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Evaluation the performance of Rigid Pavement Modified with admixture of Nano Silica and Glass Fiber: A review

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Abstract

Durability is an essential component that plays a crucial role in the rigid pavement performance and service life. However, with the rapid growth of traffic loads and climate change, rigid pavement suffers from various distresses, including thermal cracks, freeze-thaw cycles that lead to moisture damage, and chemical attacks. Thus, the researchers applied a novel technique to improve the overall performance of rigid pavement by using different types of additives. Among many kinds of additives, the current study seeks to review the use of Nano-silica and glass fiber in concrete admixtures. Nano-silica is a nanoparticle that acts as a pozzolanic fabric that improves the bonding between debris, while glass fibers are synthetic fibers that offer additional tensile strength and reduce cracking. Flexural strength, compressive strength, and skid resistance tests were conducted in the previous studies to evaluate the performance of modified rigid pavement. Results demonstrated that the rigid pavement modified with Nano-silica improved the compressive strength and moisture resistance compared with the control rigid pavement. Nonetheless, the Nano-silica had a slight improvement in tensile strength. Moreover, the best dosage of Nano-silica in the concrete mixture was from 1% to 3% by weight of cement. Glass fiber has a significant influence on the tensile strength of rigid pavement. The recommended percentage for adding glass fiber is 0.4–1% by weight of aggregate. Finally, adding single additives to rigid pavement is not enough to improve the overall performance. Therefore, it is recommended to use the admixture of Nano-silica and glass fiber in rigid pavement.

Keywords: Rigid pavement, Durability, moisture damage, Nano-Silica, Glass Fiber.

Introduction

Rigid pavement, also known as concrete pavement, is a well-established pavement type for highways because of its durability and long service life. It is composed of interconnected concrete slabs; it provides a smooth surface for vehicles while withstanding heavy traffic loads and environmental effects. The design and construction of rigid pavement require high level of care. Rigid pavements are commonly utilized in highways, airports, and commercial areas where high strength, durability, and resilience are essential. Initial cost of rigid pavement can be higher than that of flexible pavement, but flexible pavement needs for frequent repair due to cracks or damaged sections on the long term can offset the initial cost of rigid pavement. Despite this downside, rigid pavement continues to be a dependable choice for lasting infrastructure that require durable surface [1].

Utilizing effective additives is one of the main changes made to rigid pavement design. Ordinary rigid pavement consists of a concrete slab supported on a compacted base or subbase layers. However, admixture materials science has led to the development of high-performance rigid paving mixes that offer high strength and durability. These mixtures may contain additives such as fly ash or silica fumes in order to increase the concrete resistance to cracking and improve its load-bearing capacity. Another modification that has been implemented is the slab thickness modification, increasing the thickness of the concrete slab leads to better perform against heavy vehicles, thus reducing cracking and structural failure and other environmental factors such as freeze-thaw cycles and temperature fluctuations, resulting in greater pavement durability. Reinforcing elements such as steel bars or fibres are often added into the concrete mixture to increase tensile strength. This reinforcement help distribute the load more evenly across the road surface, reducing the possibility of cracking and increasing the overall load capacity. Steel bars, known as reinforcing bars or rebar, are usually placed in the concrete slab during construction, while fibres be added directly to the concrete mix.[2]

It is well known that rigid pavements have many challenges and disadvantages, which may affect their overall performance and durability. One of the main problems of rigid pavements is their susceptibility to cracks, which can be caused by a variety of factors such as temperature fluctuations, heavy traffic, and insufficient joint spacing. These cracks can cause water infiltration, weaken the pavement structure, and potentially cause potholes and other types of failure. Furthermore, rigid pavements are more likely to suffer damage from underlying soil movement and settlement as they are less flexible than common flexible pavement. Applications for the rigid concrete pavement are numerous and include everything from heavy vehicle traffic to paths for people [3]. Mixing Nano-silica and glass fibre with the rigid paving mixture clearly improves the performance and durability of pavements. Silica nanoparticles provide a denser microstructure within concrete, which helps increase strength and reduce permeability. Nano silica works to enhance the adhesion and bond between the aggregate grains inside the concrete by filling its micro voids in the concrete body, which means higher efficiency and performance [4]. While adding glass fibre improves the tensile strength of the pavement results in a reduction in cracks and a prolongation of pavement life [5]. The idea of adding both Nano-silica and glass fibres together has not been proposed in recent literature. Most researchers tend to use both materials independently. In this study, both additives to rigid pavement will be combined, each additive produces impressive result and play a major role in improving the properties of the concrete mixture used in pavement. Therefore, it is expected to obtain even higher performance of concrete pavement when adding both Nano-silica and glass fibres.

