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A Literature Review on the Role of Zycotherm as an Additive used in Bitumen

Dr. Maninder Singh[1], Dr. Kunal Jain[1], Sukhjinder Singh Kahlon[2]

[1]Assistant Professor, [2]M Tech Scholar,
[1,2]Department of Civil Engineering, Punjabi University, Patiala (Punjab), India

ABSTRACT

Water is one of the prominent damaging elements in asphalt pavement due to its enormous detrimental effects on pavement performance. Moisture damage induced by the actions of water reduces the strength as well as durability of asphalt mixtures, tends to cause various types of distress such as potholes, stripping, and others to the pavement, formed by lack of cohesion and adhesion. To sort out this problem, the modification of bitumen is needed to enhance its properties for pavement surface. Ergo, the current paper introduces the findings of prior research studies on Zycotherm's effect as an anti-stripping agent, recently developed, chemically reactive nanomaterial that imparts strength to the surface of the pavement. In this study, optimum bitumen content by Marshal Mix Design, without and with necessary dosages of Zycotherm (upgraded from Zycosoil) and alterations in properties are reported through various tests.

KEYWORDS: *Zycotherm, Anti-stripping, Optimum binder content, Zycosoil, Nanomaterial*

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I. INTRODUCTION

The presence of moisture causes the early collapse of hot-mix asphalt layers which leads to a deterioration of asphalt pavements. Moisture damages are caused by various factors including properties of asphalt mixture, environmental conditions, construction methods, and so more [1]. Moisture damage can usually be divided into two mechanisms, firstly, adhesion loss and secondly cohesion loss as the latter is caused by asphalt concrete mastic softening whereas former occurs while the asphalt film washed away or water passes through the asphalt binder as well as the aggregates. A pavement damaged by moisture can result from a combination of both mechanisms [2]. Moisture decreases the internal strength of the HMA mix and also causes rutting and fatigue cracking of the HMA layer with stresses increased by traffic loads and from other sources.

Use of anti stripping agents (ASA) is the most popular way of enhancing the resistance of asphalt mixes to moisture. A primary purpose of anti-stripping additive is to reduce the moisture damage of asphalt mixture by strengthening the bond among the aggregate and asphalt binder [3]. Zycotherm is an odourless product based on nanotechnology with a substantial potential to boost the adhesion of bituminous mixtures. It acts as an anti-stripping agent makes asphalt mixtures more resistant to moisture. Zycotherm allows lower mixing temperature and lowers compaction temperature as well as perform in an environment-friendly way [4, 5].

II. Literature Review

Performance Characteristics of Zycotherm Modified Bitumen

In the study [6] they investigated the performance of bituminous concrete in addition to zycosoil nanotechnology, to meet the ideal demand of engineering properties of flexible pavement as well as enlightens the procedure to search out optimum bitumen content through Marshall Mix design technique for Bituminous Concrete mix which attains maximum stability by using innovative nanotech chemical material. After laboratory investigations, the optimum bitumen content of 5.4 % for BC mix was obtained. Apart from this, the suitable dosages of Zycosoil chemical (0.02%, 0.03% and 0.04%) were added to VG 30 bitumen and modified bitumen's properties were recorded. Thus, the study shows that with the addition of zycosoil to asphalt mix minimizes the moisture damage; however, this modification increased the stiffness, temperature susceptibility along with workability of bitumen mix that fulfills the standard criteria and coating the aggregates.

In another study they checked out the performance characteristics of asphalt binders and mixtures prepared with silane additive zycotherm. Nanotechnology anti-stripping agent named zycotherm added in the proportion of 0.1% weight to enhance the production of WMA mixture at lower temperatures along with improving the workability and compactability of typical materials used in Malaysia. Modified asphalt binder with zycotherm gone through various binder tests such as penetration, softening point, and so more. Further, the performance of mixture evaluated in cylindrical samples and tested for dynamic creep, Hamburg wheel tracking, indirect tensile strength (ITS), resilient modulus, and moisture-induced damage. As compared to the conventional mixture samples, WMA modified mixture, not only shown lesser compaction efforts but also impart better resistance to distress, cracking, moisture damage and mixing stability, albeit at a lesser temperature [7]. Another study examined the impact of lime as filler materials by adopting the Marshall method of bituminous mix design and compared its behaviour with warm mix asphalt. Materials such as (1% and 2%) of lime as a filler material as well as zycotherm(0.1%) by weight of bitumen binder were used as additives. After concluding the optimum bitumen content (OBC) with Marshall Method of bituminous mix design, other properties were determined and analyzed through various tests. As a result, there was a marginal stability performance of the bituminous mixes in Marshall than the WMA. Moreover, with the enhancement in filler content, the proportion of air voids decreased, along with this, the amount of air voids, VMA and VFB of bituminous mixes declined slightly in contrast with WMA. While bituminous concrete sampleshad a better indirect tensile strength but a slightly superior resistance to moisture susceptibility than WMA. Bituminousmix of Warm mix asphalt displayed the inferior ordinary performance than the bituminous concrete mixes which could be used as an additional form of a bituminous mix [8].

