Literature Review on a Study on Improving Conventional mix of Flexible Pavement using Additives

[1]Shivani Patel, [2]Dr. V.R. Patel

[1]M.E. Student, [2]Associate Professor
[1]Department of Civil Engineering,
[1]L.D. College of Engineering, Ahmedabad, India.

Abstract : Roads play a major role in the overall infrastructure development of any country. India has a vast road network spread throughout the nation. Any kind of deterioration in roadways needs to be restricted, as it directly or indirectly affects the overall growth of our country. Road material is composed of aggregates and bitumen. Aggregates form the structure that resists vehicle loads and provide skid resistance, while bitumen binds the aggregates together. With time, due to environmental exposure, bitumen degrades chemically and becomes brittle. In addition, moisture may penetrate in the pavement/road structure, causing loss of adhesion between aggregates and binder. And if the moisture penetrates up to the sub-grade then it will cause structural defect to the road throughout all the layers. Furthermore, thermal effects, freeze-thaw action, traffic movement, poor underlying support or some combination of these factors may be the cause of crack propagation and aggregate losses that lead to formation of different distresses. Any kind repair is necessary in those situations where distresses compromise safety and pavement work-ability. As per the present scenario, temporary and semi-permanent solutions are there, but rather than that we can improve our conventional mix and overcome those future problems like potholes, Alligator cracking, Longitudinal cracking etc. As urbanization takes place we need to improve old techniques of mix to overcome new problems. In the study we are mainly focusing on the improvement of material strength by adding admixtures like SBS(Styrene Butadiene Styrene), Nanoclays and other polymers. The main goal of our study is to understand the different properties of material used in the mix and to improve the properties of conventional asphalt mix by adding some admixtures.

***Index Terms* – Conventional mix of flexible pavement, Performance Evaluation of mix with different additives.**

I. INTRODUCTION

Among the various modes of transport, road transport plays the vital role in economic, social and industrial development of the country. Just like arteries in human being, roads perform the similar function in the transportation of people and goods from one place to another. Before the advent of automobile carts and pedestrians were the main road users, pathways and kachha (Earthen road) roads catered to their needs .but emergence of automobiles and all-round developments the earthen road could not help for the smooth flow of goods and passenger. Hence there was a need arose for all-weather and better surface road so as to provide comfortable and efficient movement of vehicular traffic. If the pavement is not suitably designed and properly constructed it would lead to uneven surface having poor riding quality causing discomfort to passengers. In addition it will increase fuel consumption, wear and tear of vehicle components resulting in overall increased vehicle operation cost. On the other hand pavement design on scientific basis with proper material and adequate thickness provide smooth riding surface and durability apart from providing comfort to the passengers in order to understand the concept of flexible pavement design lets us have a look at the components layers of the pavement structure the different component layers of the flexible pavement comprise sub-grade, sub-base, base course, wearing course, surface seal coat, constructed over a prepared soil layer.

A pavement structure can be designed either as a flexible pavement or a rigid pavement based on its structural behaviour. But flexible pavements are widely preferred in India due to its advantages over rigid pavements and it is comparatively economical. Flexible pavements have low or negligible flexural strength and are rather flexible in their structural action under the loads.

The layered pavement structure transmits vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure with strong graded aggregates and should transfer the compressive stresses to a wider area. In light of the above factors, it can be learnt that bituminous mix is one of the best flexible pavement layer materials. Bituminous mix is generally used as a surface course and wearing course in flexible pavements since it is necessary that the wearing course must provide a smooth riding surface that is dense and at the same time take up wear and tear due to traffic.

Damage in pavements is a phenomenon that pavement design and maintenance engineers are dealing with for years. There are two main reasons for damage i.e. fatigue cracking and rutting in the pavement. Cracks are unavoidable and if neglected then leads to accelerated cracking and formation of potholes which further reduces the pavement serviceability. The problem of cracks is handled in many ways, ranging from pavement maintenance activities, such as surface treatments and crack filling, to full-scale pavement rehabilitation projects.

