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STUDY THE RELATION BETWEEN STRUCTURAL AND TRANSPORT PROPERTIES ON ACOUSTICAL PERFORMANCE OF COMPOSITE MATERIALS

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Abstract: *Modern urbanization and industrial progress have unintentionally created obstacles in the never-ending quest of comfort and efficiency made possible by growing technology, with noise emerging as a major problem. Recognizing the complex effects of noise on our daily lives, this study explores the critical need to efficiently regulate noise levels in several engineering domains. This paper covers a wide range of materials, including advanced materials, met materials, recycled fibre and composite concrete material. Taken together, these materials are at the vanguard of modern research. The effectiveness of natural fibre recycled materials and composite materials in noise control applications are evaluated in light of their sustainable and environmentally friendly qualities. In this paper, advanced materials also take the stage, offering fresh approaches to the enduring problem of noise pollution because of their inventive compositions and qualities. The knowledge gained from this paper is well-positioned to direct future research projects and open the door to more practical and long-lasting noise control techniques as technology develops.*

Keywords: *Materials, Structural property, Transport property, Acoustical property, Composite materials, Polymer, Fiber.*

1. INTRODUCTION

A multitude of parameters intricately influence acoustic performance, a vital aspect in the aim of noise mitigation. The variety of constituent materials, the material's shape, the constituents' elastic qualities, and the percentage of materials utilized all influence a material's acoustical behavior. This paper, which is organized into sequential forms separate but related phases, aims to clarify the complex interactions that determine the diverse character of materials' acoustical effects. The first step explores the "Impact of Materials on Structural Properties," identifying the basic changes that materials might go through to acquire the right acoustical qualities. The second phase examines the "Impact of Materials on Transport Properties," explaining how a material's composition and structure affect how sound waves travel through it. The third step covers the "Impact of Materials on Acoustical Properties," which summarizes the comprehensive analysis of how materials affect the acoustical environment as a whole. Fourth step explains the role of composite materials on acoustic performance.

