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A Review on the Evaluating the Influence of Employment Nano-Matekaolin and Additive Materials on the Improvement of Hot Mixture Asphalt Properties

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ABSTRACT

In previous years, the world witnessed great urban development which increased interest in this aspect. To keep pace with this development, several things and new materials have been created to raise the standard of road construction. One of these things is the use of nanomaterials. Currently, the use of nanomaterials has become common to improve the asphalt mixtures which are used in the construction of flexible pavement because of the rise in traffic volumes and vehicles loads. This study deals with review of past related studies that improving the properties of asphalt mixtures through the use of nanometakaoline in the hot asphalt mixture in different proportions. Different proportions of nanometakaoline were used for the Hot Mixture Asphalt properties revised in these studies which were shown that the adding of nano-metakaoline led to improve the properties of Hot Mixture Asphalt to resist the traffic load and environmental effects. They used Marshall Test, indirect test, wheel track tests and others tests to exam the properties of improved Hot Mixture Asphalt and compared with the standard mixture (control).

Keywords: Metakaolin; nano-materials; hot mixture asphalt; Marshall Test; indirect test; improvement

INTRODUCTION

In the late 1800s, asphalt was first used to build roads and streets, and as the automotive industry increased, so did its use. Since then, advancements in asphalt technology have led to the use of increasingly sophisticated tools, methods, and materials when constructing structures built of asphalt pavement (Jony et al. 2011). Many sizes and shapes of contemporary infrastructure have been constructed, and in order to meet this requirement, the best quality concrete that is safe, straightforward, compact, environmentally friendly, and secure must be used. whose components, ratios, and manufacturing techniques are especially selected to satisfy unique performance and consistency requirements that are not usually achievable by employing simply conventional materials. (Prajapati et al. 2020) The ingredients of asphalt concrete are filler, aggregates, both fine and coarse, and asphalt cement, which is employed as a bindery. These ingredients are mixed in a certain ratio to create asphalt concrete. The inert substance that goes through sieve No. 200 and fills the spaces left by the coarse aggregate particles' pores and voids between them is called mineral filler. Instead of using regular Portland cement and powdered limestone as mineral fillers in hot asphalt concrete mixtures, a variety of locally available waste materials can be employed with effectiveness (AL- Saffar 2013).

The bulk of building materials that are currently accessible have already been recognized, as the discovery of fundamentally new materials is quite rare. As a result, there is little reason to expect significant advancements in this field. Therefore, the main trend in creating novel construction materials is the introduction of reinforcing elements like fibers, nanoparticles, and other materials into building materials. Because of their many potential applications, nanomaterials and fibers are a rapidly expanding field of study; the building industry is one area in which they play a particularly important role. Analyzing how fibers and nanoparticles affect the characteristics and functionality of building supplies like concrete and mortar is essential (Rahmah 2022). Rehabilitating deteriorating concrete structures that are exposed to extreme living loads, increased traffic volume, structural aging, and other environmental effects is becoming increasingly important. The use of this toxic resin has negative effects on human health and the environment, as evidenced by scientific studies and published literature, even when combined with some traditional retrofit procedures. The main goal is the increasing of the blend percentage of a recently developed Mineral Based Composite (MBC) adhesive by presenting different concentrations of metakaolin and fly ash, two industrial byproducts. Because of the event-grade bonder may one day replace epoxy in FRP reformation. a higher degree of sustainability was discovered when a certain quantity of this replacement was used (Vasudeva & Suntharavadivel 2019).

The tensile strength and flexibility of asphaltic concrete determine how resistant it is to cracking. Additionally, it has been determined that a low tensile strength significantly contributes to other performance issues. When tensile strength is reduced, mixes' fatigue life rapidly reduces. The loss of stiffness, which causes cracks and stripping, justifies this trend. A statistical analysis model for tensile strength in asphalt mixtures presents the key influencing factors, which include temperature, compaction, asphalt content, soaking, and the maximum size of the aggregate (Al-Baiti 2012). The three main problems with asphalt pavements are adhesion loss (moisture susceptibility), fatigue, and rutting. The demonstration of asphaltic concrete mixtures between moderate and hot temperatures in terms of fatigue and rutting can be enhanced by substitution filler by up to 25% when compared to standard mixtures. Simultaneously, replacement filler provides better adhesion properties, improving them by 70% over the traditional mixture (Ullah et al. 2020). The characteristics of cementitious composites are adversely affected by high temperatures, which can result in irreversible changes or even complete failure. There are several ways to prevent concrete from deteriorating in high-temperature environments. Nanomaterials have been added as admixtures recently, and they prevent cement-based composites from thermally degrading when exposed to high temperatures (Sikora et al. 2018).

Utilizing materials with nanotechnology has become more common in recent years to improve and reinforce concrete's mechanical characteristics and behavior. The unique qualities of these materials, such as their minuscule size, significantly enhance the inner structure of concrete, bestowing upon it novel attributes and markedly improving its behavior, are the reason for this (Al-Luhybi & Altalabani 2021). Metakaolin, which is typically low in compressive strength, is widely used in soft clay soils found in Iraq and other countries worldwide, in addition to asphalt and concrete. Soft clay exhibits problematic behaviors as a result. One appropriate approach is to use chemical additives to improve soft soil. (Abdulkareem & Abbas 2021). Neat binder-made asphalt pavement is insufficient to withstand high traffic volumes and adverse environmental conditions. Consequently, in order to improve the binder's properties, polymers must be added. The properties of the resulting polymer-modified asphalt were found to be influenced by a number of blending process parameters, including temperature, shear rate, mixing time, and blade shape, according to literature (Babalghaith et al. 2019).