Patching is becoming a difficult task as permanent solutions are not available so potholes are needed to be repaired again in short time intervals after patching. Road maintenance agencies are facing the challenge in dealing with these problems. There are various methods that are presently being used to repair the potholes such as blow patch, cold patch (throw and go method), concrete panel replacement, crack sealing, hot mix blow and roll, hot mix wedge paving, infra-red recycling, mill and fill, microwave recycling, poly patching, rapid set and slurry crack sealing are many of the methods. The traditional method of using “throw and go” cold patch is increasingly perceived as ineffective, and therefore costly method. On a small scale or at isolated locations patching is the most common maintenance technique used to restore pavement functionality. While actual figures are difficult to obtain, it was estimated that a huge amount of money is being spent on pothole patching and maintenance of pavements. Here main focus is to find different additive components to improve the mix rather than spending tons of money over maintenance work.

II. LITERATURE REVIEW

The literature review section discusses the various causes of localized damage to flexible pavements and various methods/materials used for retrofitting it.

Ala R. Abbas et.al (2013) presented an effect of recycled asphalt shingles on physical and chemical properties of virgin asphalt binders. A virgin asphalt binder was mixed with varying percentages (0%, 5%, 7%, and 10%) of RAS. The physical properties of the binders were measured using the rotational viscometer (RV), dynamic shear rheometer (DSR), multiple stress creep recovery (MSCR), and bending beam rheometer (BBR) tests and the results showed an improved resistance to rutting but showed higher susceptibility to thermal cracking. Then the chemical properties of the binders were evaluated using the Fourier transform infrared spectrometry (FTIR) and gel-permeation chromatography (GPC) tests and the results showed an increased level of aging. The results were inconclusive regarding the fatigue resistance of the RAS-containing asphalt binders so additional research is needed to develop new test procedures for it. However, significantly higher levels of aging were obtained for PAV-aged binders containing higher percentages of RAS, indicating that the addition of RAS will primarily impact the long term performance of the asphalt binders. The addition of RAS causes the asphalt binder to become stiffer and harder to mix and handle and the addition will also improve the asphalt binder performance in the context of rutting. Super-pave asphalt binder test procedures are not suitable for analysing the performance of asphalt mixtures with respect to fatigue cracking. Future research will also be developed to help in determining the optimum amount of RAS to be used in asphalt mixtures.

Jizhe Zhang et al.(2016), showed the work on the Development of a composite substrata peel test to assess moisture sensitivity of aggregate and bitumen bonds.This paper presents the development of a suitable procedure to prepare peel test specimens using coarse aggregates and compare the results with the established standard peel test.The newly developed composite substrate peel test (CSPT) was found to be effective to show characterizing the moisture sensitivity of the aggregate and bitumen bond and the results correlated with the results taken from a SPT.The results from the CSPT and the standard peel test showed that the fracture energy after moisture damage was found to be aggregate type dependent.Limestone tends to have better resistance to moisture damage than granite when moisture adsorptions are similar.Also in terms of similar aggregates, lower moisture adsorption results in better moisture resistance.
This study suggests that in a moisture susceptible asphalt mixture,the effect of aggregate may be more influential than the effect of bitumen. Strong correlations were found between the standard peel test and the CSPT in terms of moisture damage evaluation and suggest that the CSPT maybe a more practical procedure to test the aggregate–bitumen bond for actual aggregates used in asphalt mixtures than the SPT. As shown in the both the tests ,aggregate does not influence the bonding properties of bitumen and aggregate in the absence of moisture.And under dry conditions the samples from both tests showed similar fracture energy values. The magnitude of the fracture energy in the presence of water was found to be aggregate type dependent rather than bitumen dependent with failure being adhesive in nature. The test results shows that physio chemical properties of aggregate plays crucial role in the moisture damage performance of aggregate and bitumen bonding. Limestone tend to have better resistance to moisture damage than granite with the same moisture adsorption.And also in terms of similar mineralogical compositions lower moisture adsorption resulted in better moisture resistance.

