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Effect on stability of asphalt using COVID-19 single use face mask and saline tube waste

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Abstract

During the COVID-19 pandemic, there was a significant increase in the production of single-use face masks and saline tubes, leading to a considerable rise in biomedical waste pollution and its adverse effects on the environment. To address this issue, the utilization of shredded face masks and saline tubes as additives in asphalt mixtures was proposed in this study, aiming to reduce the pollution caused by excessive biological waste. The effects of incorporating shredded face masks and saline tubes into the asphalt mixture were investigated. Different percentages of single-use face masks (1%, 1.25%, 1.50%, 1.75%, and 2%) and waste saline tubes (0.5%, 1%, 1.5%, 2%, and 2.5%) were used to partially replace coarse aggregate and asphalt. Additionally, filler materials such as Metakaolin and M-sand were employed. Preliminary tests were conducted on bitumen, fine aggregate, and coarse aggregate. The dispersion of waste face masks and saline tubes within the asphalt mixture was examined using a scanning electron microscope (SEM). The influence of the face mask and saline tube content on the asphalt mixture was evaluated through a Marshall stability test. Various combinations were analyzed, and their results were compared to those of the existing mixture. Based on the tested ratios, the mix proportion of 1.25% shredded face masks and 1% waste saline tubes (1.25FM1ST) produced the optimum results in terms of stability and performance. The utilization of shredded face masks and saline tubes as additives in asphalt mixtures offered a promising solution for reducing pollution caused by the growing biomedical waste associated with the COVID-19 pandemic. Further research and implementation of this approach could contribute to sustainable waste management practices while maintaining the performance and durability of asphalt pavements.

Keywords

Shredded face mask, Saline tube, Metakaolin, Asphalt mixture, Marshal stability test.

1.Introduction

Highway infrastructures play an important part in local and international studies of emerging metropolitan cities because of their direct and indirect impact on urban expansion, environmental issues, and socioeconomic challenges. Transverse and longitudinal fractures, potholes, and subgrade deformation in flexible pavement result from the higher rate of vehicle addition on the roads to the space of road building. Due to an increase in the number of vehicles on the road, flexible pavements have developed cracks and deformations below the subgrade [1].

Different types of waste plastic bottles and optimizing the percentage of additive for improved performance of the asphalt [2].

The effects of waste polymer modification on the performance and sustainability of asphalt mixtures. Their findings indicated improved resistance to fatigue cracking and reduced environmental impacts, particularly in terms of energy consumption and carbon emissions [3]. Incorporating disposable medical masks (DMM) enhanced the high and low-temperature performance of the asphalt, leading to improved complex modulus, rotational viscosity, and tensile elongation. Furthermore, the addition of DMM fibers improved the moisture susceptibility, rutting resistance, and cracking resistance of the asphalt

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mixtures [4]. Performance of asphalt mixtures with recycled plastics, considering factors such as rutting resistance, fatigue resistance, moisture susceptibility, and aging characteristics [5]. Effects of styrene-butadiene-styrene (SBS) and crumb rubber on various properties of asphalt, including rheological properties, temperature susceptibility, aging resistance, fatigue resistance, and moisture resistance. The mechanisms of interaction between SBS/crumb rubber and asphalt are explored, providing insights into how these modifiers improve the performance of asphalt mixtures [6]. The addition of waste polyethylene terephthalate (PET) improves the moisture resistance of the asphalt mixtures, reducing the moisture-induced damage. The inclusion of recycled concrete aggregates (RCA) further enhances performance by enhancing the interlocking effect and reducing moisture infiltration [7]. Using European rock bitumen and waste cooking oil as modifiers for asphalt mixtures, highlighting their positive impact on the mechanical behaviors of the asphalt. The modified mixtures exhibit enhanced Marshall stability, increased indirect tensile strength, improved resilient modulus, and increased resistance to rutting [8]. The incorporation of grafting-activated waste leather powder (GAWLP) improves the rheological properties of asphalt, enhances its high-temperature stability, and increases its resistance to low-temperature cracking. GAWLP also contributes to improved water damage resistance of the modified asphalt. Regeneration of asphalt using waste engine oil improves its rheological properties, enhances its resistance to aging, and reduces its moisture susceptibility [9]. The primary objectives of this study are to investigate innovative packaging materials and analyze their impact on pavement performance and cost efficiency. To enhance the properties of paving materials used in the construction of high-performance pavement structures. By improving the design mix of packaging surfaces, particularly asphalt surfaces, and optimizing the behavior of hot asphalt mixtures (HMA) in terms of strength and stability. As a result, improving the road surface's attributes and lowering the maintenance problem is critical [10]. Natural building materials are growing more expensive by the day; as a result, developing alternatives to replace them, which could improve road quality, is becoming more vital. Considering the properties of paving materials is the most important factor when evaluating and enhancing pavement performance. To build high-performance floor structures, the materials used in the blends used to create the floor surface must be of higher quality than the materials used. As a result, highway development projects are more expensive and researchers are focused on finding alternatives for different routes to packaging structures to overcome highway construction cost issues while maintaining good structural performance. The most popular approach investigated in packaging material research is to change the design mix of packaging surfaces, especially asphalt surfaces. The contributions of this research lie in the exploration of waste material additives as potential solutions to enhance the strength of asphalt binders. Analyze the effect of these additives on the stiffness modulus of HMA mixtures. It is essential to strike a balance between the concentration of additives to ensure increased stiffness and binder flow, which may result in further overlays and maintenance expenses.