To enhance hot mix asphalt's functionality, numerous researchers have attempted to reduce or eliminate the sensitivity of moisture damage to temperature. This is because moisture damage is shortening the structural and functional life of fixable pavement by exposing it to moisture. The study's requirements were satisfied by evaluating the index of retained strength in accordance with ASTM D 1075 and the indirect tensile strength test in accordance with AASHTO T 283 criteria. Additionally, the study evaluated the extent of moisture damage and evaluated the temperature sensitivity of the hot mix asphalt using modification and net asphalt through an indirect tensile strength test. These tests showed that the resistance to moisture damage and temperature sensitivity of hot mix asphalt with modified asphalt has changed significantly in comparison to the reference mixture (Hadi 2017). In order to increase the range of applications for geopolymer mortar and concrete in building construction, researchers are currently working to improve their mechanical properties at room temperature (Jindal 2019).

Mineral filler is an integral component of asphalt mixtures because it allows the asphalt binder to become more rigid and resilient. Mineral fillers have an impact on asphalt's mechanical qualities, but they also have an impact on stripping and moisture damage. Hydrated lime was used in place of some of the filler in asphalt concrete. Results from laboratory studies confirm the benefits of adding lime that's hydrated to asphalt mixtures. The enhanced susceptibility to moisture and rutting resistance of lime that's hydrated, a mineral filler with activity, help to extend the asphalt pavement's lifespan. The filler's characteristics dictate how it interacts with bitumen and enhances the performance of the mixture. The article discusses how hydrated lime improves bitumen-aggregate affinity and has a stiffening effect when combined with bitumen (Remisova 2015). Figure 1 shows the hot mixture asphalt components and Figure 2 shows the nano-metakaoline structure. This research's primary goal is to conduct an experimental investigation into the viability of using nanometakalin to improve the performance of hot asphalt concrete mixtures as a filler and content (Mustafa et al. 2019).

FIGURE 1. The hot mixture asphalt components

FIGURE 2.The nano-metakaoline, (a): Powder, (b): production process of powder (Mustafa et al. 2019)

LITERATURE REVIEW OF RELATED STUDIES

Ibrahem & Wahab 2008 used of Metakaolin, a super pozzolan made by converting kaolin clay, which is found in the Dwekhla region of Iraq, into Metakaolin. In order to transform kaolin clay into metakaolin, the ideal calcination temperature and the ideal calcination time were determined in a laboratory experiment conducted for this work. According to the findings, 700°C was the ideal calcination temperature, and an hour was the ideal calcination time at that temperature.

Abd Tayh & Jabr 2011 employed Marshall test procedure to examine the possibility of improving the properties of Hot Mix Asphalt. Determining which additive is superior to the others for use and how to incorporate this type of filler into the mixture are additional goals. Based on the findings, we can conclude that Portland cement, when added to the aggregate at the mix temperature, has the greatest effect on the hot mix asphalt's mechanical characteristics.

Yilmaz, et al. 2011 produced hot mix asphalts to examine the viability of employing asphaltite, matching the mineral filler ratio by using mixing ratios of 25%, 50%, 75%, and 100%. The findings show that at 15 C, employing asphaltite as a whole filler greatly raised the stiffness modulus by 91% and retained 27% increase in Marshall stability. In terms of the test for tensile strength, Asphaltite-only mixtures lost only 13% of their weight after a single freeze-thaw cycle of their tensile strength ratio; control mixtures lost 35%of tensile strength. At the fatigue test, there was a notable increase. When 300 kPa of stress is applied, the leading cycle number that is causing the mixtures to fail with filler weights of 25%, 50%, 75%, and 100% asphaltite were, in that order, 2.9, 3.6, 5.4, and 7.9 times greater than the mixtures used as controls. The performance of using asphaltite as a filler was excellent, particularly regarding endurance and resilience against moisture-related harm.

Yao et al. 2012 looked into the features of asphalt binders' rheology after nanomaterial addition. The two types of nanoclay are polymer-modified (PMN) and nonmodified (NMN) are the additives which used. At two and four percent concentrations by the asphalt binder's weight, respectively, and were incorporated into the control PG 58-34 asphalt binder. The results demonstrate that the addition of NMN to the control asphalt increases the viscosity and complex shear modulus of the asphalt binder, while adding PMN causes a slight decrease in both. Furthermore, when compared with the NMN adapted binder for asphalt, the PMN When viewed through the lens of dissipated work, modified asphalt binder exhibits superior overall resistance to rutting and fatigue cracking.

Fang et al. 2013 explained the review that begins with an introduction to the various kinds of nanomaterials applied to modified asphalt. Next, it discusses the techniques used to change the asphalt using nano-materials., and lastly, it presents and discusses how base asphalt performs in relation to nanomaterials. The present study's results are used to describe the impact of parameters of the preparation procedure on the modified asphalt system's stability and each phase's compatibility with the modified asphalt. Lastly, a projection of the topic field's development trend is made.

Jassim et al. 2014 focused on the retained strength index and the Marshall test, which measure the characteristics of waste plastic particles, including their size, thickness, and percentage of content that give hot mix asphalt its optimal performance to ascertain the characteristics of plastic waste particles this study. Four mm thicknesses (0.2, 0.5, 0.8, and 1.0 mm), five content percentages (five, ten, fifteen, twenty, and twenty-five) based on the aggregate's weight overall were added for this purpose, along with six distinct particle sizes (passing through a 3/4" (19.0 mm) sieve to be retained on a No. 50 (0.3 mm) sieve. Plastic waste with thin thickness and fine particle size added to the aggregate at a rate of 15% by weight not only increased Marshall stability and resistance to water damage, but also helped mitigate some of the issues with the environment brought about by the traditional disposal of plastic waste techniques.