2 .Effect of temperature on performance of rigid pavement

Temperature is one of the most important factors that affect the behaviour of pavement, whether it is rigid, or flexible. Therefore, by considering temperature and its impact on stresses, deformations and structural integrity, researchers and engineers are able to develop more effective pavement designs that can withstand the challenges posed by temperature fluctuations. In rigid pavements, temperature gradients are crucial for estimating curling stresses and considering seasonal and local temperature variations in pavement design [6]. Factors such as temperature differentials and subgrade quality affect stress, curling, and deflection behaviour in rigid pavement [7]. Modelling temperature distribution in rigid pavement slabs is vital, especially considering the impact of air temperature [8]. Stresses in rigid pavements result from various factors, including traffic wheel loads, concrete expansion and contraction due to temperature changes, subbase yielding, and volumetric changes [9]. Critical bending stresses in Portland cement concrete layers with asphalt overlays are determined based on factors like curling and temperature effects [10]. The combined effects of moving loads, pavement thickness, and soil type underneath rigid pavements influence stress distribution and deflection [11]. The impact of high temperatures on Nano-modified concrete mixtures' compressive strength is analysed. The proposed models were assessed and validated for their significance and adequacy, and the influence of each parameter was analysed using ANOVA and other statistical measures. Strong correlations were observed between compressive strength and the substitution of NS (Nano silica) and/or NC (Nano concrete (for cement. The optimal levels of cement replacement with nanoparticles and temperature to maximize concrete's compressive strength were determined through numerical optimization, using 2–3% NS to improve the performance and durability of pavements and increase the compressive strength at 200 °C. The outcomes from the developed models aligned well with the experimental data [12] [13]. The objective of this study is to evaluate the impact of temperature gradient within the concrete slab of a rigid pavement and to investigate its interaction with traffic load and heat transfer pattern. The rigid pavement model employed in this research considers anisotropic, uniform, and linear-elastic properties to simulate the material behavior. To conduct the analysis, a numerical approach using Abaqus software incorporated with a 3D Solid model was utilized. The traffic loads were obtained through field surveys, while the temperature of the slabs was directly measured on-site. The dimensions of the rigid panel are 2.75 m in width and 5 m in length, with a slab thickness of 25 cm and a concrete specification of 41.33 MPa. The findings of this study revealed that the temperature gradient significantly influenced the development of stress within the concrete slab of the rigid pavement. It was observed that during the daytime, the temperature gradient resulted in higher stress levels compared to the night-time, with stress values reaching the Modulus of Rupture (MOR). When the rigid pavement was exposed to a temperature of 500°C, it generated a principal slab stress of 2.395 MPa, while the traffic load contributed to a stress of 1.31 MPa. When these two factors were combined, the concrete slab experienced a maximum principal stress of 3.322 MPa, which is close to the MOR of 83.34% fa. These results indicate that the pavement is capable of withstanding stress from temperature gradient and traffic load, as evidenced by a ratio of less than one (1). However, this ratio is relatively high for fatigue failure mitigation purposes, which ultimately reduces the quality of life of the rigid pavement [14] [15].

3 .Effect of permeability on performance of rigid pavement

Permeability plays a crucial role in the performance of ordinary rigid pavement. Studies have shown that the permeability of materials used in pavement concrete, directly impacts various aspects of pavement behaviour. Additionally, the permeability of prefabricated permeable pavements influences their hydrological effects, with the material composition affecting the overall performance [16]. Moreover, the permeability of interlocking concrete pavement is essential for stormwater filtration, showcasing the importance of material selection in achieving desired outcomes [17]. Clogging is identified as a critical issue that can reduce the functionality of permeable pavements, emphasizing the need to consider long-term maintenance and performance [18]. Studies have also explored the impact of permeable pavements on stormwater management. The effectiveness of permeable pavements in reducing runoff is influenced by factors such as rainfall patterns and surface characteristics [19]. The maintenance and type of permeable pavements have been found to be significant in flood mitigation efforts, underscoring the importance of proper design and upkeep [20]. Additionally, the efficiency of permeable pavements in controlling runoff quantity and quality is affected by material properties, emphasizing the need for comprehensive studies on material effects [21]. An investigation become carried out to expand pervious concrete pavement with high-strength, excessive porosity, and permeability. The take a look at concerned various mix proportions which includes cement content, coarse combination-cement ratio (CA/C), and water-cement (W/C) ratio. After reading unique blend proportions, the only that provided the great mixture of strength and porosity became decided on. Polymer super plasticizers were then introduced to assess their impact on strength and porosity. The findings indicated that a water-cement ratio of 0.2 produced a dry and brittle mixture with compressive strength below 15MPa but a high permeability rate of around 20mm/s. On the other hand, a mix with a w/c ratio of 0.3 and CA/C ratio of 4.25 resulted in compressive strength of 13.9MPa, flexural strength of 3MPa, and porosity exceeding 20%. Furthermore, incorporating a high cement content of 495kg/m3 led to impressive compressive strengths of 51.8MPa, flexural strength of over 4MPa, although permeability decreased to approximately 1mm/s [22]. Permeable concrete pavement is highly advantageous and necessary for parking lots and pedestrian walkways in urban settings. This type of concrete has a lower density and contains more air voids, facilitating the absorption of storm water. Following a thorough review of various research studies, the current investigation proposes an improved version of permeable concrete with different mix proportions through experimental analysis. The study includes tests for compressive strength and permeability flow rate on permeable concrete containing 1% aluminium (Al) powder and 15% Fly Ash (FA) as a partial replacement for cement by weight. A total of 18 cubes were produced and divided into two groups: one with fine aggregate and one without. The results indicate that the average compressive strength of permeable concrete using 15% FA and 1% Al admixtures, with and without fine aggregate, increased by 13.90% and 1.05% compared to the control mixes, respectively. The permeability flow rate of permeable concrete with and without fine aggregate ranges from 7.67–9 ml/s and 14.83–15.83 ml/s, respectively. The scientific significance of this research suggests the appropriate type of permeable concrete and its potential applications based on performance [23]. The laboratory assessment of Portland cement pervious concrete (PCPC) concentrated on freeze-thaw (F/T) durability. The influence of Nano-silica (NS) and super plasticizer (SP) on PCPC performance was investigated across various mixtures. Two waters to binder (w/b) ratios of 0.34 and 0.30 were analyzed to accommodate the different behaviours of PCPC manufactured in the laboratory. Four different concrete blends were created for this research, some containing Nano-silica (NS) and some without. The mixtures included 3 percent Nano-silica by weight of cement. The samples were subjected to freeze-thaw testing, following the guidelines outlined in ASTM C 666/C 666M – 03 standards. Various parameters, including compressive strength, percentage weight loss, specimen density, and ultrasonic pulse velocity (UPV) for cubes, were measured and recorded. The modulus of elasticity was determined using UPV, and the relative modulus and durability factor were also computed. The findings revealed that specimens with Nano-silica displayed superior resistance to F/T cycles in comparison to the control mix specimens. The observed durability factors were over 70% for pervious mixes containing Nano-silica[24].