Mohd Ezree Abdullah et al. (2016), showed the study on Engineering properties of asphalt binders containing nanoclay and chemical warm-mix asphalt additives.The objective of this study is to improve the properties of the asphalt binders using the addition of nano-clays and chemical WMA additive. In this study materials used are ,Nano-clay A (montmorillonite clay surface modified with 35–45 wt.% dimethyl dialkyl (C14–C18)amine, Nano-clay B (montmorillonite clay surface modified with 35–45 wt.% octadecylamine, and 0.5–5.0 wt.% aminopropyl-triethoxysilane), and chemical WMA additive (fatty polyamines polymer non-ionic component).An asphalt binder of 80/100 penetration grade was modified with different percentages of Nano-clay A,Nano-clay B and chemical WMA additive. After modification, the asphalt binders were named Nanoclay A modified asphalt binder (NCMB A), Nano-clay B modified asphalt binder (NCMB B), and chemical WMA modified asphalt binder (CWAA).In the sample modification process, 400 g of base asphalt binder was heated in an iron container until it became fluid under a medium shear mixer using the Silverson-L4RT at a speed of 2000 rpm.When the temperature reached 155 ± 5 .C, the chemical WMA additive was gradually added at 1%, 2%, 3% and 4% by weight of asphalt binder for 10 min. On the other hand, Nano-clay A with 3%, 4%, and 5% was gradually added into the melted asphalt binder under a high shear mixer of 5500 rpm for 30 min. The similar procedure was used for Nano-clayB.The physical properties of unmodified and modified asphalt binders were measured using the softening point and penetration tests in accordance with the ASTM D5 and ASTM D36.The Brookfield viscometer was used to measure the viscosity of the asphalt binders.Other tests were also performed during this study which are given as following,A hot storage test,Rolling Thin Film Oven test ,Pressure Aging Vessel test ,creep test with a bending beam rheometer ,Surface free energy test.After performing tests we can show results like,The NCMB A and NCMB B reduced penetration and increased softening point. The modified asphalt binders exhibited significantly higher Surface Free Energy when compared with unmodified asphalt binder and could have good adhesion between aggregates. Therefore, modified asphalt binders could potentially be good at increasing the resistance of asphalt mixes to moisture induced damage. NCMB B4% could potentially become a new WMA binder in comparison to CWAA. The gap for this particular study is that, availability is not there and cost of nano-clay is almost 14,000 Rs/Kg., which lead to an uneconomical model.

Mahyar Arabani et.al (2017) presented a study on assessment of mechanical properties of rice husk ash modified asphalt mixture. Using rice husk ash (RHA), as a waste byproduct of rice milling, in bituminous roadways provides valuable advantages such as reduction of environmental degradation, lowering construction costs and saving natural resources. The objective of this study was to investigate the effects of RHA as an asphalt modifier on hot mix asphalt. Bitumen blends with 5%, 10%, 15% and

20% RHA modifier. For evaluation of the rheological properties of asphalt binders, various tests including penetration grade, ductility, softening point, rotational viscosity and dynamic shear rheometer were conducted. Also, the mechanical properties of Asphalt mixtures including Marshall Stability, stiffness modulus, rutting resistance and fatigue behaviour were assessed. The results showed that the rheological properties of bitumen were enhanced by adding RHA. Furthermore, RHA modification had positive impacts on the Marshall stability, stiffness modulus, rutting strength and fatigue performance of asphalt mixtures.
Reducing penetration makes the asphalt binder stiffer, which causes its strength against mechanical damage to improve. The increase in RHA content led to an increase in softening point and reduction in penetration of bitumen, resulting in stiffer asphalt binder. Besides, addition of RHA increased the viscosity of asphalt binder. Also, PI was enhanced with increasing RHA content that caused a reduction in thermal susceptibility of asphalt binder. Modification of asphalt binder with RHA could improve stability of mixtures. But, the increasing trend of stability was decreased significantly by adding 20% RHA. Besides, MQ as an indicator of rutting resistance of asphalt mixture was positively promoted by addition of RHA. Stiffness modulus of RHA modified asphalt mixtures was higher than those of conventional mixtures. This enhancement was more considerable at higher temperatures, as the thermal sensitivity of RHA modified binders was improved, resulted in better performance of RHA mixes at high temperatures. The addition of RHA could improve significantly the rutting resistance of HMAs at different stresses and temperatures that could be attributed to the improvement of rutting parameter and elastic behavior of modified binders. Also, the rutting performance of HMAs with 15% RHA and 20% RHA are almost similar According to fatigue test results, mixtures containing RHA exhibited better fatigue life compared to control mixtures. This enhancement might be due to reduction of air void in mixture and/or improvement of adhesion between binder and aggregates. The mixture with 15% RHA had the highest fatigue life.