Zafari et al. 2014 looked at the possible advantages of using nano-silica as an anti-aging additive. To achieve this, various amounts of nanosilica were added to neat asphalt binder. The asphalt binder in the nanosilica-modified specimen was subsequently subjected to Short-term oxidative aging using a rolling thin-film oven (RTFO) in comparison to those in the non-modified specimens. Asphalt naturally contains carboxylic acids, but oxidative aging has been shown to dramatically increase the concentration of these acids. Thus, the oxidation aging of modified asphalt is decreased. Furthermore, it was discovered that the asphalt binder's G* and η*, or complex modulus and viscosity, respectively are greatly increased in the presence of nanosilica. This enhances the pavement's ability to withstand rutting. The findings demonstrated that incorporating nanosilica into asphalt binder can improve its rheological properties, antiaging properties, and ability to resist rutting.

Murana et al. 2014 examined the effectiveness of partially substituting cement for metakaolin in asphalt concrete. Tests on bitumen (consistency test), aggregate and cement, and oxide composition on metakaolin were conducted. Using the marshal stability method of pavement design, several mixes with different proportions of metakaolen and common Portland cement was prepared in order to evaluate their strength. It was found that, with an optimal bitumen content of 5.5%, the level of stability, flow, gaps in mix aggregate, and void in mix all meet the standard at different percentages of bitumen content.

Rashwan 2015 studied the impact of aggregate type and mineral filler on hot mix asphalt (HMA) is investigated in this study in a lab setting. Crushed basalt, crushed limestone, and crushed gravel were the aggregate types used in the mixtures. The kind and concentration of the filler mineral were the two parameters used to examine the filler's impact on HMA. Three ingredients: hydrated limestone powder, cement, and lime powder were the three types of mineral fillers used in the mixture. In this study, fillers made up 4, 6, and 8% of the total. Indirect tensile testing and Marshal tests were used to examine how various samples behaved differently depending on the parameters taken into account for this investigation. Based on the results, basalt outperforms gravel and limestone in terms of Indirect Tensile Strength, Marshall Stability, Marshall stiffness, Marshall Quotient, and Stiffness Modulus. In contrast, basalt produced lower values of air voids, density, and flow than limestone and gravel. The outcomes also demonstrated that cement was a better mineral filler than other varieties and that the mix's mineral filler content shouldn't go above 4%.

Ameri et al. 2016 showed how nano clay affected the tenacity of the clean and SBS-modified asphalt mixture and binder to rutting and moisture damage. In order to compare clean and asphalt binder and mixes modified by 4% SBS, 2% and 6% nanoclay were combined with 4% SBS. Tests including rotational viscosity, dynamic creep, indirect tensile strength, dynamic shear rheometer, and repeated creep recovery demonstrated that nanoclay enhances the resistance of the modified and neat asphalt binder to moisture damage and rutting.

Al-Busaltan 2016 evaluated the volumetric and mechanical characteristics of HMA that uses various waste and/or by-product compositions as filler materials. Ordinary Portland Cement (OPC) in HMA was proposed to be partially or entirely replaced by Cement Kiln Dust (CKD), with the addition of two fillers, RHA (rice husk ash) and SF (silica fume), up to a 30% reduction in OPC. The designed HMA was evaluated using conventional volumetric and mechanical properties. The results indicated that, in cases where a complete replacement of CKD would not meet local specification requirements, CKD containing less than 25% RHA or 15% SF could bring design HMA to compliance. Additionally, a key instrument for understanding the variation in HMA properties is the microanalysis properties of various filler types.

Salman 2017 work's goal was to look into how adding NMK, or nano-metakaolin, as a pozzolonic substance affected some of the mechanical characteristics of OWC, or oil well cement specifically its compressive strength. Kaolin rock was used to create nano-metakaolin (NMK) by thermally activating kaolin clay at various temperatures (700–800 oC) for two hours. The clay was then crushed and ball milled for forty to sixty hours. The cement utilized in this study is Oil Well Cement class G. NMK was added to the cement as a partial replacement additive at weights of 3%, 6%, and 10%. The cement has two average particle sizes, 75 nm and 100 nm, and a w/c of 0.44. The findings demonstrated and validated that non-malic acid potassium (NMK) served as an activator to boost the hydration process in addition to being a filler. This is achieved by the NMK particles through the consumption of calcium hydroxide CH crystals, producing more C-S-H, filling pores to boost strengths, reducing the size of the crystals at the interface zone and converting the weaker calcium hydroxide crystals into C-S-H crystals, upgrading the cement paste domain and the interface zone.

Salem et al. 2017 studied the impact of the resistance against water and the O.A.C., or optimal asphalt content, at different percentages of fine glass were investigated using Marshall design. It is anticipated that leftover glass can be repurposed for asphalt mixtures. As a result, by obtaining affordable and cost-effective mixtures that will increase the mix's durability and stability while lowering the O.A.C., and increase the road surface's resistance to skids, accidents will be decreased and significant financial savings will be realized. Glass waste can be crushed and sieved to make glassphalt, which is used as fine aggregate in asphalt concrete. It is possible to achieve satisfactory performance for the upper layers of asphalt pavement by including 10% glass waste in the mixture.

Al-Jumaili 2018 recycled tire rubber and plastic bottles are two waste materials that have been evaluated as extra materials with percentages of the aggregate's total weight retained on a 2.36 mm sieve of 3, 6, 9, and 12. By adding5, 10, and 15% of the weight of asphalt, As a modifier for asphalt cement, leftover engine oil was used, replacing a portion of the asphalt content. The goal of The purpose of this experiment was to use Marshall properties. The results showed that the 12%PB mixtures appeared to increase air gap, VMA, indirect tensile strength, and Marshall stability while decreasing density and rut depth. The recycled tires demonstrated a strong resistance to water damage, with 9% of the total weight held in reserve on a 2.36 mm sieve. Compared to the standard mixture, the indirect tensile strengths of the asphalt mixtures containing waste oil engines were lower. Additionally, a strong resistance to moisture damage was demonstrated by these modified mixtures.