Another study used and compared the characteristics of Nano clay and Zycotherm as nanomaterial admixtures in bituminous mix opposite to the design of orthodox mix utilizing for plotting graphs air voids, flow value, stability value and bulk unit weight relative to proportions of bitumen content by weight. Specific mixtures contained Zycotherm volume equal to 0.1 per cent, 0.2 per cent and 0.5 per cent by bitumen weight at Optimum bitumen concentration 5.5 per cent were made. As a result, the Marshall Stability Value at 5.5 per cent bitumen content was 11.7 KN, as opposed to sampling modified with Zycotherm at 0.2 per cent (by Bitumen weight) at optimal dosage had the Stability Value slightly higher at 13 KN. As far as stripping concerned, the Stripping Value without Zycotherm was 20% while Stripping Value with Zycotherm was 5%. The workability of the blend was considerably improved at a maximum dosage of 0.2 per cent (by weight of bitumen), and the sample with Zycotherm demonstrated better compaction and was also lower in height compared to sample without Zycotherm, 64 mm and 59 mm respectively. The stability value of Marshall without nanoclay was 11.7 KN whilst the stability value of Marshall with nano clay was 10.9 KN (10 per cent). The stability value for the HMA mix at 160 ° C was 16.02 KN at 125 °C and the stability of the WMA mix was 17.28 KN due to the inclusion of 0.1% Zycotherm. That indicates the mix's stability values increased with the incorporation of the Zycotherm at 125 ° C [9].

Another study investigated the glass-containing warm mixed asphalt performance and moisture sensitivity, improved with zycotherm as an anti-stripping additive. Fine Glass particles were used as aggregates in the mixtures of warm mix asphalt, because its high-potential favourable properties. The WMA mixtures used four distinct amounts of zycotherm (0.05%, 0.1%, 0.15%, and 0.20%) according with weight of binder content to act as modifier and anti-stripping agent. Warm Mix Asphalt and glass-asphalt usually have inferior adhesion properties among the crushed glass bitumen and aggregates, which create exertion, such as low resilient modulus and others. Mechanical properties such as moisture susceptibility of glass-asphalt, Fourier Transform Infrared spectroscopy, Scanning Electron Microscopy (SEM) along with binder tests were conducted to examine the performance characteristics of the neat and the zycotherm-modified bitumen. Along with this, the resilient modulus test, Modified Lott man's test, creep test for controlled and WMA specimens were performed. Consequently, the FTIR test evaluated the effect of zycotherm modified bitumen's chemical structure with wave numbers range from 450 to 4000 cm^1. Adherence between small crushed glass and bitumen were explored by using the SEM technique, not only this but also, zycotherm effect on the mixing process to achieve a uniform mixture. In indirect tensile strength (ITS), in both dry and saturated conditions, the HMA samples depicted elevated tensile strength in contrast with the WMA mixtures. Besides this, the glass-containing HMA, without glass fragments, had a less significant resilient modulus in contrast with HMA, since, the lesser adhesion forces between bitumen and glass pieces, as well as the fragility of the fragments of glass, which crushed under the constant load. Using zycotherm content over 0.15 percent able to increase the heat resistance, robust modulus, and specimen's creep. As per bitumen test findings, the application of zycotherm increased ductility and enhances the rotational viscosity (RV) relative to the initial bitumen. Bitumen coats the aggregate surface better by reducing the viscosity, thus stronger bonding of aggregates occurs[10].