Nyoman Arya Thanaya et.al (2014) presented a study on properties of Cold Asphalt Emulsion Mixtures (CAEMs) using materials from old road pavement milling. Cold Asphalt Emulsion Mixtures (CAEMs) can be produced at room temperature which can incorporate milled old road pavement (upto 72.73%). Some virgin aggregate and rice husk ash as filler material and cement was added into the mixture. The samples were subjected to compaction delay for up to 24 hours and cured at room temperature for up to 8 days and cured to full curing condition. The cured samples met the minimum stability of 3 KN in less than 2 days of curing at 20-30 C. The increment in temperature plays a major role in increasing strength, than the cement content. The decrement of stability is due to the compaction delay which increases the porosity. The loose mixture of CAEMs becomes slightly stiffer, hence less workable during compaction. Although the porosity increases, the overall porosities still remain within the spec limit, i.e. 5-10 %. The samples containing ordinary Portland cement (OPC) showed higher stability, as the cement would assist the hardening of the compacted samples. All properties of the CAEMs well meet the specification, further tests like stiffness tests, creep tests, and fatigue tests are necessary, in order to attain a broader appreciation on the performance of CAEMs.

Obaidi et al. (**2016)** presented a fast pothole repair method using asphalt tiles and induction heating.In this method we are using an asphalt mixture tile with a bottom bonding layer made of bitumen, and steel fibers, exposed to high frequency electromagnetic fields to heat the fibers up and melt the bitumen(modified bitumen with 4% of SBS) in the bonding layer. Recycled steel fibers from old tyres were used to minimize the environmental impact .The bond between the tile and the old road is created by heating the fibers, by using of induction energy, and applying light compaction.With this technology, in less than 1 min of induction heating, the bonding layer reaches temperatures above 100’C and tile and old pavement stick together. Some tests were performed in this study which are following ,(1)Tensile bond tests were used to evaluate the tensile adhesion strength between asphalt tiles and blocks,(2)Shear bond tests were used to measure the interface shear strength of the tiles.(3)Simulation of traffic over a pothole,in that the visibility of the concept was tested by exposing the tiles to cyclic loading caused by wheel track tests,(4)X-ray CT scanning to know the internal structure of potholes repaired using induction energy.The first observation is that there is a linear relationship between shear and tensile strength and that shear strength seems to be 2.54 times smaller in average than tensile strength.the temperature was higher in test samples with higher content of fibers. The physical principle behind the strength gain of tiles is the drain of bitumen towards the gap between the asphalt tile and block.This was powered by the (1) total pressure exerted over the bonding layer, e.g. by the weight of the tile, (2) viscosity of bitumen and (3) total amount of bitumen available. The rutting deformation of asphalt tiles under simulated traffic conditions was very similar to that of original asphalt mixture and approximately 40 times smaller for the same loading time and energy.
But the gap of this particular is given as following, (1) When we encounter many different size of potholes, it will going to be tedious work to make Asphalt tile every time with different sizes. (2)As we are using here induce heating and for that we are using coil and 6 Kw induction heating generator., which makes it a bulky structure to carry at traffic road site.(3)we cannot use this kind of tile technology in patching work of small potholes or cracks on the flexible road.