4 .Effect of fatigue on performance of rigid pavement

Fatigue is a critical issue affecting both flexible and rigid pavements. In rigid pavements, fatigue damage can lead to distress, with cracks typically initiating at the bottom of the rigid layer due to repeated loading [25]. The weakening behaviour of semi-rigid base materials under repeated loads at certain stress levels can also contribute to fatigue-related distress in pavements [26]. Furthermore, the effects of traffic load, temperature, and material properties play a significant role in the fatigue performance of pavements [27]. Research has shown that the type of materials used in rigid pavements can impact their fatigue resistance. For instance, using fly ash-based geopolymers instead of ordinary Portland cement can offer advantages in terms of mechanical properties and durability, potentially improving the performance of rigid pavements [28]. Additionally, enhancing the fatigue resistance of concrete pavements can be achieved through measures such as prestressing and optimizing pavement structures [29]. Moreover, the design and analysis of rigid pavements need to consider factors such as pavement thickness, materials, and construction techniques to enhance fatigue properties. Increasing the thickness of pavement layers, especially the bottom layer in double-layer pavements, can effectively improve fatigue performance [30]. Furthermore, utilizing advanced design methodologies based on fatigue cumulative damage theory can aid in predicting and improving the fatigue life of rigid pavements [31]. Roller compacted concrete (RCC) pavement is subjected to continues traffic loading from vehicular activities which can results to fatigue cracking. Fatigue is one of the commonest defects affecting pavement which affect the cost of maintenance and shortens pavement design life. To carter for these factors, higher deformation resistant pavements with longer design life need to be designed. Therefore, in this study, crumb rubber was used as a partial replacement to fine aggregate in RCC pavement to improve its fatigue life. Five mixtures were considered; one control mixture, two mixtures with fine aggregate replaced using crumb rubber at 10 and 20% by volume; one mixture containing 20% crumb rubber as partial replacement to fine aggregate 1% Nano silica added by weight of cementitious materials. Lastly, one high volume fly ash (HVFA) RCC pavement mixture where 50% cement was replaced with fly ash, and 20% fine aggregate replaced with crumb rubber. The results showed that both crumb rubber and Nano silica increases the bending resistance and fatigue life of RCC pavement. While HVFA decreases both flexural strength and fatigue performance of RCC pavement. The double logarithmic-equation can best be used to determine the stress level–number of cycles (S–N) fatigue behaviours and relation for RCC pavement mixtures [32]. This study investigates the fatigue characteristics of mix asphalt enhanced with Nano silica and incorporating recycled asphalt pavement (RAP) with self-healing capabilities. In order to achieve this goal, Sasobit was added at a concentration of 2% by weight and nitric oxide at concentrations of 3%, 5%, and 7% by weight to the bitumen, followed by mixing using a high shear mixer. To simulate aging in warm asphaltic mixtures, slabs for four-point bending tests were prepared using 0%, 70%, and 100% weight percentages of RAP. Subsequently, the beams derived from these slabs were subjected to constant strain at two levels: 400µm and 800µm. The findings indicate that the addition of Nano-silica can significantly enhance the self-healing behaviours of warm asphalt mixtures. Moreover, the healed specimens exhibited notable flexural stiffness. Conversely, the self-healing behaviours of asphalt samples with and without RAP, as well as Nano-silica, exhibited substantial differences under constant strains of 400µm and 800µm [33]. In India, there has been a developing trend of utilizing cement concrete pavements in new avenue projects because of their prolonged lifespan, reduced protection desires, and smoother surface for motors. There is a complete overview of the studies performed on fiber reinforced concrete pavements using specific forms of fibers which include polypropylene, steel, hybrid, and glass fibers. The advent of polymer fiber strengthened concrete pavements represents a current development inside the design of strengthened concrete pavements. These pavements, bolstered with polymer fibers, showcase better efficiency compared to ordinary cement concrete pavements. The reduced rigidity and larger diameter of the GFRP dowels lead to decreased pressure between the concrete and dowel, which are significant factors contributing to the loosening of dowels and the occurrence of faults in the slab [34].

