizer though this is not environmentally sustainable (Schettino&Holanda, 2015). Water has to be added to the ash to avoid wind blowing it around thus causing environmental hazard. This calls for urgent ways of handling the waste as it isbecoming a menace.

Srinivasan and (Srinivasan&Sathiya, 2010) carried a study on partial replacement of cement with Sugar Cane Baggase Ash (SCBA) and concluded that SCBA improves the quality of construction material such as concrete blocks, mortar, and soil cement interlocking block and thus reducing their production cost. Also the compressive strength of blocks is improved((Dhengare, Raut, Bandwal, &Khangan, 2015), (Anand& Mishra, 2016) and workability of fresh concrete was improved(Anand& Mishra, 2016).

Typical fillers are fine powder in nature with particle size of less than 75μm and they include industrial waste such as fly ash or natural occurring products like cement, stone dust or calcium carbonate. Filler modify a material by the manner in which it gets distributed in a liquid and how it interacts with the liquid phase of the mixture (Mohi et al., 2015). This interaction creates a chemical bond or physical interactionleading to a reinforced material strength.

Ishfaq and Supriya (2015) carried out a study on the influence of fillers on paving grade bitumen using cement, fly ash and stone dust. The stability value of bitumen was found to improve with cement giving the highest stability value.

This could be attributed to the fact that, the fillers tend to fill the voids in the aggregates and also improved the resistance of pavement to permanent deformation. Konstantin et al (2013) investigated on the effect of fly ash on bituminous mixture andconcluded that fly ash improved the rheological properties of bitumen, its ageing resistance and consequently increasing the longevity of a pavement. WSCA has pozzolanic properties comparable to Ordinary Portland Cement (OPC) and can have particles size comparable to filler material making it suitable as an additive in bituminous mixtures. The Utilization of WSCA as bitumen modifier may improve the properties of bitumen and minimize the negative environmental effects withits disposal.

MATERIALS AND METHODOLOGY

Material properties

Materials needed for this study are the constituents of hot mixasphalt and molasses, present sources of these materials.

Table: 3.1. Material Details

Materials	Material Source
Aggregates	Crushed Stone
Bitumen	Bitumen
Zycotherm	Nano material additive

Materials Used

- Coarse Aggregates (stone)
- Fine Aggregates (Natural Sand, stone chippings)
- Filler Material (Crushed Stone Dust)
- Binder (Bitumen)
- Replacement Material (Zycotherm)

Zycotherm

ZycoTherm is an organo silane odour free, chemical warm- mix additive(WMA) .Additives are added to materials to enhance their properties. They are mostly added to improve either workability or durability. However, there are also certain targeted additives that work on improving a particular aspect of a material, like lowering softening point of bitumen. In this study the Nanomaterial used is Zycotherm. Zycotherm is an organo silane odour free, chemical warm-mix additive (WMA). In India Zydex Industries is a chemical company that produces Zycotherm and for the current study, it was procured by directly contacting their sales headquarters in Vadodara (Gujrat).

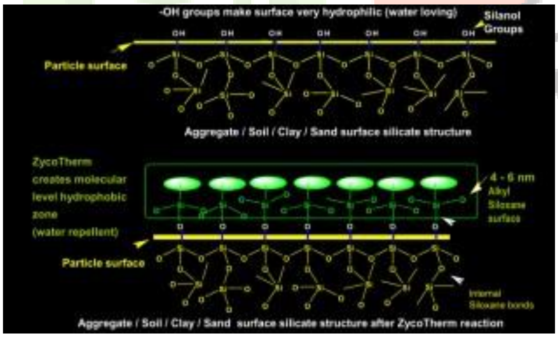


Fig.: Chemical action of Zycotherm

The Nanomaterial additive is added to the mixture to enhance the properties of the bituminous mixture. The nanomaterial used for this study is the Nano clay. The Nano clay used is Montmorillonite Bentonite Clay ($Al_2O_34SiO_2H_2O$) withpurity of 99.9%.The clay comes in form of powder and the colour of the clay is light cream.

BC MIX DESIGN FOR GRADE -2:

Bitumen is a black or dark-colored (solid, semi-solid, viscous) amorphous, cementitious material that can be found in different forms, such as rock asphalt, natural bitumen, tar and bitumen derived from oil, which is referred to as petroleum bitumen. The specific gravity is 0.97 to 1.02.

Currently most of the roads globally are paved with bitumen. Today the world’s demand for bitumen accounts for more than100 million tons per year which is approximately 700 million barrels of bitumen consumed annually.