2. STRUCTURAL PROPERTIES

A large number of researchers have focused their efforts on examining the impact of materials on structural characteristics Liu et al., (2023) examined the impact of the bonding characteristics between the inorganic grout and the porous asphalt mixture (PAM) in semi-flexible pavement (SFP) materials. The study highlights the fact that the composite interface has been overlooked in favour of the grout material in the majority of SFP research. To solve this, the scientists created SFP samples with different strengths (40 MPa, 60 MPa, and 70 MPa) by altering the PAM surface with a coupling agent. Three laboratory studies were conducted to assess the mechanical properties. The results demonstrate that the interfacial bonding strength of SFP has a significant impact on its splitting tensile strength at low temperature, penetration strength in uniaxial direction, and compression strength in uniaxial direction. Zhuang et al. (2023) studied mechanical properties and design considerations of Polyurethane mixture pavements, emphasizing critical findings from dynamic modulus tests, uniaxial penetration tests, and fatigue tests. It was found that PU mixtures demonstrate exceptional elastic characteristics, making them suitable for pavements subjected to dynamic loads and traffic stresses. They exhibit excellent shear resistance, which is vital for pavements enduring shear forces. Favourable fatigue properties make PU mixtures a durable choice for pavements facing repeated loading and traffic-induced stresses. This design optimizes the mechanical properties and load-bearing capacity of PU mixtures. PU composite pavements display temperature stability, with minimal effects on load response. As studied by Buruiană et al. (2023) recycling micro polypropylene in modified hot asphalt mixtures offers several benefits, including improved rutting resistance, crack prevention, increased durability. The studies by Yasser et al. (2023) reported that rubber particles also appear to have substantial impact on ability to absorb sound. The study examined to substituting 0%, 10%, 15%, and 20% of volume replacing fine aggregates and suggested that workability although enhanced with the increase in percentage of rubber but this was achieved at the cost of compressive strength which decreased considerably. Youssf et al. (2023) examined that crumb rubber concrete with high concentrations of heat-treated rubber and magnetized water showed higher modulus of elasticity, tensile strength, and compressive and flexural strengths than untreated rubber mixtures. The study also shows that rubber components' resistance to impact failure ultimately increases when heated. The incorporation of biochar, as explored by Quintana et al. (2022) made use of Biochar in asphalt pavement which is produced by incinerating wastes. According to them it has unique physical-chemical features that make it suitable for use as an asphalt modifier while also assisting in the reduction of harmful environmental effects. As an asphalt modifier, BC has a tendency to make asphalt binders more viscous and rigid, which increases their resistance to permanent deformation (rutting). Additionally, it often improves aging resistance. Bhat and Mir (2022) explored how bituminous binders' varied performance characteristics were affected by nano Al_2O_3. According to the study's findings, bituminous binders' rheological performance is greatly impacted by the introduction of nano Al_2O_3 and it was found that bitumen is stable at high temperatures due to the integration of nano Al_2O_3. They observed that the viscosity increased when Al_2O_3 was added, storage modulus, and complex modulus. Victory et al. (2021) stated and demonstrate that bitumen blends modified with LDPE display superior performance compared to standard bitumen. When LDPE was added, bitumen performed better than traditional bitumen and bituminous mixtures met their performance requirements. The study also shows that the modifications made with LDPE extended the service life. Ziari et al. (2019) examined another category of waste material in pavement mixes, it includes Electric Arc Furnace (EAF) dust and waste Polyvinyl Chloride (PVC) they observed it provided moisture resistance, rutting resistance, and fatigue resistance to the pavement mixes. The enhancing properties by such waste materials can tackle the problem of waste streaming but it needs a comprehensive investigation. Usahanunth et al. (2018) investigated the process of combining waste Bakelite aggregate (WBA) with concrete and mortar mixtures to create waste Bakelite aggregate concrete (WBAC) and waste Bakelite mortar (WBM). The investigation tests a variety of concepts, including the mechanical characteristics of WBAC and WBM, the physical and chemical characteristics of WBA, and others. The investigation comes to the conclusion that natural aggregates, both fine and coarse, can be substituted with WBA particles of varying sizes. Saha and Suman (2017) conducted a comprehensive investigation into the effects of incorporating Bakelite, a thermosetting plastic, into bitumen binder. Bakelite's amorphous three-dimensional structure imparts characteristics such as hardness, strength, and rigidity. In the experiment, bitumen was mixed with Bakelite in different ratios ranging from 1% to 5%. A number of the blended bitumen's important characteristics were evaluated and contrasted with unaltered bitumen that had a penetration grade of 60/70. Using a rotating viscometer, the evaluation criteria comprised penetration, softening point, and dynamic viscosity Nassiri et al. (2016) noted that hot mix asphalt (HMA) over PCC or Portland cement concrete (PCC) over PCC are examples of composite pavement structures that have been deployed in various in-service projects in Europe with reported success. The planning and building of these parts have proven to be continuous issues in the United States. The study conducted by Fini et al. (2016) explores the potential of bio-based modifiers, derived from various biomass sources, to enhance the low-temperature properties of asphalt binders. Bostancıoğlu and Oruç (2015) explored the effects of adding furan resin and activated carbon to asphalt to produce asphalt-modified mixtures. The Marshall quotient was greatly boosted by 25% by FR modification, while Marshall Stability was significantly increased by 9% by using CA and FR, according to the results. 10% CA and 5% FR were discovered to be present in the specimens with the highest indirect tensile stiffness modulus values, which are 16% higher than those of the original combination. Zhu et al. (2014) suggested that polymer modification offers a promising means of boosting the performance and durability of asphalt pavements, opening the door to more durable and long-lasting road infrastructure. This paper reviews certain technical advancements for overcoming limitations, such as saturation, sulfur vulcanization, antioxidant addition, use of hydrophobic clay minerals, functionalization, and antioxidant addition. Hınıslıoğlu (2004) carried out the investigation of employing plastic waste-more especially, High Density Polyethylene (HDPE) - as a polymer component in asphalt concrete. The study aimed to assess the impact of binders modified with HDPE on critical properties such as flow, Marshall Stability, and the Marshall Quotient, which is the stability to flow ratio, while accounting for changes in mixing temperature, mixing duration, and HDPE content. It was discovered that adding HDPE to asphalt concrete significantly raised the Marshall Stability