Wahjuningsih et al. 2018 explained that by decreasing the temperature at which asphalt mixture is mixed and compacted, this research aims to improve the asphalt industry and reduce fuel consumption. Warm Mix Asphalt is the name of this technology (WMA). Because of the addition, Buton Natural Asphalt Rubber (BNA-R) has been able to enhance HMA's performance. Zeolit can be used as an additive to bring down the temperature of mixture. Composition of aggregate: BNA-R contents of 5% and 10% and 2% zeolite content, according to aggregate grading specifications for airport pavement. The combination has yielded a Resilient Modulus value based on the ideal bitumen concentration, as established by the Marshall test, as determined by the Universal Material Testing Apparatus (UMATTA). Also, the Wheel Tracking

Machine (WTM) was used to test the asphalt mixtures' value of permanent deformation. The outcome demonstrates that the rutting potential can be reduced through WMA with a modified BNA-R binder. With some limitations, The WMA's performance has improved since local materials have been added. for airport pavement. According to this research, the BNA-R addition for the particular aggregate composition type has changed the resilient modulus and permanent deformation characteristics.

Mohd et al. 2018 investigated how adding kaolin clay affected the hot-mix asphalt's characteristics. By weight of binder, there are four kaolin clay replacement levels: 2%, 4%, 6%, and 8% were taken into consideration. Using a Marshall flow and stability examination, the impact of hot-mix asphalt with kaolin clay were assessed in terms of rigidity, density, mix voids overall and asphalt-filled voids. The outcomes of the tests demonstrated that filler can be successfully replaced with kaolin clay to enhance the properties of the asphalt mixture. In general, 2% kaolin clay replacement level asphaltic concrete performs exceptionally well, showing good stiffness and stability.

Al-Khafaji et al. 2018 assessed how well a flexible pavement performs composed of two additives that are readily available locally and asphalt from the Al-Dauray refinery. Polypropylene and hydrated lime. In a dry state, hydrated lime was used at 1% of the aggregate's weight as a partial filler replacement. A percentage of 1, 2, and 3% of the asphalt's weight was added with polypropylene. Through the use of the Marshall index of retained strength and indirect tensile strength tests, the primary mechanical properties of asphalt mixtures were assessed. When compared to the control mixture, the retained strength test index increased by 1.3 times; the results of the indirect tensile test and the Marshall test increased by 1.5 and 1.3 times, respectively when hydrated lime and polypropylene were used. In order to precisely fulfill the demands for stability, moisture sensitivity, and indirect tensile strength, a blend of 1% hydrated lime by aggregate weight and 2% polypropylene by weight of asphalt-to-asphalt mixtures was administered.

Abed & Oudah 2018 determined how Styrene butadiene styrene (SBS) and nanosilica (nSIO2) are two modifiers that affect the rheological characteristics and chemical fusion of the regional asphalt sealer. The control asphalt binder's viscosity was found to be caused to slightly increase by the addition of nanosilica. However, adding SBS polymer caused the control asphalt binder's viscosity to rise three times greater than the control binder's reference viscosity. The findings indicate that SBS and nSIO2 have somewhat affecting performance at low temperatures; hence, low temperature grade remains unchanged. Enhanced asphalt binders' performance will be achieved. Because of and according to FTIR results, When the altered binder was contrasted with the standard binder, anti-oxidation was enhanced.

Raufi et al. 2019 assessed how three different types of nanomaterials—nano-Bentonite, nano-CaCO3, and nano-ZycoTherm—affected the characteristics of asphalt binder and HMA. The study's findings showed that the rheological characteristics, storage stability, and resistance to high temperatures of asphalt binder samples may all be improved by nanomaterials. The results of the mix design showed that Marshall stabilities were marginally improved and the ideal binder contents dropped with nano-modification. Furthermore, in comparison to the control mixture, 0.1% of ZycoTherm raised the TSR by 22%, according to the modified Lottman test results, indicating its effectiveness in enhancing The HMA's ability to withstand damages caused by moisture.

Crucho, J., Picado-Santos, L., Neves, J., & Capitão, S. (2019). This review is mostly concerned with the mechanical characteristics of asphalt mixtures, both in fresh and aged conditions. The effects of every nanomaterial were generally assessed using the most advanced tests available today for characterizing a combination of asphalt mixtures' mechanical properties, such as their stiffness modulus, Marshall stability, fatigue resistance, and indirect tensile strength. The impact on the resistance to aging of the asphalt mixture were assessed using aging indicators, such as the aging sensitivity. To provide a more thorough comprehension of the nanomaterials under analysis from an economic standpoint, a basic cost analysis is conducted.

Kareem et al. 2019 studied a set out to ascertain the optimal amount of NMK to incorporate into hot mix asphalt, assess how the mix's properties are affected by the addition of Nano-Metakaolin, as well as contrast the outcomes with both domestic and global standards. Several amounts of Nano-Metakaolin by weight of bitumen, specifically 1, 2, 4, 8, 16, and 20%, were used as a modifier to the bitumen. Testing methods include kinematic viscosity, ductility, penetration, softening point, and conventional tests, were performed on modified asphalt binders. The ideal Nano-Metakaolin from these tests was 16%. Once the ideal Nano-Metakaolin was identified, two sets of asphalt concrete mixtures were prepared. The ideal Nano-Metakaolin, or 16% (modified mixes), was present in the second set, while the first set contained only pure asphalt (the control mixture). Experiments were carried out to assess the modified and control mixtures. The findings of the tests showed enhancements to the mechanical attributes, including increased Indirect Tensile Strength (ITS) and Marshall Stability, and index of retained strength. In the end, adding 16 percent of Nanometakaolin by weight to asphalt improved its qualities and produced mixtures that are durable enough for use in highway construction.