5 .Utilization of Nano-Silica in rigid pavement

5.1 Nano-Silica

Currently, there exist various techniques for the production of Nano scale (NS) products. One such method involves utilizing a sol-gel process, which can be carried out either through an organic or water route and is conducted at room temperature. In this particular process, the initial materials used, primarily Na2SiO4 and organometallics such as TMOS/TEOS, are introduced into a solvent. Subsequently, the pH of the solution is altered, leading to the precipitation of silica gel. The resulting gel is then subjected to aging and filtration processes, ultimately transforming it into a xerogel [35]. This xerogel undergoes a drying process and is subsequently either burned or dispersed once again with a stabilizing agent (such as Na, K, NH3, etc.) in order to create a concentrated dispersion with a solid content ranging from 20 to 40%. This concentrated dispersion is specifically designed for application in the concrete industry [36] [37]. A different approach to manufacturing involves the vaporization of silica at temperatures ranging from 1500 to 2000 °C through the reduction of quartz (SiO2) in an electric arc furnace. Additionally, the production of NS occurs as a secondary outcome during the manufacturing process of silicon metals and Ferro-silicon alloys. This NS is then gathered through subsequent condensation into fine particles within a cyclone [38] [39]. The method yields Nano-silica in the form of a fine powder composed of spherical particles or microspheres measuring 150 nm in diameter, exhibiting a high specific surface area ranging from 15 to 25 m2/g [40]. Agricultural waste within the form of rice husk ash (RHA) is an enormous by product of rice milling. It is known to contain an enormous quantity of silica. In order to harness this green technology, researchers have targeted on extracting SiO2 nanoparticles from rice husk ash. The extraction strategies worried combusting the rice husk ash at a temperature of 700 °C for a length of 2 hours. The ash was then subjected to precipitation methods and sol-gel method to provide Nano silica. The precipitation methods involved refluxing the silica from rice husk ash in boiled answers of one.0 N and 2 N NaOH. On the opposite hand, the sol-gel approach required the calcination of the rice husk ash handled with HCl at seven hundred °C for 2 hours, observed with the aid of chemical remedy. The consequences acquired from the Infrared spectral (IR) evaluation revealed the presence of hydrogen-bonded silanol institution and siloxane companies within the silica. The optical houses of the Nano silica samples were tested the usage of UV-visible spectroscopy, which showed a wide band gap fee and absorption peaks in the UV location. Additionally, the particle length analysis yielded values of 13.02 nm, 16.83 nm, and 23.96 nm for the samples categorized as 1NSiO2, 2NSiO2, and acid leaching, respectively[41].

5.2. Properties of Nano- Silica

The utilization of Nano-silica in cement-based composites has been observed to be advantageous up to an optimal dosage of 2–3% owing to its high pozzolanic reactivity and filler effect. However, a higher dosage of Nano-silica can have a detrimental impact due to increased porosity and micro cracking caused by the agglomeration of Nano-silica particles. The incorporation of NS in the optimal amount may lead to a potential enhancement in mechanical strength by 20–25%. The developed prediction models for assessing the strength of Nano-silica-modified concrete have shown good agreement with experimental data, characterized by lower error values.

Such analytical approaches can be instrumental in estimating crucial material properties, thereby reducing the need for extensive experimental tests. It is advisable to explore cost-effective techniques for dispersing Nano-silica in higher concentrations within cement mixes. Moreover, further comprehensive investigations are essential to refine prediction models for accurately forecasting the properties of Nano-silica-modified concrete [42].Table 1 provides the chemical composition of Nano–silica.

Table (1) Chemical Compound of Nano – silica [42]

Chemical Compound	Composition %
SiO_2	95
Al_2O_3	1.08
Fe_2O_3	0.45
MgO	1.06
CaO	0.2
SO_3	0.31
K2O	0.12
Na_2O	0.68
TiO_2	0.18
$P2O_5$	0.12

Nano silica, also called silicon dioxide Nano particles, possesses unique properties that make it a particularly sought-after material in various industries. One of its key homes is its extraordinarily small particle size, usually starting from 1 to 100 Nano meters. This Nano-scale size gives it a great surface area to volume ratio, ensuing in more advantageous reactivity and progressed overall performance in lots of application [43]. Adding Nano silica into cement paste improve the durability of the concrete [44]. The influence of nano-SiO2 on setting time, slump, shrinkage, durability, and mechanical properties of concrete by scanning electron microscope (SEM) and the content of various hydration products obtained by X-ray diffraction (XRD). The result shows that the setting time of nano-SiO2 concrete is shortened, the slump is reduced, and the shrinkage is improved owing to the high activity and nucleation of nano-SiO2. The improvement effect of nano-SiO2 on concrete is remarkable, especially in the aspect of enhancing the durability of concrete. It should be noted that nano-SiO2 shows limited improvement in the mechanical properties of concrete [45] [46].

6 .Utilization of Glass Fiber in rigid pavement

6.1 Glass Fiber

Glass fibre is a type of inorganic fibre. Its forming element is glass, it is produced from raw materials, which has high strength [47]. In the contemporary glass fibre manufacturing facility, the direct manufacturing process is favoured. This method involves storing raw materials separately in silos and then accurately weighing them before transferring them to the mixing tank. Subsequently, the materials are moved to the batch silo for charging into the furnace. The entire system is computer-controlled and designed to be airtight to prevent the dispersion of dust. The raw materials utilized in the production of E-glass include sand for silica, clay for alumina, colemanite or boric acid for boron oxide, and limestone or calcite for calcium oxide. The E-glass furnace typically has a rectangular shape with a short exit channel that connects to the narrow fore hearth channel where fibre formation takes place .[٤٨]

6.2 Properties of Glass Fiber

The utilization of glass fibres in composite materials is dependent on their chemical reactions, resulting in the formation of various composites with either favourable or unfavourable characteristics. For instance, to enhance the resistance of glass fibres to lime produced during the curing of Portland cement, zirconium dioxide (ZrO2) can be incorporated into the mixture prior to the melting and Fibreization of the raw materials. This zirconium becomes part of the molecular structure of the glass fibre during the production process, rather than simply acting as a protective coating. These glass fibres containing zirconium, known as Alkali-Resistant (AR) glass fibres, exhibit chemical stability and can withstand both alkaline and acidic environments. Table 2 provides the oxide percentage for different common and commercial types of glass fibre materials [49]. Glass fibres play an important role in obtaining concrete that is lighter in weight and higher in tensile strength when compared to regular concrete [50]. Concrete, known for its brittleness, is inherently weak in tension. However, the incorporation of fibres into concrete has tested to noticeably beautify each its compressive and tensile strength. Researchers have located advantageous responses whilst the use of numerous types of fibres and manipulating their orientation within the concrete mixes. The laboratory consequences indicated an increasing in compressive and tensile strength by way of up to 26.19% and25.4% respectively. Interestingly, the addition of fibres did now not have a widespread effect at the workability of the concrete mixes. This development in tensile power, executed via the usage of glass fibres, indicates that the inclusion of fibres in concrete mixes may additionally effectively deal with the difficulty of low tensile power without compromising workability and compressive strength [51] [52].