As per MORTH 5^{th} Revision BC content minimum 5

Material required for casting each specimen

Test Results

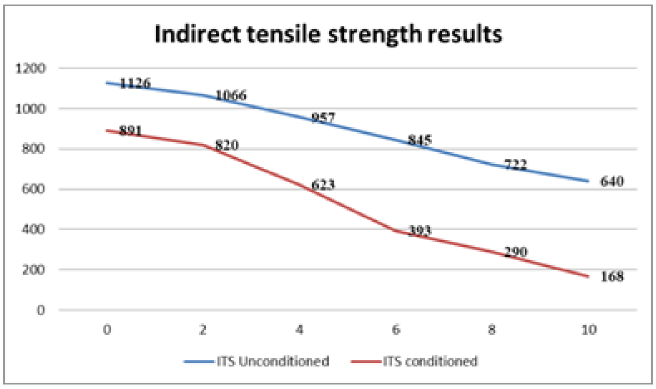
Trail	Zycotherm Content in %	Air voids	VMA	VFB	Flow	stability
1	2	4.94	14.0	64.71	2.50	13.92
2	4	4.22	13.90	69.61	2.97	13.04
3	6	3.73	14.00	73.36	3.23	14.36
4	8	3.70	14.52	74.53	3.67	11.86
5	10	3.62	14.99	75.83	4.27	11.73

Indirect tensile strength results

Zycotherm %	ITS		TSR(%)
	Unconditioned	conditioned	
0	1126	891	79
2	1066	820	78
4	957	623	65
6	845	393	46
8	722	290	36
10	640	168	24

Material	Proportion	Weight of material in grams
Bitumen	5.5	66
19 to 14 mm aggregates	14.175	170.10
14 -7 mm aggregates	15.120	181.44
7 -3mm aggregates	17.955	215.46
3 mm down	45.36	544.32

Sample Weight (gm)	Bitumen Content (ml)	Zycotherm Content (%)	Weight of sample @ Zycotherm	Weight of sample @ Bitumen
1200	66	2%	1.32	64.68
1200	66	4%	2.64	63.36
1200	66	6%	3.96	62.04
1200	66	8%	5.28	60.72
1200	66	10%	6.6	59.40



Mix Proportions

EXPERIMENTAL RESULTS

The research clearly shows the scope of using Nano Chemicals in the field of pavement construction. Addition of Zycotherm has the following advantages:

Improved Marshall Stability Value The Marshall Stability Value % bitumen content whereas when Zycotherm at 2% (by weight of bitumen) was used which was calculated as the optimum dosage for the Nano chemical the Marshall Stability Value was considerably higher.

Improved Workability at optimum dosage 4% (by weight of bitumen) the workability of the mix was greatly improved. The mixing force required for the manual mixing of the bituminous concrete was enough to support the claim. Improved Compaction The heights of the two Marshall Stability samples in the two cases with and without Zycotherm were different. The sample with Zycotherm showed improved compaction and therefore was lesser in height when comparedto sample without Zycotherm.

Reduced Stripping Value Though Zycotherm is not advertised as an anti-strip its use still improved the stripping resistance of the bituminous concrete mix. Stripping Value without Zycotherm= 20%. Stripping Value with Zycotherm= 5%.

However it too has benefits especially when considering the stripping resistance of flexible pavement.

From a technical point of view, various solutions have been put forward to reduce energy consumption and diminish release of pollutant gases to protect environment. One such solution is Warm Mix Asphalt which provides a decrease in manufacturing and compaction temperatures by lowering the viscosity of the binder using organic and chemical additives or foaming process. Nevertheless, water susceptibility has been a major concern in WMA mixtures. Water permeates through pavement surface, causing wreck at the interface of aggregate particles and binder which will eventually lead to stripping in pavements. Stripping is recognized through raveling, flushing, localized bleeding, and others. This distress is usually because of either the reduction in the mixing temperature, which unpleasantly affects evaporation of the entrapped moisture in aggregate particles or to the inferior coating of aggregates due to high viscosity of binders. Investigational mechanisms and theories of stripping are still intricate. Most researches ascribe water susceptibility to factors such as bitumen chemical and rheological characteristics, morphology and adsorbed coatings, chemistry and energy of the aggregate surface, pH at the interface, traffic, construction operations; and presence andnature of ASA1 .

It is also important to see how aggregate type and gradation can affect the fundamental properties of bituminous mixtures in terms of moisture susceptibility because bituminous mixtures are composed of nearly 80% by volume or 95% by weight, coarse and fine aggregates. Adherence and cohesion between asphalt mixture particles must be strong enough to resist stripping in the presence of water. Chemical features of coarse and fine aggregates related to their nature, significantly contributes in this adhesion. Furthermore, compatibility with ASA that is probably incorporated in the binder is another main parameter which, unquestionably, has a significant influence on performance of asphalt mixtures against moisturedamage. Therefore, the surface chemistry of the aggregateparticles plays an important role in performance of both HMA and WMA. It was also firmly established in SHRP studies that mineralogy and chemical composition of aggregate are of primary importance in stripping.