3. TRANSPORT PROPERTIES

Singh et al. (2023) study examined the ultrasonic pulse velocity method's capability to determine effective flow resistance for the parametric evaluation of pervious concrete. The study's findings suggest that non-destructive testing, which usually employs the ultrasonic pulse velocity (UPV) test, needs to be investigated further so as to assess the hardened properties of pervious concrete mixtures. The incorporation of waste materials, recycled glass powder De Moura et al. (2021) studied the effects on concrete permeability the study by him reported that by incorporating waste glass powder in concrete, it enhances both performance and environmental sustainability, achieving a notable 23.0 MPa compressive strength and a permeability coefficient of 10.5 mm/s with 34% glass powder waste while as the study by Cheng et al. (2015) explored the use of waste ceramic polishing powder as a supplementary cementitious material in concrete production. The research highlighted the positive impact on permeability resistance, with the most favourable results achieved at a 30% cement substitution rate. Additionally, combining waste ceramic polishing powder and fly ash further enhances concrete's permeability resistance, demonstrating the potential for sustainable and durable concrete formulations.

4. ACOUSTICAL PROPERTY

Moges et al. (2022) investigated the surface perforated mortar (SPM), an acoustic substance made of cement, can lessen train noise. The majority of the SPM's absorption performance is influenced by the geometry of the macro-sized holes that are present on its surface. By reducing the resonance induced by the holes, a prior study was able to obtain a better sound absorption capacity in comparison to traditional pervious concrete. Since most acoustic materials include pores, it was assumed that adding tiny pores to SPM would improve its ability to absorb sound. Because of this, this work uses aluminium powder to foam cement and looks at how SPM's micro-sized pores affect sound absorption. Mohammadi et al. (2021) explored the construction of the model to predict traffic/pavement sound levels based on the composition of asphaltic mixture components is covered in the study. The authors present evidence that the asphalt mixture's composition affects how much noise is reduced by low-noise flexible pavements. The suggested linear model's components, which meet the specifications for premium asphalt mixtures, are based on the bitumen content, air-void content, and aggregate form. The model makes it easier to forecast tyre and road noise levels during the design stage by using the volumetric characteristics and ingredients in the asphalt mixture. Furthermore, in each of the previously described investigations, the linearity of the link was evaluated using Pearson's correlation coefficient. The field distance was assessed using the close proximity test and significance was determined using the Anova test. Nowoświat et al. (2020) investigated the impact of emulsion mat micro surface (thin) on noise levels in the vicinity. The results of the study showed that applying micro surfacing decreased noise exposure by an average of 50 meters at night and 30 meters during the day. The main objective of the article is to compare a new road pavement made of a thin, cold-produced emulsion mat micro surface with a 0/5 mm graining against an old, worn course made of SMA Mix. Using the Close Proximity Measurement Method (CPX) and the noise measurement method, testing was conducted at intervals of 1.5 m, 5.25 m, and 10 m along the roadway. The noise exposure maps for the regular road pavement and the micro surface were used to demonstrate the findings. Li et al. (2018) carried out an experimental programme in order to investigate the abrasion resistance and acoustic wave attenuation of engineered cementitious composites (ECC) for runway pavement, the testing results made it possible to compare the abrasion resistance of ECC concrete with a 3% fibre volume ratio to that of regular concrete with the same compressive strength. In addition, it was demonstrated that the acoustic wave attenuation of ECC was significantly larger than that of traditional concrete with the same fibre volume ratio and was associated with the fibre volume ratio. The article claims that ECC's exceptional abrasion resistance is due to its high tensile strength and ductility, which allow it to take in energy and bend without breaking or cracking. The exceptional acoustic wave attenuation of ECC can be attributed to its higher void ratio and fibre content, which allow for more efficient scattering and absorption of sound waves. Biligiri and Way (2014) indicated that impedance has an inverse relation to the acoustical properties of a sample. This was confirmed by changing the binder content (asphalt content) of the flexible pavement which indicated that an increase in binder content results in an increase in sound damping because of increase in viscoelastic properties. Biligiri and Way (2014) created a novel and unique parameter known as the damping acoustical measurement parameter (DAMP) to characterize the noise-damping capabilities of various road materials. A laboratory acoustical study was carried out on samples consisting of two non-asphaltic mixtures and nine conventional and modified asphalt mixes using the ultrasonic pulse velocity (UPV) technique. Impedance (Z) was determined during the process. DAMP for various mixes from Z were calculated. A pavement's greater ability to dampen noise is demonstrated by a lower Z and a larger DAMP. The asphalt rubber friction course, which is the quietest pavement material according to the results of the field noise measurement, has the greatest DAMP (20%) of all the asphaltic mixes when compared to the other mixes. The