Shifeng Wang et.al (2016) presented a study on recent developments in the application of chemical approaches to rubberized asphalt. A binder called Rubberized asphalt which is produced by adding crumb tire rubber modifier into heated asphalt. It shows better cracking resistance and fatigue resistance as compared to conventional asphalt. By adding chemical additives to rubberized asphalt, many improvements like low rutting resistance, high viscosity and poor storage stability are achieved. Various techniques like infrared spectroscopy, thermogravimetric analysis, gel permeation chromatography and sol-gel analysis are used for analysis of chemical composition of rubberized asphalt. It was found that rubber type, rubber particle size, and temperature, significantly influence the interactions between tire rubber and asphalt. The key factors described are chemical degradation of rubber in asphalt and stabilization of rubber in asphalt. The degradation promotes the swelling of tire rubber because of the looser cross-linked network. The degree of interaction between rubber and asphalt influences the aging properties of rubberized asphalt. CRMA and TB rubberized asphalt have shown similar weathering resistance, regardless of the degree of interaction in the rubberized asphalt. Minimizing the rubber sediment in the asphalt and reducing the degradation of physical properties are key requirements for improving the storage stability of rubberized asphalt. Degraded tire rubber hybridized with SBS is accepted for its usage in pavements. Inorganic filler can be used to improve rutting resistance and moisture resistance. However, the sediment of filler in the asphalt prevents it from being implemented on a large scale. Plasticizer improves process ability but influences high temperature properties. Therefore, different additives must be combined in order to maintain a suitable balance between processing and acceptable physical properties.

Umme Amina Mannan et al. (2017), presented the study on Influence of moisture conditioning on healing of asphalt binders. Healing is an important property of asphalt binder as it helps to recover the fatigue damage during rest period. However, the effect of moisture conditioning on asphalt binder healing has not been studied yet.
In this study, Moisture Induced Sensitivity Test is used to moisture-condition the binders and then tested using a Fourier Transform Infrared and Dynamic Shear Rheometer to evaluate the chemical and healing properties. Also, cohesion properties of the binder are calculated from the tack test using DSR. FTIR results show that water is absorbed in the asphalt binder due to the moisture conditioning. Additionally, results show that the healing rate of asphalt binder decreases due to moisture conditioning. A healing model is developed to separate the total healing into instantaneous and long term healing. The instantaneous healing is the instant healing that occurs just after the loading is removed. Moisture conditioning decreases the amount of instant healing by reducing the cohesion or energy of separation of the binder. Results also show that moisture conditioning reduces the long-term healing rate by increasing the required activation energy for diffusion. Therefore, the overall healing of fatigue damage reduces due to moisture conditioning of the asphalt binder.
Asphalt binders are moisture conditioned in three different levels. Healing models and all the healing parameters are estimated from the healing test for moisture conditioned binders.It can be concluded that moisture conditioning results in short-term aging of asphalt binder.The proposed healing model of asphalt binder is divided into two part: instantaneous healing and time-dependent healing. Results show that time-dependent healing rate is inversely proportional to percent water absorbed in the binder due to moisture conditioning. And the instantaneous healing is proportional to the cohesion of binder,which can be calculated from the work of separation of the tack test.In summary they conclude that the healing property of asphalt binder deteriorate when the binder is moisture conditioned.

Yuming Yang et.al (2015) presented a study on a pothole patching material for epoxy asphalt pavement on steel bridges: Fatigue test and numerical analysis. Considering the requirements of steel deck pavements, a patching material was developed using a fast cure thermosetting binder and a fine gradation. Then, to evaluate the fatigue performance of patched structure, a three-point bending fatigue test was conducted on three types of composite beams under four different stress ratios. After that, the Prony series presentation of the generalized Maxwell model was used to analyze the viscoelastic response of different patched beams and the effect of viscoelastic difference. The results showed that the fatigue test performed well on exposing the vulnerable parts of patched structures. The developed patching material had a smaller dynamic modulus and performed better in fatigue resistance than commonly used epoxy asphalt mixture. With the growth of viscoelastic difference between patching material and original material, the stress state on vertical patching interface becomes worse, and the interface becomes easier to fracture under cyclic load.