Table (2) Chemical Compound of Glass Fiber [49]

Type of GF	Percentage of Composition (%)										
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	B_2O_3	CaO	MgO	Na_2O	K_2O	ZnO	ZrO_2
A	67.5	3.5	-	-	1.5	6.5	4.5	13.5	3	-	-
C	64.3	4.1	-	-	5	13.4	3.3	9.6	0.5	-	-
D	74	-	-	-	22.5	-	-	1.5	2	-	-
E	55	14	-	0.2	7	22	1	0.5	0.3	-	-
R	60	24	0.1	-	0.3	9	6	0.5	0.1	-	-
S	65	25	-	-	-	-	10	-	-	-	-
ECR	58.2	11.6	0.1	2.5	-	21.7	2	1	0.2	2.7	-
AR	61	1	-	-	-	5	1	14	3	-	15

7. Performance of Rigid Pavement Modified with Nano-Silica and Glass Fiber

In latest instances, nanomaterials and fibers have won extensive importance in various industries, especially in the raw material. Therefore, it's far essential to behaviours a complete evaluation that examines the simultaneous effect of fibers and nanomaterials on the technical overall performance of key material like mortar and concrete. The review is based totally on an extensive experimental database that includes research in which at least one sort of fiber and one nanomaterial were used inside the identical blend. The collected information had been meticulously analyzed and in comparison, to control mixes that did now not include any fibers or nanomaterials. The look at normally specializes in evaluating the results of fibers and nanomaterials on the clean and hardened homes of the produced mixes, which includes density, workability, mechanical electricity, sturdiness, microstructure, and electrical resistivity. The findings of this have a look at provide treasured insights and a comprehensive manual for selecting and mixing various fibers with nanoparticles to efficiently decorate the overall performance of concrete and mortar. Not only does it discover the most beneficial percent of fiber and nanomaterial utilization, but it additionally serves as a valuable resource for promoting in addition studies on this area [53]. Concrete is the second most typically used construction material after water. However, cement, that is a key thing of concrete, possesses certain drawbacks including brittleness, low ductility, low tensile strength, early setting, and micro-crack propagation because of shrinkage all through the early degrees of concrete curing. In the beyond a long time, the manufacturing of concrete has substantially expanded by incorporating supplementary cementitious substances (SCMs) and nanoparticles along with SiO2, TiO2, Fe2O3, Cr2O3, and Al2O3. The usage of nanomaterials in concrete holds extraordinary capacity for enhancing its properties, together with compressive strength, cut up tensile strength, flexural strength, water permeability, abrasion resistance, and pore shape [54]. The voids in concrete pavement have been implemented as a method to reduce storm water runoff by capturing and allowing rainwater to infiltrate into the ground. The primary issue with porous concrete pavement lies in its strength. This study aims to assess the utilization and effectiveness of Nano-silica in porous concrete pavement. Previous research literature indicates that traditional porous concrete pavement lacks the necessary strength for pavement applications. Incorporating Nanomaterials can enhance both the physical and chemical characteristics of porous concrete pavement [55]. Porous concrete era has been utilized in one-of-a-kind areas of the US since the Nineteen Seventies as an alternative in problematic drainage systems and water retention regions. Porous concrete pavements have received reputation as an efficient storm water management tool for controlling storm water runoff on pavements. Porous concrete pavement is hired as a technique to lessen storm water runoff by way of shooting and facilitating the drainage of rainwater into the ground surface. However, the primary issue with porous concrete pavement lies in its strength. It is examining the utilization and performance of Nano silica in porous concrete pavement, as well as previous laboratory studies conducted on this type of pavement. The incorporation of nanomaterials has been investigated to enhance the physical and chemical properties of porous concrete pavement. Despite this, the optimal conditions for producing high-quality porous concrete have yet to be established. Previous studies have shown that the use of a standard Proctor hammer (2.5 kg) and pneumatic press (70 kPa compaction effort) in preparing laboratory specimens yield properties that closely resemble those of field porous concrete [56]. Nowadays, the construction of highways, bridges, and other structures where strength is a major concern often involves the use of Nano concrete. Nano concrete is a relatively new material that enhances the qualities of traditional concrete. It is known for its chemical resistance and durability, making it an ideal choice for pavement design. In this research paper, we focus on a comparative study between conventional concrete and Nano concrete pavements look table 3, 4. Due to the difficulty of conducting direct tests on specimens, we employ indirect tests such as compression, split tensile, flexure, and durability tests. Nano concrete is prepared by incorporating Nano silica and Graphene into high-performance concrete (M40). Using ANSYS Workbench 19.2, we establish a finite element model to analyse the behaviour of both conventional and Nano concrete pavements under static loads. By substituting the properties of concrete with those of Nano concrete, we determine the stress distribution and deformation of the pavement. Experimental observations reveal that Nano concrete exhibits higher capacity in tension, compression, and flexure compared to conventional concrete. The results obtained from the Finite Element Model demonstrate that the performance of Nano concrete pavements surpasses that of conventional concrete pavements [57].