El & Mohammed 2019 examined the effects of utilizing nanomaterials on bitumen properties by using asphalt binder 60/70, two distinct nanomaterials (micro-sized silica and clay), as well as one additive (styrene-butadiene-styrene). The modified binder underwent screening and selection in accordance with standard asphalt binder performance indicators, such as tests for softening points and penetration. The findings demonstrated that the softening point was raised when SBS was added to nano silica and nano clay and decreased penetration.

Zghair et al. 2019 developed a more efficient method for processing asphalt binder that has been altered by adding micro-silica particles. The study's findings demonstrated that improving the physical characteristics of asphalt binder with the use of micro silica as a modifier was beneficial. Overall, it was discovered that the temperature sensitivity was enhanced, the value of penetration decreased, and the temperature of the softening point increased as the viscosity value did. In addition, it was more practical to use high shear mixing to create a homogenous composite binder and to effectively disperse the asphalt binder with microscopic silica particles. The tested specimens ultimately demonstrated that a microsilica content of 6% was sufficient to improve the physical properties of asphalt and make it more suitable for use in the construction of road surfaces in hot climates.

Zghair et al. 2019b improved the efficiency of nanosilica (NS) particle mixing with bitumen adhesive is the study's objective. The properties of the asphalt sealer were found to be improved by the incorporation of nanosilica. In general, it has been found that not only does the softening point increase, the penetration value falling, the temperature sensitivity developing, and the viscosity rising. Additionally, higher shear mixing was more advantageous, particularly in achieving a uniform composite material and a thoroughly mixed layer of nano silica powder in the binder for asphalt.

Arshad et al. 2019 explored the application of using nanosilica to improve bitumen resistance to rutting and moisture susceptibility of Asphaltic concrete with a dense grade. The way the dense asphaltic concrete mix performs was found to be enhanced by the inclusion of nanosilica in the bitumen.

Addahhan et al. 2019 analyzed the differences in Marshall properties distinguishing traditional Hot Mix Asphalt (HMA) from WMA mixtures. The analysis was done on specimens composed of 40/50 PEN asphalt binder from the Al-Dorah Refinery and source aggregate from Al-Nibaae, with two modified organic additions (Asphaltan A and Asphaltan B). The mechanical characteristics of aggregates and asphalt binder are tested in laboratories. Using the Marshall design method, HMA and WMA preparations are carried out using two distinct kinds of aggregate gradation mixtures. The additives were chosen in dosages of 1, 2, and 3% of the asphalt binder's total weight. WMA mixes are created using the same process but at a temperature 40 °C lower than HMA specimens. The presence of additives and dosages is responsible for numerous changes in properties, both physical and mechanical that are seen. The outcomes demonstrate that the properties obtained from incorporating Asphaltan A and Asphaltan B into the Iraqi asphalt binder as WMA additions are improved.

Qasim et al. 2020 mentioned that to strengthen the cement concrete mixture, metakaolin has recently been studied as a Pozzolanic admixture. The mechanical properties of the HMA were evaluated experimentally after cement mineral filler was partially replaced with metakaolin that carried out in this study. Five mixes with the ideal amount of asphalt were made, with the percentages of regular cement replaced by 0, 25, 50, 75, and 100% metakaolin. It was discovered that the HMA's mechanical behavior is significantly impacted in addition to various amounts of Metakaolin replacement in place of cement. The outcome showed that Flow, Density, and Stability of Marshall increase with increasing Metakaolin content up to 50%, at which point they begin to decrease at 75% and 100%. As the percentage of Metakaolin increases, the air and void spaces in the mineral aggregate decrease, reaching their lowest point at 50% of Metakaolin. At 25, 40, and 60 degrees Celsius, As the metakaolin content rises, the indirect tensile strength increases gradually, but the temperature susceptibility falls as the metakaolin content rises. By using Metakaolin filler, the ability to withstand moisture damage has been improved. Conclusion: Metakaolin can be added to the hot asphalt mixture at a 50% replacement rate as a mineral filler, with a 5.2% optimal asphalt content.

Joni et al. 2020 explored the potential utilizing waste plastics like polyvinyl chloride (PVC) and low-density polyethylene (LDPE) as well as waste vegetable oil (WVO) as enhancing additives for (40/50) asphalt cement. The objective is to lessen the amount of waste that is illegally disposed of, alter the asphalt binder's characteristics, and use less bitumen, which lowers costs. The findings showed that bitumen modified with spent vegetable oil is more suited for use in temperate and cold climates because it has a lower resistance to rutting and better withstands heat cracking; however, the addition of plastic wastes in addition to spent vegetable oil may have the opposite effect. As a result, By incorporating waste vegetable oils and waste plastics into asphalt cement in the right amounts, new binders suitable for hot and cold climates can be created. Ultimately, it can be said that recycling waste plastics and oils from the industry for hot mix asphalt is a practical and legitimate way to get rid of these wastes.

Mohammed et al. 2020 explain that in accordance with Iraqi specifications, the gradation of aggregates chosen with the midpoint and Portland cement (PC) and high reactivity attapulgite (HRA) are two varieties of mineral filler materials—that were used in asphalt mixtures with asphalt binder grade (40–50) are presented in this paper along with their mechanical properties. Furthermore, this study illustrates the beneficial effects of HRA and PC in asphalt mixtures on variables like moisture susceptibility, indirect tensile strength, volumetric properties, and marshall stiffness. The findings clarified how the characteristics of mixtures of asphalt were significantly impacted by the HRA (5%) and (7%) percentages. The volumetric characteristics of asphalt mixes improved with an increase in HRA percentages. The advantage of including HRA in asphalt mixtures is supported by the findings of a laboratory investigation. The excellent mechanical and moisture-sensitivity resistance of a mineral filler with activity HRA helps to prolong the pavement layer's life cycle.