DiVito and Morris evaluated the performance of aggregates treated with silane to aggregates treated with commercial aminebased ASAs against moisture damage and their investigations revealed that silane treated materials have better resistance than the other one does. In recent years, some researches have been carried out focusing on the use of nano-organosilane as ASA in HMA mixtures; however, the effects of these additives on moisture susceptibility of WMA are still contemplative.

The main work of this research is to investigate the role of a warm-mix and anti-striping additive named zycotherm on moisture susceptibility of asphalt mixtures prepared with different aggregate types and gradations in terms of laboratory tests. Test methods related with the evaluation of water damage. To better investigate and analyze the parameters which affects the stripping of the mixtures, FTIR was performed on binders and XRF was applied on aggregates in Further Work.

CONCLUSION

Nanotechnology offers the possibility of great advances and incremental improvements in construction materials. Nano particle additives have high potential for application in bituminous concrete mixes. Addition of Zycotherm as an additive improves the durability of the pavement and hence helps in decreasing the maintenance cost. Hence it is evident that Nano Chemicals such as Zycotherm have many benefits and have favorable results for flexible pavements. It helps in stiffening of the binder material and also increases its strippingresistance. The only problem with utilization of Nano materials is its cost effectiveness. As the cost of these Nano materials are very high the application of these materials is therefore limited. Adequate research still needs to be carried out as well as implemented if the sector has to progress. Just like the Nano Chemicals used in this study there are numerous others available commercially manufactured chemicals which have not been tested for the flexible pavements and can have other advantages. The benefits of Zycotherm mentioned aboveare a testament to this statement.

- The physical properties of the aggregates and bitumen of 60/70 (VG – 30) grade and warm mix binder used for the present studies satisfies the requirements as per MORT&H specifications.
- The Optimum Bitumen Content was found mix at 160oC mixing temperature.
- The maximum stability for 60/70 grade bitumen is achieved at 135º C temperature with the additive dosage of Zycotherm by the weight of binder.
- This study tries to study the conventional and rheological properties of binder mixes, HMA made from this binder mixes and their sensitivity to moisture. In doing so, test parameters were evaluated. Based on the results obtained fromthis study, the following conclusions can be made:
- Neat asphalt binder was more affected by aging compared to asphalt binder containing Molasses. Meaning addition of Zycotherm to asphalt binder decreases the aging effect of HMA mixtures.
- Addition of Zycotherm has affected rheological behavior of asphalt binder thereby making the asphalt binder stiffer at high temperatures which results in a durable binder.
- The replacement of asphalt binder with Zycotherm at optimum binder content of 6%, decreased the stability, flow, unit weight and the Va% of the HMA, while the VMA and VFA percentages increased as the percentage of Zycotherm increased. The increment and reduction value of these properties of HMA up to 10% Zycotherm is within theMarshall criteria for heavy traffic.
- The Warm Mix Asphalt with Zycotherm of 4% hasthe Optimum Binder Content value.
- The Warm Mix Asphalt with Zycotherm of 6% hasthe maximum Void

REFERENCES

1. Ali, J., Meor, O., Zhanping, Y. (2013). ―Performance of Warm Mix Asphalt containing Sasobit: State-of-the-art.‖ Journal of Construction and Building Materials, 38, 530–553.
2. Al-Qadi., Jeff, K., and Jim, M. (2012). ―Short-Term Performance of Modified Stone Matrix Asphalt (SMA) Produced with Warm Mix Additives.‖ Report No.FHWA- ICT-21-001, Illinois Center for Transportation, University of Illinois, Urbana, IL.
3. Bheemashankar, Amarnath.M.S. ―Laboratory studies on effect of Zycotherm additive on bituminous concrete mix‖ abstract number 22.
4. Harpreet Singh, Tanuj Chopra, Neena Garg, Maninder Singh , (2017). ―Effect of Zycotherm additive on performance of neat bitumen and bituminous concrete mixes‖.
5. Kanitpong K, Charoentham N & Likitlersuang S. (2011). ―Investigation of effect of gradation and aggregate type to moisture damage of warm mix asphalt modified with Sasobit‖, Taylor & Francis, International Journal of pavement engineering, Vol. 13, No. 5, 451-458.
6. Manjunath S Sharanappanavar, (2015). ―Study on Behaviour of Warm Mix Asphalt Using Zycotherm.‖ International Journal of Science and Research (IJSR) Volume 5, Issue 10, October 2016.
7. Mirzababaei P (2016), ―Effect of Zycotherm on moisture susceptibility of Warm mix asphalt mixtures prepared with different aggregate types and gradation‖, Elsevier, Construction and building material 116, 403-412.