Table (3) Mechanical Properties of Nano and Conventional Concrete [57]

Properties	Conventional Concrete	Nano Concrete
Young Modulus of Elasticity	31622.747 Mpa	37080.99 Mpa
Poisson's Ratio	0.16	0.15
Coefficient Of Thermal Expansion	1.19 x 10^{-5} / C	1.20 x 10^{-5} / C
Ultimate Compressive Strength	40 Mpa	55 Mpa
Density	23 K N/m3	24 KN/m3

Table (4) Proportion of Mix Design of Nano and Conventional Concrete [57]

Component	Conventional Concrete	Nano Concrete
Cement	450	450
Fine Agg.	585	585
Coarse Agg.	1305	1305
Superplasticizer	3	3
W/C Ratio	0.4	0.4
Graphene	0	0.2
Nano Silica	0	6.75
Water	148.8	148.8

The initial cost of rigid pavement is drastically higher than that of bendy pavement. However, cost isn't always the only issue to recollect with regards to construction. Other essential elements include the principal disasters which include mud pumping, sagging of slabs because of low flexural strength, and the brittleness of concrete. Despite these drawbacks, concrete roads have demonstrated to be advanced to flexible pavement in phrases of lengthy-term upkeep, layout lifestyles, and using best. Rigid pavements are more liable to bending screw ups, ensuing inside the improvement of cracks. Additionally, there is a problem of steel reinforcement corrosion in rigid pavement, which necessitates thicker slabs and increases material requirements. To deal with this issue, glass fibres are being used as a reinforcing agent in concrete for this project. The random distribution of glass fibres within the concrete enhances its ductility and improves its usual traits. By incorporating glass fibres, the thickness of the concrete slab can be reduced, as the strength of the concrete will increase. This, in flip, reduces the material requirements for building inflexible paths. Glass fibre bolstered concrete is a complicated material composed of sand, cement, coarse combination, and randomly disbursed fibres. These glass fibres, while allotted at some stage in the concrete, beautify its power and ductility properties. The results of diverse laboratory checks conducted on concrete with distinctive chances of glass fibre by using volume of concrete are as follows: The workability of concrete, as indicated by the droop cost, decreases with a growth in the proportion of glass fibre. The compressive strength at 7 days and 28 days will increase with a better percent of glass fibre through quantity of concrete. The maximum boom in compressive strength is 32% at 7 days and thirteen% at 28 days, respectively [58]. The combination of 1% NS and 10% SP, along with 0.5% PPF, led to a substantial enhancement in the compressive strength of HSC, with an improvement of approximately 123%. On the other hand, the influence of SF on the tensile strength was found to be more significant. The addition of 0.5% SF, in conjunction with 2% NS and 10% SP, resulted in a remarkable increase in the tensile strength by 104%. Furthermore, it was observed that an increase in the SF content contributed to a reduction in the electric resistivity of the concrete. Conversely, the utilization of PPF had a positive effect on this property, particularly when combined with 1% NS. The electric resistivity was enhanced by approximately 68% when 0.5% SF and 1% NS were employed in conjunction with 10% SP [59] [60]. The utilization of Nano-silica in cement-based composites has been observed to offer advantages when applied within a specific range of 2–3%. This is attributed to the high pozzolanic reactivity and filler effect of Nano-silica at this optimal dosage. Utilizing Nano-silica within the recommended range of 2-3% has demonstrated promising results in improving the mechanical properties of cement-based composites. This optimal dosage has been found to enhance the material's strength by around 20-25%. By staying within this range, the Nano-silica particles are able to effectively fill in the gaps within the composite structure, leading to improved overall performance. Moreover, the development of prediction models for estimating the strength of Nano-silica-modified concrete has demonstrated promising results. These models have exhibited good agreement with experimental data, indicating their reliability in predicting the properties of Nano-silica-modified concrete. Moving forward, it is advisable to explore cost-effective techniques for dispersing Nano-silica in higher concentrations within cement mixes. Additionally, further comprehensive studies are necessary to refine prediction models and enhance the accuracy of estimating the properties of Nano-silica-modified concrete [61] [62]. High-performance concrete (HPC) is the first choose to utilize in infrastructure based on its durability and sustainability advantages. Fibre reinforcement plays great role in decrease shrinkage-induced stresses and enhancing the durability of concrete. Compressive strength exhibited a proportional increase with higher fibre contents in concretes with a w/b ratio of 0.32. Conversely, a different pattern was observed in concretes with a w/b ratio of 0.25, where strength decreased as fibre additions rose. The modulus of elasticity only improved with fibre additions in the mixtures with a w/b ratio of 0.25, showing no correlation with the results of compressive strength. In shrinkage tests, the incorporation of glass microfibers up to specific thresholds (0.20% for a w/b ratio of 0.25 and 0.25% for w/b of 0.32) exhibited enhancements in controlling concrete deformation in unrestrained shrinkage analyses. However, concerning the reduction of cracking in restrained concrete specimens, the mixtures did not show significant improvements in crack prevention [63] [64]. Nano-silica particles with a size of 236 nm were utilized to reinforce the compressive strength of concrete. It is evaluated the effect of substituting cement with Nano-silica in exclusive ratios of 0.3%, 0.6%, and 1% relative to the burden of cement. The results from the experiments indicated to improve the resistance of the compressive strength of the concrete use to its ability to fill in the gaps between cement particles [65] [66]. The impact of NS on the compressive strength and flexural strength of HPC with a nominal strength of 70MPa. Seven different mixtures of HPC were prepared, each containing varying NS ratios of 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% relative to the total weight of the adhesive. The reliability of the test results was carefully evaluated. The results of the study indicate that, during the early stages of HPC, an NS ratio of 1.5% exhibits the optimal value for enhancing the performance of the concrete. This result holds significant implications for the application of NS in HPC, particularly in terms of quality control during on-site implementation [67] [68] [69][70].