Marshall properties of Zycotherm Modified Bitumen

A study [11] was carried out laboratory investigation on the execution of polymer modified bitumen mix (PMB 40) with an additive zycosoil by making procedures to obtain optimum Binder content with the help of Marshall Mix design. In this study, after the adoption of suitable aggregate by grading as per MORTH specification, Marshall Specimens were prepared to further test, where, specimens checked out for Marshall Properties. Stability curve values, mineral aggregate voids, specific gravity, flow value, bitumen-filled voids and air voids were measured with Marshall Test which demonstrated improvements in the properties of the test specimen. This study also considered, ASTM boiling test, PMB 40 grade of Asphalt along with 0.03% 0.04% and 0.06% zycosoil chemical as an additive was compound in melted Asphalt Binder and mixed thoroughly and then the sample had remained at room temperature. Then, the boiling test was conducted at 100 degrees C for 10 minutes, 30 minutes, 1 hour and 6 which showed the significant changes in shear resistance of mix. Noticeably, modification with the Nanotechnology zycosoil depicted the increased polymer-modified mix's performance, coupled with, an increment in stiffness, flexibility as well as enhances the condition of temperature and workability.

Another study [12] Utilized Zycotherm as an additive in bitumen and evaluated its effect on the mechanical properties of the bituminous binder by contrasting the results of the Marshall stability test with the indirect tensile strength test. Thus, with the introduction of Zycotherm as an additive, there was an increment in the viscosity of the base bitumen till a temperature of 100 C, after a further increase in temperature, there was a reduction in the viscosity of bitumen which leads to a reduction in the compaction temperature by making the binder less viscous in order to coat the aggregate properly at a lower mixing temperature. Rheological tests indicated, the Zycotherm additive in bitumen had a minor impact on the binder's rutting and fatigue resistance. Zycotherm additive had no significant effect on the Marshall Stability and Tensile strength of bituminous mixes.

Study [13] compared the Marshall properties and environmental impacts of Warm Mix Asphalt modified with a newly developed chemical additive Zycotherm and Hot Mix Asphalt for bituminous concrete (BC) Grade-2. The mixing temperatures adopted for HMA were 160°C and mixing temperatures for WMA was 130 °C, 125 °C and 120 °C; with a dosage additive average of 0.1 per cent by binder weight. Optimal binder was figure out individually for different mixing temperatures. Consequently, as compared to HMA, the additive decreases the compaction temperature and mixes along with improved workability and optimal bitumen material. The Marshall Stability Test found that the warm mix asphalt found better results than the hot mix asphalt, as with its addition it increased the bulk density and thus demonstrated higher optimum density. Not only this, but also the use of Zycotherm by the WMA gave satisfactory results and thus used as an alternative to HMA. Lowest air voids of the bituminous concrete mixture with WMA additive relative to HMA mixture reflects that the WMA additives were efficient in compacting mixtures at lower temperatures.

Modified Bitumen's Properties Compared with Other modified bitumen

They [14] studied the everlasting impact of anti-stripping agents especially zycosoil, in contrast with, hydrated lime and proposed a model for evaluating the rehabilitation time of pavements. Response surface methodology was employed in this study, in order to find independent factors such as anti-stripping additives (hydrated lime and zycosoil) and time as well as the time-dependent models between tensile strength ratios as a response parameter. The aggregate type used corresponding to three grading levels according to (ASTMD3515-01) by means of distinct size distribution (85% 70% and 55%) passing from 4.7 mm sieve were selected. The grading levels were named as the fine, medium and coarse subsequently. The optimum bitumen content identified as 6%, 5.5 % and 5.1 % for mixtures with different grading levels. From the semi-empirical modelling, bitumen content of the asphalt mixture was one of the pre-eminent factors affecting the tensile strength ratio. Zycosoil not only improved the moisture resistance, also the long lasting potential of asphalt mixture to hydrated lime. The maximum resistance of anti-stripping agents was at 1.5% and 0.1% for both hydrated lime and zycosoil subsequently. A mathematical model progressed and estimated the exact time of rehabilitation prior to stripping failure in the pavement.