Oda et al. 2020 investigated how to evaluate how well the performance of modified HMA and modified asphalt binder, A program of experimentation has been implemented. Both nanoclay (NC) and nanosilica (NS) function as modifiers, were employed. By bitumen weight, the addition of NS and NC was 3% and 5%, and 7%. The control mix was compared to the results. Findings indicate a considerable improvement in the majority of the properties of HMA and asphalt binder. At 3% NC and 5% NS, penetration dropped by 24.07% and 20.37%, respectively. The ideal nanomaterial content was determined to be 3% NC and 5% NS (ONMC). Modified asphalt mixtures were created by adding 3% NC and 5% NS to bitumen. In contrast, the modified mixtures had a detrimental impact on the stability loss (LOS) despite demonstrating a notable enhancement of both stability and indirect tensile strength (IDT).

Abd Shareef & Al-Hdabi 2020 assessed the impact of incorporating Sugar Waste (SW) components, this study compares the characteristics of hot mix asphalt in relation to the specifications provided by the State Commission on Roads and Bridges (SCRB, R9). Asphalt mixture in two separate batches heated were made: one using SW materials (modified mixtures) and the other using Mineral filler (control mixture) consisting of Standard Portland cement (OPC). An enhancement in Indirect Tensile Strength, a minor increase in Marshall Stability, and improved Marshall Stability after aging in the mixture are observed when tests are conducted in accordance with LTA. Moreover, the adjusted mixtures meet (SCRB R9).

Zghair et al. 2020 examined how the use of nanometakaolin filler affects the rheological characteristics of asphalt binder. The objective's findings demonstrated that modifying asphalt binder properties with nanometakaolin filler was beneficial. It was discovered that In contrast, the temperature susceptibility (P.I.) and penetration values dropped, the viscosity and softening point values generally increased. High shear mixing produced a homogenous composite binder by facilitating good NMK filler diffusion into the asphalt binder. Furthermore, the findings shown that adding 5% nano metakaolin to the weight of the asphalt was a reasonable way to improve the rheological properties, leading to greater percentage reductions of about 30% and 18%, respectively, in the penetration value and ductility value, and an increase in values for viscosity and softening point of roughly 77% and 14, respectively. This makes this better suited for building highway pavements in warm climates.

Joni et al. 2020 investigated the viability of using metakaolin powder in micro and nanosizes, three contents (1%, 3%, and 5% of the asphalt weight) in a high shear mixer set for 60 minutes at 4000 rpm will develop the properties of the binder for asphalt. The modified asphalt binder's rheological properties are positively impacted through the inclusion of metakaolin. With 6% of the metakaolin's nano (nMK) and micro (mMK) content, the higher percentages of improved viscosity and values for the softening point were approximately (77, 40) % and (14, 9) %, correspondingly. In addition, there were larger percentage declines in the nano (nMK) and micro (mMK) ductility and penetration values at 6% content of Metakaolin, which were approximately (18, 11%) and (30, 16%), respectively. Additionally, the incorporation of the metakaolin contents' micro (mMK) and nano (nMK) dimensions resulted in an increase in the complex shear modulus values and a decrease in the phase angle. The higher the value of the complex shear modulus was found to be 5% of the content of metakaolin in the micro and nano size. Moreover, higher the values of the complex shear modulus for the Nano, micro, and control asphalt binder types were determined to be PG 76, PG 64, and PG 58, respectively. It is a sign that the rutting performance has improved and that it is now suitable to construct flexible highway pavements in hot weather.

Alamrew & Mollenhauer 2021 examined the advantages of adding Wetfix BE surfactant additive and hydrated lime filler to the mix to decrease its susceptibility to moisture. It also looked at the impact of Bituminous mixtures' aggregate mineral composition susceptibility to moisture. Four laboratory Bituminous mixtures' aggregate mineral composition were used to investigate aggregate minerals' effects as well as the benefits of Wetfix and hydrated lime BE: pull-off tensile strength, indirect tensile strength, rolling bottle, and shaking abrasion tests. Every test's outcome demonstrated that the mineral composition of aggregate has a major impact on how well bituminous mixtures resist moisture, and that adding Surfactant additives Wetfix BE and hydrated lime filler can help bituminous mixtures perform better against moisture sensitivity and enhance asphalt mix performance over time.

Al-gurah & Al-Humeidawi 2021 determined how three different kinds of mineral filler affect the hot mix asphalt's (HMA) mechanical properties. Portland cement that is average (OPC) and limestone were also utilized the use of mineral fillers (MF) in addition to Rice Husk Ash (RHA). Two stages of burning were used to prepare the RHA: burning it in a closed space for the first stage and burning it for two hours at 800 °C in an oven for the second. In the production of HMA, various percentages of these mineral fillers—25%, 50%, 75%, and 100%—were used to replace OPC and RHA with traditional mineral filler. The outcomes demonstrated that RHA can be added to HMA as a mineral filler; Yet, a 25% RHA and a 75% limestone mineral filler ratio was optimal.

Hasan et al. 2021 explained that according to the theory of surface free energy, to determine whether mixtures of pure and modified asphalt binders (Styrene–Butadiene Styrene (SBS)) could be harmed by moisture, the adhesion, de-bonding, wettability, and energy ratios were computed, BG plus, an anti-stripping agent, and Butyl Rubber (BR) with various aggregate types. It was completed with the sessile drop technique. The findings of the experiment indicate that for both types of asphalt binders and aggregates, the addition of SBS and BR modifiers will cause an increase in adhesion work, a decrease in de-bonding work, and a decrease in ER2 and wettability. Conversely, reduced adhesion and de-bonding work, as well as increased ER2 and wettability between the asphalt binder and aggregate surface, were the results of adding an anti-stripping agent (BG plus). These results will improve the potential for the aggregate and asphalt binder to bond stronger, strengthening the asphalt mixture's resistance to damage caused by moisture.