Researchers and engineers have sought to evaluate the performance of rigid pavement, especially pavement modified with Nano-silica and glass fibre. This review aims to determine the extent to which different proportions of these additives affect the performance and behaviour of rigid pavements. The use of rigid pavements is widespread on highways and airports due to their mechanical properties, durability, and ability to bear heavy traffic loads. However, it is subject to cracking and deterioration over time. Due to the seriousness of these problems, researchers turned to using some additives to improve rigid pavement, such as Nano-silica and glass fibres. Nano silica has been defined as a nanomaterial that has a clear role in improving the mechanical properties of concrete. It is characterized by a high surface area and thus can fill the spaces between cement particles, resulting in a stronger density. Glass fibre is also considered a reinforcement material that can provide additional strength and rigidity to the pavement. The results showed that the use of Nano-silica at a rate between 2 and 4 percent had a significant impact on improving the physical, durability, and mechanical properties of pavement concrete as shown in table 7 [72]. Samples of modified concrete were tested and produced impressive results in compressive, tensile, bending, abrasion, and friction strengths compared to traditional concrete. The results also showed that the use of glass fibre at a rate ranging from 0.2 to 0.4% has a significant impact on improving the physical properties, flexural strength, and split tensile strength of concrete pavement as shown in table 5,6 [71] . Samples of improved concrete were tested and obtained greater strength than control concrete. All previous studies and research aimed to determine the effect of adding Nano-silica and glass fibres separately. But they are not added together in the same mixture. Given the great results when using each of them separately, it is expected to achieve a clear and strong improvement in the physical, mechanical, and chemical properties of rigid pavement. Through previous studies, we can highlight a comparison with clear results of the effect of adding both glass fibers and Nano-silica separately on the properties of the concrete mixture used in rigid pavement, whether in compressive, tensile, or flexural strength. As shown in Tables 8 and 9, the effective role of each addition becomes clear.

Table (5) Flexural Strength after 7 and 28 days (Glass Fibre) [71]

Days	CM	M1 - GF (0.05%)	M2 - GF (0.1%)	M3 - GF (0.2%)	M4 - GF (0.4%)
7 Days	3.96	4.5	4.69	5.24	6.37
28 Days	4.87	5.32	7.14	7.86	9.74

Table (6) Split tensile Strength after 7 and 28 days (Glass Fibre) [71]

Days	CM	M1 - GF (0.05%)	M2 - GF (0.1%)	M3 - GF (0.2%)	M4 - GF (0.4%)
7 Days	2.65	2.67	2.78	2.87	3.14
28 Days	4.01	4.07	4.13	4.29	4.96

Table (7) Optimum percentage of Nano-Silica in concrete [72]

P1		**P2**		**P3**		**P4**	
Flexural Strength	**Nano Silica Content %**	**Flexural Strength**	**Nano Silica Content %**	**Flexural Strength**	**Nano Silica Content %**	**Flexural Strength**	**Nano Silica Content %**
0.75	0	1	0	1.75	0	2.4	0
0.85	1	1.2	1	2.2	1	3	1
1	2	1.4	2	2.4	2	3.25	2
1.1	3	1.5	3	2.5	3	3.4	3
1.25	4	1.6	4	2.65	4	3.5	4
1.2	5	1.6	5	2.5	5	3.4	5

Table (8) Comparison between effect of different ratio of Nano silica on rigid pavement [32] [57] [61] [73] [74]

.Ref	**Additive type**	**Additive % of rigid mixtures (by weight of cement)**	**Max. Compressive Stress (MPa)**	**Max. Tensile Stress (MPa)**	**Max. Flexural Stress (MPa)**	**Age Days**
32	**Nano silica**	0 %	-	-	5.50	
		1%	-	-	6.50	
57	**Nano silica**	0 %	30.77 - 47.2	3.06 – 4.710	4.81	7 – 28
		1.5%	39.14 – 60.03	4.36 – 6.70	6.94	7 – 28
61	**Nano silica**	0%	57 – 76	4.10	13	7 – 28
		1%	88 – 115	8.70	18	7 – 28
		2%	90 – 118	9.05	19.5	7 – 28
		3%	93 – 120	9.30	19.9	7 – 28
		4%	83 – 109	7.70	18.1	7 – 28
		5%	81 – 103	6.90	17.6	7 – 28
73	**Nano silica**	6%	47.38 – 48.81	-	-	7 – 28
		0%	27.04 – 32.06	-	-	7 – 28
		3%	66.99 – 80.04	-	-	7 – 28
74	**Nano silica**	5%	22.71 – 33.40	9.94 – 11.98		7 – 28

Table (9) Comparison between effect of different ratio of Glass Fiber on rigid pavement [51] [75] [76] [77] [78]