Another study [15] used Evonik, Zycotherm, and hydrated lime as additives to determine and compare their effects of additional performance characteristics of asphalt mixtures and the moisture susceptibility through several tests. 60–70 penetration grade asphalt binder had been used. Evonik and Zycotherm at 0.1 percent and 0.3 percent by bitumen weight were applied to the neat bitumen sequentially. As filler, hydrated lime added in the proportions of 1% to 2% by the weight of the aggregates. Test results of Marshall Stability indicate increased moisture resistance of asphalt mixtures modified with nano materials. The addition of hydrated lime leads to elevated Marshall Stability values and stiffer mixture. Modified mixtures having optimal concentrations of those with 0.1 percent of Zycotherm, 0.3 percent of Evonik, and two percent of hydrated lime had the utmost consistency in Marshall. Evonik and Zycotherm anti-stripping agents generate covalent bond within bitumen and aggregate, avoiding moisture penetration into a hydrophobic coating at the bitumen aggregate interface. On the one hand, zycotherm leads to a rise of 15% in the Indirect Tensile Strength Ratio, on the other hand, Evonik the increasing the ITS values by 9%. Evonik demonstrated inferior efficiency compared to modified Zycotherm mixtures. Mixtures contained 0.1 percent of anti-stripping Zycotherm and Evonik (0.3 percent) had the highest results in testing the rutting behaviour. With regards to creep behavior, the composite additive (2 per cent hydrated limes) worked better.

Some other study [16] scrutinized the varying effect of three forms of nanomaterials, including nano-Bentonite as a filler, nano-CaCO3, and Zycotherm to improve the asphalt binder properties. HMA computed with laboratory methods namely Marshall Mix design and modified Lottman's tests, performed on laboratory-prepared Hot Mix Asphalt specimens along with conventional and rheological tests to show the nano modification effect. To study the impact of the above listed threenanomaterials,physical, mechanical and rheological properties of asphalt binder and the efficiency with exposure to moisture were evaluated. Materials such as 50/70 penetration grade neat asphalt binder, limestone crushed aggregate, Nano- bentonite (2%, 4%, 6%), Nano-CaCo3 (3%, 6%, 9%) and Zycotherm(0.1%, 0.2%, 0.3%) by weight of bitumen. It was concluded that all stability values were far above than the minimum Limit of 900 kgf. Stabilization values increased markedly when modified with 6 per cent Nano-Bentonite. Stability value was 11 per cent which was higher than the control mixture. Through modification of Zycotherm caused increasing consistency in the mix was nevertheless negligible. The TSR value surged up to 22 % with 0.1 % Zycotherm, at optimum dosage. The measured different values for the dry and the conditioned ITS samplesready with precise dosages of the nanomaterial additives were 1724 and 488 correspondingly, that correlates to a variation coefficient, at the value of 0.06 and 0.04 sequentially. Conclusively, nanomaterials increased the asphalt binder's rheological properties and nanomaterials perceived to be highly prominent for overcoming the susceptibility to high temperatures by enhancing the capability for storing the modified binders at high temperatures.

Another study [17] ascertained the potential of utilizing Zycotherm as an additive and understand the effect of the latex-modified natural rubber asphalt binder at extreme temperatures as well as loaded conditions. In materials, bitumen penetration grade of 60/70 used for specimen preparation, the percentages of latex-modified natural rubber was 3 per cent and 6 per cent subsequently according to the weight of asphalt binder while dosage of Zycotherm was of 0.1 per cent of the asphalt binder's weight. Thermocell was used to control the asphalt binder temperature, during the blending process. Tests such as complex modulus, penetration value, the viscosity of rotation, angle of phase, softening point, rutting potential and torsional recovery (TR) were performed. Subsequently, a polarizing optical microscope was used to observe the spread ability of latex-modified natural rubber in the asphalt binder. Consequently, with the inclusion of NRL asphalt binder's performance improved in terms of its G*/sinδ parameter. Regardless of the ageing condition, an agglomerated network of mix microstructures was created in the modified asphalt mixture. Meanwhile, uniformly dispersed network monographs revealed from the morphology structure of pure and binders which were short-term aged processed with Zycotherm. From modified asphalt binder examination, asphalt binders prepared with Zycotherm demonstrated excellent potential resistance to rutting.