DAMP of Portland cement concrete was the lowest (12%), and the highest (37%), for Poroelastic road surface among the non-asphaltic combinations. Diamond grinding, as was previously noted, has shown to be a very successful technique for reducing noise. Kim et al. (2014) According to their research, there is a chance to lower traffic noise levels between 4 and 9 decibels by using quiet asphalt surfaces and unique concrete bases. Base blocks with the same Hot Mix Asphalt (HMA) and other base blocks with the same HMA were the two categories into which the noise reduction findings were separated. On the same base concrete block, HMA 3 produced the best noise reduction results; measured values varied from 3 dB to 6 dbs. Meanwhile, different base concretes have observed noise reduction values ranging from 3 to 4 dB utilizing the same HMA. These results suggest that a concrete block has less capacity to attenuate noise than a quiet asphalt surface. Park et al. (2005) examined the acoustic performance of porous concrete based on the quantity of recycled aggregate and goal void ratio and found that the Noise Reduction Coefficient is at its highest at void ratios of 25% and percentage aggregate of 50%. A loss in compressive strength would result from a reduction in the void ratio below this range.

5. ACOUSTIC PROPERTY OF COMPOSITE MATERIALS

Kanda (2024) investigated the possibilities for using waste concrete powder (WCP-S) as a reinforcing agent in plastic composite materials. They produced composite materials using compression moulding and investigated the effect of WCP-S content on mechanical characteristics. Flexural strength in polypropylene (PP)-based composites reduced as WCP-S concentration rose, showing a lack of adhesion between matrix resin and WCP-S under high flexural loads. However, the flexural modulus increased. Flexural strength in polyethylene (PE)-based materials remained stable as WCP-S content increased, but flexural modulus improved. These data imply that WCP-S is a viable reinforcement for PP and PE resins, particularly in terms of flexural modulus. Linghu et al. (2022) propose a novel approach, the ensemble wavelet-neural network method, for correctly and efficiently predicting the mechanical properties of concrete composites. It solves the difficulty of managing high-dimensional data and computing expenses by dealing with the intricacies of structural heterogeneities and mechanical properties. Key features include using a Weibull probabilistic model to model uncertainties, extracting geometric and material characteristics with the asymptotic homogenization method and a background mesh technique, and pre-processing data features with wavelet transform to create a concrete material database. By incorporating wavelet coefficients into the artificial neural network, the approach minimises input data while preserving robustness and accuracy. Numerical measurements show that the method is useful for forecasting the mechanical properties of concrete composites.