.Ref	**Additive type**	**Additive % of rigid mixtures**	**Max. Compressive Stress (MPa)**	**Max. Tensile Stress (MPa)**	**Max. Flexural Stress (MPa)**	**Age Days**
51	Glass Fibre	0 %	27	3.1	-	28
		0.02 %	36	4.2	-	28
		0.04 %	39	5.05	-	28
		0.06 %	41	5.8	-	28
		By total weight				
75	Glass Fibre	0 %	24.51 – 38.66	1.37 – 2.35	2.24 – 3.75	7 – 28
		0.4 %	24.73 – 39.10	1.69 – 2.83	2.49 – 4.15	7 – 28
		0.8 %	25.03 – 39.19	1.96 – 3.21	2.85 – 4.77	7 – 28
		1.2 %	25.70 – 39.47	1.97 – 3.10	3.11 – 5.21	7 – 28
		1.6 %	25.77 – 40.66	1.99 – 2.97	3.44 – 5.74	7 – 28
		By the volume of concrete				
76	Glass Fibre	0.5 %	17.7 – 27.06	1.41 – 3.4	1.42 – 2.45	7 – 28
		1 %	20.76 -28.46	2.83 – 3.92	1.47 – 2.94	7 – 28
		2 %	19.64 – 26.98	2.62 – 3.57	1.3 – 2.6	7 – 28
		3 %	18.4 – 26.11	2.43 – 3.42	1.28 – 2.45	7 – 28
		By weight of cement				
77	Glass Fibre	0 %	21 – 30	-	3.9	14 – 28
		5 %	23 – 33	-	4.8	14 – 28
		10 %	25 – 35	-	5.1	14 – 28
		15 %	30 – 40	-	5.7	14 – 28
		By weight of fine aggregate				
78	Glass Fibre	0 %	23.36 – 33.85	2.25 – 3.25	3.86 – 5.70	7 – 28
		0.3 %	24.99 – 35.96	2.65 – 3.81	4.76 – 6.58	7 – 28
		0.5 %	25.92 – 38.69	2.79 – 4.53	5.63 – 7.27	7 – 28
		0.7 %	26.81 – 40.62	3.22 – 5.05	6.30 – 7.80	7 – 28
		By weight of total binder				

By reviewing the results in Table 8, we can say that the use of nano-silica in rigid concrete pavements, when using a percentage of 1%, helped improve the flexural strength properties range between 18% to 38% [32] [61]. In the case of using a ratio of 1.5%, this helped improve the properties of the compressive strength by 27% at the age of 7 days and 28 days [57]. It was also found that the higher the percentage of use of nano-silica, the better the properties of compressive strength, tensile strength, and flexural strength gradually until it reaches the peak, which is 3%. After that, there is a clear decline in these strengths. The percentage of improvement in compre4ssive strength reached 63% at the age of 7 days and 57% at the age of 28 days, while the improvement in tensile strength reached 126% at the age of 28 days, while the percentage of improvement in flexural forces was 53% at the same age [61][73].

By reviewing the results in Table 9, we can say that the use of glass fibres in rigid concrete pavements, when using 0.06% helps improve compressive strength properties by 52% at 28 days old. [51]. The results also showed that we can obtain a clear improvement in compressive strength by 15% at the age of 7 days and 20% at the age of 28 days when using a percentage of 0.7%, while the tensile strength improves at the same percentage by 43% at the age of 7 days and 55% at the age of 28 days, while the results for flexural strength increased by 63% at the age of 7 days and 36% at the age of 28 days [75] [78].While it was found that using approximately 1% glass fiber helped to obtain the best results in compressive strength, tensile, and flexural at the age of 7 days and 28 days, as shown in Table 9.

8. Conclusions and recommendations

This paper targets to analysis earlier studies examined the effect of temperature, permeability, and fatigue performance in the rigid pavement. Therefore, the possible effects of adding Nano Silica or Glass Fibre on improving resistance to abrasion, high temperature cracking, moisture damage and fatigue cracking can be explored, that enhances resistance to distress happening in the pavement, because of traffic loads. According to previous reviews it is observed the main conclusions and recommendations, can be outlined as follows:

1. The overall performance of rigid pavement modified with glass fibre and Nano silica has given invaluable insights in the expected benefits of using those materials in pavement construction. The results of this study indicate that the mechanical characteristics and longevity of rigid pavements can be considerably improved by adding glass fibre and Nano silica.
2. The inclusion of Nano Silica in the pavement mix has been found to enhance the compressive strength and flexural strength of the rigid pavement. This is attributed to the pozzolanic reaction among Nano Silica and the cementitious matrix, resulting within the formation of extra calcium silicate hydrate (C-S-H) gel. The elevated C-S-H gel content material contributes to the densification of the pavement structure, leading to improved strength and reduced cracking potential.
3. Moreover, the addition of Glass Fiber to the pavement blend has demonstrated promising outcomes in terms of enhancing the rigid pavement's toughness and fatigue resistance. The pavement gains additional tensile strength and crack resistance through Glass Fibre reinforcement, which serves as a reinforcing element. This reinforcement structure makes it easier to distribute the applied loads more accurately, which reduces the probability of cracks and enhances the pavement's overall performance and service life.
4. The optimum ratio of using Nano silica is between 1 to 3% by weight of cement, while the optimum ratio of using glass fibre is between 0.4 to 1 %.

Finally, the results of this study support the idea that further research and practical application should be conducted regarding the usage of glass fibre and Nano silica as admixtures in the construction of rigid pavement. These materials have proven to be incredibly effective at improving rigid pavements' mechanical characteristics and longevity. To achieve the desired overall performance, more research is needed to determine the best dosage and combination of these admixtures. Furthermore, to evaluate the long-term performance and cost-effectiveness of pavements modified with glass fibre and Nano silica, long-term monitoring and assessment are required.

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