Moisture susceptibility of Zycotherm Modified Bitumen

A study [18] determined the impact of Zycosoil in asphalt mixes and calculated the behaviour of asphalt mixes incorporation with and without Zycosoil layered aggregates under wet anddry conditions with indirect tensile strength (ITS) test and indirect evaluation of tensile fatigue (ITF). Aggregates which contain a significant amount of mineralogy range, such as calcareous and granite, were examined. The proportions of zycosoil additive used in this study were between 1% and 1.6 % of the gross weight aggregates. Consequently, with the introduction of Zycosoil in mixtures having limestone and granite provoke TSR value to rise to three per cent and 14 per cent, respectively, which was graeter the controled samples. Furthermore, Zycosoil formed a hydrophobic nano-coating on aggregates, like limestone mixtures and granite aggregates result in a 6% and 25% rise in fatigue life, respectively. Because of the hardness of granite aggregates and greater angularity, granite-containing mixtures undergo more fatigue life. With the increase in density, degradation of silanol groups of granite, aggregate converted into groups of hydrophobic siloxane, in mixtures. It was found that Zycosoil in granite aggregate mixture had better efficiency and improves their fatigue as zycosoil decreased the air void and increased the amount of filler in asphalt mixtures. Not only this, but also Zycosoil modified the surface of aggregate and provided better compaction to asphalt mixtures.

Another study [19] investigated that nanotechnology zycosoil improves the mechanical properties of glass asphalt and the resistance to tensile stresses prior to cracking and impart adhesion between glass cullet and aggregates, improve moisture susceptibility by using zycosoil 4.5 per cent. In the study the major causes of glasphalt worsening were the stripping and moisture damage, which occur due to lack of adhesion or cohesion, which results in reducing the stiffness of Hot Mix Asphalt, strength along with various forms of pavement distresses. Also, this study considered the creep phenomenon which was accelerated by an increase in stresses and temperature. In order to sort out these problems, anti-stripping agents were utilized, five types of mixtures with different percentage of Nanotechnology zycosoil (0%, 0.5% 2.5% 4.5%) along with glass particles (10%) were prepared and Marshall susceptibility and some of the mechanical properties of modified Asphalt mixtures, were evaluated. Hence, zycosoil as an anti-stripping agent improved the water sensitivity and mechanical properties of glass asphalt.

Another study [20]investigated the effect of zycotherm on moisture susceptibility of warm mix asphalt mixtures prepared with gradations and different aggregate types, in which, different tests were performed on aggregates as well as modified and unmodified binders such as X-ray Fluorescence test for former, Fourier Transformed Infrared spectroscopy (FTIR) test for latter. Research indicates that as per FTIR test, H-bonds were more vulnerable than the covalent ones, through responding with silanoles on the surface of aggregates, Si-OH silanoles produced hydrophobic layer, that forestalls water entrance and development of H-bonds occurred in addition to its formation at the binder-aggregate interface. Moreover, with regards to the calcareous aggregates, these had a higher degree of alkalinity and lower affinity to water than siliceous one, therefore, more vulnerable to water damage. A significant effect on the functional properties of bituminous mixtures depicts that the comparison between the same and varying gradations of aggregates was not identical. This study advised to avoid the use of siliceous aggregates without an anti-stripping additive due to unsatisfied performance and ensure adequate performance against the stripping of mixtures.

Use of Zycotherm in SMA with RAP

A study [21] ascertain the effect of alterations in the proportion of recycled asphalt pavement material on the resistance against rutting.This was calculated with the three-stage flow number analysis and with the least value of overall permanent damage obtained. To prepare the stone matrix asphalt (SMA) mixtures, aggregate gradation with Nominal Maximum Aggregate Size of 19 mm, a virgin binder 60–70grade and RAP material in six different ranges (0, 10, 20, 30, 40 and 50 percent) selected. Zycotherm and sasobit were used to conduct complex creep tests in two stress ranges (300 kPa and 650 kpa) in the manufacturing (SMA) samples, and Topcel fibers as an additive were used to avoid the leakage of these types of asphalt mixtures. As the findings the Flow Number content rose with the application of RAP to the SMA specimen strength. Besides this, by introducing Zycotherm to samples provided by RAP-containing SMA specimens, the FN concentration amplified by RAP up and about 40%. Furthermore, by introducing sasobite in SMA samples comprising both RAP as well as Zycotherm, the Flow Number content rises by boosting RAP to 30%.Thus, this inference was made that the correct proportion of RAP in hot stone matrix asphalt mixtures were 20 to 30 percent since as the number of blows required attaining acceptable density and air void was a necessary factor in the laboratory case. Even, stone matrix asphalt in WMA mixture comprised of sasobit additive, the correct amount of RAP was 30 percent. The maximum flow number was for specimens, which containedzycotherm, Sasobit and RAP of 30 per cent.