Epoxy asphalt concrete (EAC) is good in durability, high temperature stability and waterproofness and has been proved as a better pavement material for steel bridge pavement. Bituminous hot mixtures have higher quality but limited applicability under different weather conditions while cold-mixed mixtures have lower quality but are workable under most weather conditions. The TAF epoxy asphalt binder and fine gradation enable EAPP to perform well in fatigue resistance as a patching layer on EAC. At the same time, EAPP reduces the stiffness modulus of the patched structure due to its fine gradation. The vertical patching interface between EAPP and EAC reduces the fatigue life of the patched structure substantially. The fracture forms also show that the interface is a potential fracture section of the patched structure. The Prony series presentation of generalized Maxwell model was obtained by conducting frequency sweep test and pre-smoothing the storage modulus data. The results show that the storage modulus of EAPP is smaller than EAC under reduced frequency less than 104 Hz. The numerical analysis results indicate that the different viscoelastic properties of patching material and original material cause tensile stress concentration near the interface. With the increase of the viscoelastic difference, the patching interface is subjected to worse stress state. Since the patching interface is subjected to greater tensile stress and could be potential fatigue failure section, it is recommended that high quality adhesive materials and reasonable field procedures be selected for the pothole patching on EAC pavement. The viscoelastic difference should be considered to choose suitable patching material. Moreover, attention should be paid to the patched areas during pavement evaluation in case of second time failure.

Yanping Yin et al. (2017),showed the study on the Effect of chemical composition of aggregate on inter facial adhesion property between aggregate and asphalt.This study compared the inter-facial adhesion properties of asphalt with limestone aggregate and asphalt with granite aggregate.The main chemical compositions of limestone and granite are CaCO3 and SiO2, respectively.The main chemical compositions of limestone and granite aggregate were analyzed using X-ray diffraction XRD. A dynamic shear rheometer test was conducted to examine the rheological performance of the original asphalt, limestone-asphalt mortar, and granite-aggregate mortar. X-ray photo-electron spectroscopy was used to detect whether a chemical shift occurred between aggregate and asphalt or not and to analyze the adhesion function. The results show that the inter facial adhesion strength of the asphalt with limestone aggregate is higher than that of the asphalt with granite aggregate. The main chemical constituent of limestone is CaCO3, and the main chemical constituent of granite is SiO2. Limestone-asphalt mortar samples and granite-asphalt mortar samples were prepared by mixing original asphalt with pure CaCO3 and SiO2 powders, respectively. The limestone-asphalt mortar has lower phase angle than the original asphalt, whereas the phase angle of granite-asphalt mortar differs slightly from that of original asphalt. Carbon, oxygen, and sulfur are the main elements of asphalt,and the sulfoxide group has an influence on the adhesion property of asphalt. The adhesion function of the limestone aggregate with asphalt may depend on the migration of the outermost orbital electrons of Ca2+ to the active functional group in the asphalt, resulting in the formation of a new chemical bond. The adhesion function of the granite aggregate with asphalt is determined only in terms of its physical adhesion with the asphalt. The adhesion strength between the asphalt and limestone aggregate is over 10% stronger than that between asphalt and granite aggregate, without abrasion. After 1000 abrasion cycles, the adhesion strength between the asphalt and limestone aggregate is still stronger than that between asphalt and granite aggregate.The results indicate that the CaCO3 may react with some components of the asphalt, which leads to a chemical structure change and a phase angle reduction in the asphalt. SiO2 only achieves physical adhesion with the asphalt binder; it does not show a chemical reaction. The sulfoxide group may have an influence on adhesion ability.The adhesion function of limestone with asphalt may depend on the outermost orbital electrons of Ca2+ migrating to the active functional group in the asphalt. This would result in the formation of a new chemical bond. On the other hand, the adhesion function of the granite aggregate only depends on its physical adhesion with asphalt.In summary we can say that lime stone aggregate show more adhesion strength with asphalt as compare to the granite aggregate.