Namaa et al. 2021a used SBS, investigated and improved the properties of porous mixtures is the goal of this study. This essay provides results from laboratory experiments. They conducted on the binder, aggregate, and additive materials that make up this mixture. A percentage of the binder's weight (2.0, 3.0, and 4.0) is devoted to SBS. It was discovered that this addition causes permeability and air void to decrease by 1.7%, 3%, and 3.5%, respectively, but not as much as that without polymer modifier. In contra-staged and unaged abrasion loss dropped by (4.1, 6.67 and 10.92) (4.7, 6.3 and 2.6)%, in that order. In comparison to the original asphalt cement, there are three reductions in the drain down value: 16.5%, 38.25%, and 43.51%.

Zghair & Mohammed 2021 assessed the physical characteristics each of the original and altered asphalts made with nanoclay ingredients. The outcomes of physical testing indicated that improving the characteristics of the asphalt could be achieved by adding nanoclay material as a modifier. For instance, as the amount of nanoclay increases, so do the coefficients of viscous and point of softening. As a result, the temperatures for mixing and compaction rise to 170 degrees Celsius when the modified asphalts' nanoclay content does as well. In contrast, as the modifier content increases, the values of ductility and penetration drop. An increase in the proportion of nanoclay improves the modified asphalts' penetration index. As a result, the modified asphalt containing 7% nanoclay yields a higher penetration index value.As a result, it positively affects the resistance to rutting.

Tamiru et al. 2022 studied the impact of non-traditional materials, such as Superpave gradation and Belessa kaolin, on Marshal characteristics, the present research investigated the asphalt mixtures' resilience to moisture and irreversible deformation. At varying replacement rates (0, 10, 20, 30, 40, and 50%), Belessa kaolin was substituted for the conventional filler based on a control mix that contained the optimal bitumen content (OBC) is 5.1%. and 5% crushed stone dust (CSD). Greater resistance to moisture susceptibility and improved marshal properties are obtained using a thirty percent replacement rate for Belessa kaolin. According to the experiment results, Belessa kaolin has met the requirements outlined in the specification when used as a filler in HMA, replacing conventional filler up to 30% with Superpave aggregate gradation.

Ali et al. 2022 looked into how different Nano-Kaolinite contents affected the warm mix asphalt's (WMA) mechanical performance. Nano-Kaolinite was used as an additive because it is widely available, reasonably priced, and easy to acquire and reduce to nanoscale. The study examined the mechanical and durability properties of WMA mixes that included Nano-Kaolinite at varying percentages (2, 4, 5, 6, and 8%). based on the weight of bitumen. Applying a bitumen additive called EvothermTM, the WMA was produced. The findings demonstrated that while increasing the amount of Nano-Kaolinite reduced Marshall flow, increasing the amount of Nano-Kaolinite increased mixture capabilities. Overall, the asphalt's and mixture's effectiveness was significantly impacted by the Nano-Kaolinite content, which also seemed to make warm asphalt's effects harsher. Furthermore, the results showed increases in indirect tensile strength, the Marshall stability and compressive strength of thirty, fifty, and eighty percent, in that order. Marshall flow experienced a 9% decline. at the ideal additive percent. Additionally, adding Nano-Kaolinite at any cycle number reduces rutting depth. By strengthening the bonds and compatibility between the various asphalt particles, Warm mix asphalt can function more efficiently when nanomaterials are added, leading to more cost-effective and environmentally friendly pavement solutions as well as more durable and sustainable pavement systems.

Zhang et al. 2022 measured the mechanical and physical characteristics in a freeze-thaw environment. An analysis was conducted on the modification the impact of nano-metakaolin on concrete's resistance to frost at both the mesoscale and microscale. Examined was the effect of freeze-thaw damage on nanometakaolin-containing concrete. A meso-statistical damage model for nano-metakaolin concrete exposed to freeze-thaw cycles has been developed, along with the influence law of stress strain. The findings indicate that adding 5% nano-metakaolin can significantly reduce the rate of crack propagation and freeze-thaw cracking in concrete when compared to other nanoclays. The five percent nano-metakaolin-infused concrete has a surface crack width of only 0.1 mm after 125 cycles of freeze-thaw. The highest compressive strength is found in concrete that contains 3% nano-metakaolin when there are no freezethaw cycles, 28.75% more than ordinary concrete; the concrete containing 5% nano-metakaolin lost 12.07% of its compressive strength after 125 freeze-thaw cycles. Peak stress and strain after 125 freeze-thaw cycles are 0.45 and 3 times higher, respectively, than those of concrete without NMK.

Debbarma, K., Debnath, B., & Sarkar, P. P. (2022) The bulk of research publications available worldwide are gathered, and the impact of incorporating various nanomaterials on the behavior of asphalt and asphalt mixtures is investigated. First, a number of nanomaterial types are identified, the majority of which are utilized in asphalt modification. The difficulties associated with nano materials modification and their financial implications are then discussed, after which their methods for mixing, Performances, dispersion behavior, etc. are investigated. Ultimately, the gaps in research are determined, and the future potential of asphalt mixes modified with nanoparticles is determined. The advantages of nanotechnology in pavement construction have been demonstrated by a comprehensive analysis of the literature.; however, the lack of appropriate knowledge and practical implications makes the use of nanomaterials in asphalt mixes somewhat difficult. Further research is necessary to fully apply several nanomaterials for asphalt modifications because readily available There is a dearth of information on life cycle cost analysis, accepted practices, mixing techniques, etc.