Rheological Properties of Zycotherm Modified Bitumen

Study [22] find out the rheological properties of bituminous mastic containing chemical warm additives at medium temperatures and their relationship to warm mix asphalt fatigue for long-term results. This study was based on the findings of sweep frequency, Dynamic Shear Rheometer test conducted at distinct temperatures of 13°C, 19°C, 25°C and 31°Cseparately, the phase angle and shear modulus master curves of bituminous mastics were exposed at 20 degreeCelsius. The outcome was, the fatigue rule tendency line revealed aninferior absolute slope value by growing the fillerbitumen ratio. Thereby, fatigue tolerance of mastics at low-stress levels increased at higher filler dosages, whilst the opposite was valid for large initial strain rates. The impact of Zycotherm material on mastics' fatigue existence was marginal, as AFM's micro-structural study found comparable topographical behaviour with Zycotherm containing binders/mastics and the comparative bitumen mastic ratio to a large degree. The improvement in micro-structural activity originated from specific mixing temperatures that included mastics and corresponding to Zycotherm. Following this, maximum phase angle point versus loading period curve (Nph) and two fatigue requirements including a 50 per cent reduction in stiffness (Nf50), which used to test asphalt mastics fatigue resistance. The loading cycle curve (Nph) led to an increase in fatigue value for all the specimens than the Nf50 criterion. Both RTFO and PAV ageing exhibits that the shear modulus of Zycotherm comprising bitumen was higher than that of the normal bitumen, since, stiffing impact of the Zycotherm-bitumen mixing phase. Oppositely, introduction of Zycotherm contributed to lower shear modulus for mastics than those of the base bitumen. The findings of the conditional study of tensile fatigue conducted on both HMA and WMAs revealed the WMA's had acomparable performance with sufficient doses of Zycotherm to HMA.

Another study [23] examined the rheological and microstructural properties of chemical and wax warm additives in bituminous mastics with a recently launched additive named as PAWMA. Then, outcomes of PAWMA concluded and compared with the results of Zycotherm and Sasobit modified bitumen along with properties of conventional wax additive. Furthermore, modified and unmodified bitumen's properties were checked and assessed by using standard testing Methodologies. The dynamic shear rheometer (DSR) test was done by using The Strategic Highway Research Program procedure for unaged and aged modified bitumens at moderate in-service temperatures ranges from 16 to 34 °C and at higher temperatures between 46 and 82 °C respectively. A bitumen penetration grade of 60/70 had been used as the indication binder in the production of mastic and bitumen specimens. In the preparation of limestone powder and mastics, were added by weight of bitumen to the base bitumen around 60%. Three different warm admixture contents including 0.2, 0.4 and 0.6% for PAWMA, 1, 3 and 5% for Sasobit, and mastics to Zycotherm at the concentrations of 0.07%, 0.10% and 0.15% were added as per weight of bitumen. In conclusion, although there was reduction in the mixing temperature for warm mastics, PAWMA displayed comparable rheological and micro-structural properties to reference mastic's properties. In terms of catana-phase structure and topography roughness of micro structural properties these were, apparently altered by Sasobit. The usage of the aforementioned proportions of chemical additives had not a notable influence on the nano-scale structure and AFM topography as compared to reference mastic.

Fatigue Resistance of Zycotherm Modified Bitumen

A study [24] Utilised nanomaterial antistripping agent, namely Zycotherm, to analyze the effect of a liquid as an asphalt mixture's additive on fatigue life and rubberized asphalt resistance against rutting at both moderate and higher temperatures. In terms of fatigue efficiency, Indirect Tensile Strength and four-point beam fatigue experiments on unmodified and 15 per cent rubber containing mixtures including Zycotherm at concentrations of 0.08%, 0.1% and 0.12% by weight of total bitumen were conducted at 25 ° C. Material such as Zycotherm, binder, aggregates, and rubber were the different materials used in this study. The gradation lies between the upper and lower limits as per the Iran Highway Asphalt Paving Law gradation No.4 (Law, 2012). Additionally, PG 64-22 binder had been used as a base binder, Powdered crumb rubber, Zycotherm with varying dosages of 0.08, 0.1 and 0.12 per cent by bitumen weight prepared to determine their efficiency on the mixes' performance. Generic granulation procedure was used to extract the particles from the rubber. By using a high shear mixer, 15 per cent rubberized binders were prepared before the blending phase of Zycotherm with the binder. The formerly included heating the bitumen up to 155 °C and slowly applying Zycotherm to the vertex of 2–3 cm formed by the screw mixer. Consequently, Zycotherm had a negligible impact on the rise or fall of rubberised asphalt's rutting resistance and fatigue life. However, it improves the resistance of the mixtures to moisture damage significantly, in turn, prevents the development of premature distresses. Zycotherm had no effect on the rheological properties at various temperatures either positive or negative. Moreover, the 0.1% decline in dry Indirect Tensile Strength accompanied by 0.12, 0.08 and 0% of Zycotherm, kept approximately the same wet ITS value. There was no major difference in the flexural stiffness value of rubberized asphalt mixtures incorporating Zycotherm relative to the rubberised mix. The effects of cumulative dissipated energy were consistent with the effects of the number of cycles needed to achieve half of the initial mixture stiffness. These tests, in particular, were not inherently consistent with the initial results of stiffness.