Hamed and Bradford (2010) investigated the complex area of creep behaviour in concrete beams reinforced with externally bonded composite materials. It faces the issues of modelling creep across the many materials involved and develops a theoretical framework to solve these complications. This model's primary feature is the incorporation of viscoelasticity via differential-type constitutive relations based on Boltzmann's concept of superposition. Notably, the model goes beyond previous models by taking into account the deformability of adhesive layers as well as their resistance to stresses in several directions. Using an incremental formulation based on the vibrational principle of virtual work, this study dynamically investigates internal stress fluctuations over time and their impact on creep reactions. Lin and Liao (2004) investigated into the compressive strength of concrete columns limited by composite materials, specifically the usage of Fibre Reinforced Polymer (FRP) wrapping. It is divided into two sections, with the first comparing the behaviours of FRP-confined concrete columns with reinforced concrete (RC) columns under uniaxial compression. The results show that FRP confinements of both specimen types behave similarly, implying that analysing FRP-wrapped concrete columns can provide insight into the behaviour of FRP-wrapped RC columns. The study demonstrates the efficiency of FRP wrapping in confining RC columns since it can be applied uniformly around the column, resulting in a bilinear stress-strain figure. Orbanich et al. (2012) examined the efficiency of Carbon Fibre Reinforced Polymer (CFRP) in reinforcing concrete foundation beams. CFRP is well-known for increasing the strength of structures such as beams and slabs, but its effect on foundation beams is less well understood. The study examines bending and shearing strength, as well as load capacity change and beam deflections, taking into account various height/span beam relations. The Finite Elements Method using Abaqus programme is used in the analysis, which includes non-linear models for concrete and soil as well as a linear elastic model for composite materials. This study sheds light on the behaviour of CFRP-reinforced foundation beams, advancing our understanding of composite material interactions in structural reinforcement.

Gap in existing research concerning composite concrete materials. We acknowledge the efforts of researchers who have focused on analysing the mechanical and structural properties of such materials. These properties are crucial for understanding the durability, load-bearing capacity, and overall performance of composite concrete structures in various applications.

However, investigation of the acoustic performance of composite concrete materials. Acoustic performance refers to how well a material absorbs, reflects, or transmits sound waves. In today's society, where issues such as noise pollution and sound insulation are increasingly significant, understanding the acoustic behaviour of construction materials is paramount. By emphasizing the lack of attention given to acoustic properties, the statement suggests a need for further inquiry and exploration in this area. Understanding how composite concrete materials interact with sound waves can have practical implications for designing buildings, roads, bridges, and other structures that offer both structural integrity and acoustic comfort.

The study delved into the examination of fundamental structural, mechanical, and transport properties of two composite concrete materials. Initially, polypropylene fibers were integrated into concrete at diverse ratios, followed by the incorporation of recycled PET fibers at equivalent proportions. Upon scrutinizing the structural and mechanical characteristics, it was observed that these attributes exhibited a notable enhancement of up to 30 percent initially, subsequent to which a diminishing trend was discerned. This decline could potentially be attributed to a compromised bonding mechanism at elevated fiber concentrations. Concerning transport properties, a heterogeneous pattern was observed across different fiber proportions, necessitating further comprehensive investigation.

Moreover, regarding the acoustic performance of the composite materials, an escalation in the damping percentage was noted with an increasing proportion of fibers, reaching up to 27%. This augmentation signifies a considerable improvement in acoustic damping characteristics, thereby suggesting promising implications for noise attenuation applications.

6. CONCLUSION

This paper concludes by highlighting the interdependent nature of material properties, highlighting the interaction between structural and transport qualities and their influence on thermal and acoustical properties. In order to choose materials wisely and achieve the best results in practical applications, a thorough examination of these interdependencies must be prioritized. The investigation of noise control techniques also demonstrates the affordability and efficacy of passive noise control techniques. In order to create creative solutions for noise mitigation in engineering applications, this study promotes a comprehensive, multidisciplinary approach in materials research, acknowledging the necessity for a nuanced understanding of different features.

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