Oda et al. 2022 looked into how hot mix asphalt's mechanical qualities are affected when metakaolin (MK) is added as a modifier. As part of the filler used, to the mixtures, MK was added. Currently, filler, asphalt binder, coarse and fine aggregate, and either additional modifiers or not, make up (HMA). To verify the reliability of the materials used to produce HMA, validation tests were conducted on the HMA's component parts. The bitumen 60/70 asphalt binder was utilized. Bitumen was subjected to penetration, softening point, flash and firing point tests. 5.2% was the ideal amount of asphalt based on the planned control mix. There is no MK content in the control mix. MK was added to partially replace the limestone powder filler that was used. The HMA was supplemented with Mk 20%, 40%, 60%, 80%, and 100% of the filler can be substituted. MK performed a comparative study to evaluate the effects of HMA modification. For the mix that has been altered by 40% MK, the increase in the Marshall quotient (MQ) is 10.37%. The indirect tensile strength is significantly impacted by MK (ITS).

Sihombing et al. 2023 investigated the effect of applying BitutechRAP and BioCS bio-rejuvenators on reclaimed asphalt (RA) binder as determined by the stiffness modulus (Sbit) of the asphalt binder. The analysis is conducted in an RTFO (rolling thin film oven). By examining the adjustment factor generated by each kind of asphalt binder testing, the comparison was examined. According to the results, BitutechRAP was not as influential as BioCS when added to the RA binder, as evidenced by the value of 2.84 for the BioCS + RA binder adjustment factor is comparable to the value of 2.64 for the pen 60/70 adjustment factor. With an adjustment factor of 1.61, there was no discernible difference between the Sbit value from the DSR and Van der Poel test results.

Salman et al. 2023 Kaolin was burned at 700°C to undergo the De-hydroxylation process, which turned it into Metakaolin. Metakaolin was crushed and ground in a ball mill to produce it at the nanoscale. Total nanoparticles' high specific surface area confers special qualities when they combine with an alkali-activated solution to generate geopolymer. Using a mortar test, the optimal geopolymer result was found to be 12 molarity, which has the benefit of dissolving silica and alumina nanoparticles to create a geopolymer with exacting specifications. The geopolymer mortar has a maximum compressive strength of 73 MPa. There has been no change in compressive strength due to freezing and thawing. It was found that the absorbance during the water absorption test is nearly 1.7%. The primary advantage of the total binder nano metakaolin geopolymer lies in the absence of heat treatment during the polymerization process. This leads to the achievement of high specifications because of the high pozzolan effect and effectiveness of the nanomaterials, which improves durability properties such as compressive strength.

Abo El-Naga et al. 2023 explained that Metakaolin material was being researched as an additive to change the characteristics of asphalt cement. Asphalt binders and asphalt mixtures were the subjects of a comparative test program to assess the effect of nano metakaolin (NMK) material on pavement performance. The NMK material was added to a portion of the asphalt binder at different weight percentages (0%, 2%, 4%, 6%, 8%, and 10%). On asphalt binder, fundamental tests were carried out. The outcomes showed that the modified asphalt binder with NMK material had better physical characteristics. Furthermore, the pavement's resistance to deformation has been significantly impacted by the use of NMK material. Finally, a higher improvement in the mechanical properties of the modified mixtures was obtained when the NMK material was added to the asphalt binder at a weight percentage of 6%.

Kazim et al. 2023 evaluated previous research on using polymer materials to improve the properties of asphalt cement and hot blended asphalt. This investigation examines three distinct forms of polymers. These polymers include styrene-butadiene-styrene (SBS), polytetrafluoroethylene (PTFE), and polyvinyl chloride polymers. According to previous research in this field, these polymers are elastomers and plastomers that are used to improve the mechanical properties of hot-mix asphalt while also boosting the stability, flexibility, and rigidity of asphalt binders. The overall performance of asphalt pavement can be improved by lowering the likelihood of ruts in summertime and cracking in wintertime.

Kazem et al. 2024 explained how the various polymers influence the properties of hot mix asphalt with a wet procedure using asphalt produced locally at the Al-Durah refinery and various polymers. Styrene-butadiene-styrene (SBS), polytetrafluoroethylene (PTFE), polyvinyl chloride (PVC), and (PVC+SBS) are examples of these polymers. Three and five per cent of the polymer are utilized for SBS, PTFE, and PVC, respectively. They used asphalt cement ratio for (SBS+PVC) was 2.5% by weight at various blending times. The polymer asphalt mixtures were evaluated by using Wheel Track tests and then compared to the conventional mixture. The modification of bitumen with polymers enhanced its conventional properties, such as viscosity. In addition, it was determined that the mechanical properties of HMA prepared with PMB samples, as measured by wheel track experiments, improved with increasing polymer contents.

Shahreena et al. 2023 conducted a review and proposed waste items which might be employed as modifiers or bitumen extenders. Within these waste materials, silicon, rubber, cooking oil (mixed with various modifiers), lignin, and calcium lignosulfonate have showed promise as bitumen extenders. The financial evaluation of improved bituminous binders was additionally considered. The outcomes of this research support benzene as one of the extenders that are compared. Lignin can be added straight into bitumen with minimal processing. Furthermore, lig is a bio-based waste material and the second biggest amount of organic material on the planet, following cellulose. With a 25% replacement of bitumen, lignin minimizes the use of conventional bitumen and has considerable promise for usage in pavement creation.

CONCLUSION

The main goal of this study is to review the past related studies that deals with blending of Metakaolin material, Nano- Metakaolin, and some additives materials with asphalt or replacement filler by these additive materials to improve the properties of to resist the traffic loads and environmental actions. These studies showed that good results in the improving the properties of hot mixture asphalt when they added additives materials. These studies recommended that for using Nano- Metakaolin in the mixing of asphalt to construct the flexible pavement.

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DECLARATION OF COMPETING INTEREST

None

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