Healing Capability of Zycotherm Modified Bitumen

Another study [25]investigated the healing ability of nanozycotherm-modified asphalt and Forta fibres, which were tested in three-point bending tests and the rupture-based experiments. Specific types of asphalt developed in this study including asphalt with Forta fibres, unmodified bitumen asphalt, asphalt including nanozycotherm and asphalt along with nanozycotherm as well as Forta fibres. First, nano-zycotherm-containing bitumen and bitumen gone through four experiments to assess penetration, softening point, the extent of combustion, viscosity, and then semi-cylindrical Marshall Samples to be tested in three-point bending. Subsequently, nanoadditive bitumen was utilized for preparing the Marshall specimens of four types of asphalt-based on the aggregate and bitumen content. A three-point bending test later conducted on the specimens, which were further subjected to the hot microwaves for a 24-hour, followed by a three-point bending test. Results from the tests indicate that the initial resistance of asphalt made from nanozycotherm and Forta fibre additives was significantly higher than that of other asphalts because the inclusion of nanozycotherm decreased the density and Forta fibres, improved the asphalt tensile strength. Such compounds directly influenced the compaction of asphalt specimens, ergo, there was a greater resistance and the mixture of the two substances also improved the initial flexural resistance. Consequently, the asphalt mixtures made withZycotherm and Forta fibre additives had the lowest resistance. The non-additive amount or return strength of asphalt restoration was greater than that of other asphalt.

III. Conclusions:

Generally, the recommended range of typical dosages of Zycotherm is from 0.03 to 0.1 % by weight of the bitumen binder. From the previous studies, it is concluded that Zycotherm dramatically improves the efficiency of asphalt mixtures on water susceptibility. Zycotherm can significantly enhance the asphalt mixture's Marshall Properties. Zycotherm additive reduces the penetration value of the base. Moreover, the 0.1 per cent of Zycotherm can increase the Tensile Strength Ratio, Rutting behaviour of different asphalt mixtures and ITS value as compared with the control mixture. Besides this, usage of Zycotherm ensures lesser compaction effort to compact the WMA Samples. Zycotherm's integration into Warm Mix Asphalt (WMA) imparts better workability with a much lower temperature as compared to Hot Mix Asphalt. Furthermore, short and long term efficiency of Zycosoil was superior as compared to the hydrated lime. In combination of PAWMA and Zycotherm additives, they had not greatly altered the rheological properties of the reference binder, as both displayed extremely comparable properties and similar microstructure. Next to this, the separate application of Forta fibres or zycotherm had no major effect on self-healing capabilities, however, asphalt resistance made with zycotherm and Forta fibre additives was greater than the other asphalt since zycotherm decreased density and Forta fibres improved the tensile strength of asphalt. Apart from this, Rheological results demonstrated that the nanotechnology Zycotherm had a negligible effect on the rutting as well as fatigue properties, while Zycotherm additive appears to decrease the viscosity of bitumen at high temperatures. Using Zycosoil in asphalt mixtures improves their fatigue life by aggregate coating, also, inclined the amount of filler and declined the air voids. Using Zycotherm as an additive tends to reduce repair costs, helps to stiffen the binder material and increase its stripping resistance as well.

IV. FUTURE SCOPE

Aggregates play a crucial role in determining the properties of the mix and not just the chemical, physical and mechanical properties of aggregates, but size and shape of the aggregates have a significant effect on the service life, performance and quality of the pavement as well hence designing the pavement is very important hence, type of aggregates and the gradation of aggregate must be done properly to get the most economical mix which fulfils all the requirements of a good pavement.

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