III. CONCLUSIONS

This literature search and product review has identified several pothole repair options. The review process also showed there are a number of factors that go into choosing which pothole patch will be most suited to a particular situation. If a road is going to have full depth reclamation in the near future, a patch need only be temporary; however, if the surrounding road is in reasonably good condition then a patch needs to be more permanent. The traffic volume, the extent of the damage to the road surface, the surrounding material, the safety of the maintenance department to work in the location and the weather; these are all things to consider when patching potholes. The first step in selecting a material is to identify the key properties that a material must possess to be efficiently placed and perform successfully in the conditions provided for the time desired. Several of the more desirable properties include the following:

- Short preparation time
- Quick and easy to place (good workability)
- Short cure time
- Adhesiveness
- Cohesiveness
- Resistance to softening and flow
- Flexibility
- Elasticity
- Resistance to aging and weathering
- Abrasion resistance

Based on literature, chemicals are short listed in following table. The goal is to have a versatile means of patching potholes that is inexpensive, easily available and simple to use.

no	Author	Year	Material	Proportion
1	Ala R. Abbas et al.	2013	Recycled Asphalt Shingles	5%
2	Nyoman Arya Thanaya et al.	2014	milled old road pavement	72.73%
			RHA	
			Cement	2%
3	Yuming Yang et al.	2015	limestone filler & basalt aggregate	4%
			DCPD(Dicyclopentadiene)	1.5%
4	Jizhe Zhang et al.	2016	bitumen, L1-L2 grade of aggregate, G1-G2, (DowCorningDC4), epoxy resin bonding material (Araldite)	-
5	Mohd Ezree Abdullah a, et.al	2016	Nanoclay A, nanoclay B, chemical WMA additive	NCMB B 4%
6	H. Obaidi, et.al	2016	SBS in bitmen	4%
7	Shifeng Wang et al.	2016	Crumb rubber + SBS	5% to 12%
			Crumb rubber + polymers	-

8	Mahyar Arabani et al.	2017	RHA	15%
9	Umme Amina Mannan et al.	2017	asphalt binder	_
10	Yanping Yin et al.	2017	CaCO3 and SiO2	_

REFERENCES

Ala R. Abbas, Umme Amina Mannan, Samer Dessouky (2013) "Effect of recycled asphalt shingles on physical and chemical properties of virgin asphalt binders", *Construction and Building Materials 45 (2013) 162–172*

H. Obaidi, B. Gomez-Meijide, et.al (2017) "A fast pothole repair method using asphalt tiles and induction heating" *Construction and Building Materials 131 (2017) 592–599*

I Nyoman Arya Thanaya, I Nyoman Widana Negara, et.al (2014) "Properties of Cold AsphaltEmulsion Mixtures (CAEMs) using materials from old road pavement milling" *2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials Procedia Engineering 95 (2014) 479 – 488*

Jizhe Zhang, Gordon D.Airey, JamesGrenfell, AlexK.Apeagyei, MartynBarrett (2016) "Development of a composite substrate peel test to asses moisture sensitivity of aggregate-bitumen bonds" *International Journal of Adhesion & Adhesives 68 (2016) 133–141*

Mahyar Arabani, Seyed Amid Tahami (2017) "Assessment of mechanical properties of rice husk ash modified asphalt mixture", *Construction and Building Materials 149 (2017) 350–358*

Mohd Ezree Abdullah, Kemas Ahmad Zamhari, et al (2016) "Engineering properties of asphalt binders containing nanoclay and chemical warm-mix asphalt additives", *Construction and Building Materials 112 (2016) 232–240*

Shifeng Wang a,⇑, Dingxin Cheng b, Feipeng Xiao c(2017)" Recent developments in the application of chemical approaches to rubberized asphalt" *Construction and Building Materials 131 (2017) 101–113*

Umme Amina Mannan, Mohiuddin Ahmad, Rafiqul A. Tarefder(2017) "Influence of moisture conditioning on healing of asphalt binders" *Construction and Building Materials 146 (2017) 360–369*

Yuming Yang, Zhendong Qian, Xin Song (2015) "A pothole patching material for epoxy asphalt pavement on steel bridges: Fatigue test and numerical analysis", *Construction and Building Materials 94 (2015) 299–305*

Yanping Yin a, Huaxin Chen, Dongliang Kuang, Lifang Song, Lu Wangb(2017)" Effect of chemical composition of aggregate on interfacial adhesion property between aggregate and asphalt" *Construction and Building Materials 146 (2017) 231–237*