The research paper follows an organizational structure. Section 2 provides a summary of previous investigations, establishing the research context. Section 3 outlines the employed research methods, ensuring transparency and replicability. Section 4 presents the study's results, validating the research objectives. Section 5 offers a detailed discussion, analyzing implications and comparing findings. Finally, Section 6 concludes the paper, summarizing the study and suggesting future work.

2.Literature review

As a result, the additive content must be kept at its maximum level [11]. Waste plastic as a recycled polymer in asphalt modification should give comparable results to commercially available polymers, such as improved rutting resistance, more elastic behavior that extends fatigue life, and a cost-effective advantage [12]. The COVID-19 pandemic has had devastating effects on the ecology around the world. One of the most significant environmental issues is the worldwide use of billions of polypropylene single-use face masks (SFM). Due to the masks' lightweight nature, wind and rain can easily transport them into city streets, rivers, and oceans, where plastic-based masks can be split into microplastics. As a result, discarding masks or inappropriate waste management of discarded personal protection equipment can cause problems for wildlife or result in the death of animals and marine life. Furthermore, single-use masks are constructed of non-biodegradable plastics that take hundreds of years to degrade in the environment. To combat the COVID-19 pandemic and limit the environmental concerns related to the disposal of worn personal protective equipment (PPE), multidisciplinary collaboration is critical. COVID-19 SFM is used to improve asphalt surface rutting resistance. A novel approach for reducing pandemic-related waste has been proposed, which involves recycling used face masks in HMA. The rutting depth was decreased by increasing the SFM content, which can be attributed to the melted SFM acting as an asphalt binder in binding the aggregates. The adhesion between the aggregates was improved, and the stiffness of the mixes was increased, resulting in a pavement that is more resistant to traffic pressure [13]. The impact of waste rubber powder on the performance of asphalt mixture and the reduction of rut depth created by passing wheels. At various temperatures and pressures, waste rubber powder has a significant impact on lowering rut depth in asphalt mixtures [14]. The rutting resistance of the base binder modified with finer waste materials increased as the waste material content of the binder grew, but the fatigue resistance of the modifications reduced as the waste material content of the asphalt binder increased. This could be owing to the binders' greater viscosity, resulting in stiffer HMA [15]. The waste blinds-based additives experienced the most hardness. The waste window-based additive showed mild hardening, while the waste cable-based additive indicated the least amount of hardening. Blinds have the most brittle and toughest physical qualities of all the waste materials involved in the content. A hard and brittle material causes the bitumen to solidify more quickly, whereas a soft material causes the bitumen to harden more slowly. The retention penetration figures reveal that the waste cable-based additives outperformed the blinds-based modifiers [16]. The waste materials (waste cable) that were utilized to modify the bitumen toughened it according to their physical qualities. As a result, saline waste tubes (medical waste) were used in this study. The saline tube is a cable pattern that improved the asphalt mix performance on road surfaces. When employing saline tube waste material in HMAs, the pavement's stability factor is better than conventional pavement. The marshall stability and flow values of waste plastic were higher than those of regular plastic. It reduces the amount of bitumen in asphalt mixtures and the amount of aggregate in flexible pavement construction [17]. The filler minimizes voids in the aggregate, reduces the temperature sensitivity of the asphalt binder layer, and significantly affects the behavior of the hot asphalt packaging mixture. In this regard, Metakaolin was used in this research. Metakaolin has been studied as a Pozzolanic additive to improve the strength of cement concrete mixtures. The mechanical properties of metakaolin-modified HMA were investigated experimentally in this study. The inclusion of metakaolin filler improves moisture resistance. Depending on the results, Metakaolin can be used as a 50 percent partial substitute mineral filler in the hot asphalt mixture [18]. For all mix proportions, the mechanical performance of the Marshall stability test was done, and the stability parameter, flow value, and Marshall quotient were assessed. As a result, the use of SFM and saline tubes as asphalt mixture components to conserve the environment has been considered.

Addition of waste natural bitumen decreased the low-temperature behavior of the asphalt binder, while the addition of waste ground tire rubber enhanced resistance against low-temperature cracking [19]. The regeneration process for short-term aged crumb rubber modified asphalt (CRMA) involves reversing the aging effects, while the regeneration of long-term aged CRMA involves repairing internal structural damage, enhancing integrity, and improving thermal stability. It reveals that regeneration alleviates the self-aggregation of asphaltene in aged CRMA and improves the ordering of the colloidal structure [20]. Results of the leaching assessment indicate that the long-term environmental impact of hazardous materials of warm mix asphalt (WMA) is negligible [21]. Surface modification of waste glass powders (WGPs) using different types and contents of a silane coupling agent (SCA) to enhance the adhesion performance and water stability of asphalt mixes [22]. The macromolecular substances present in waste cooking oil play a significant role in rejuvenating aged asphalt. These substances effectively soften the asphalt, improving its high-temperature performance and enhancing its low-temperature ductility [23].

Incorporating desulfurized rubber as a modifier in asphalt binders improves their performance in terms of rutting resistance, fatigue life, and low-temperature cracking resistance. The use of waste rubber offers a sustainable and environmentally friendly solution for enhancing the durability of asphalt pavements [24]. A characteristics' relation model based on factor analysis can effectively assess the performance of asphalt pavements. The model provides valuable insights into the relationship between various factors and their impact on pavement performance [25]. By optimizing the mixing and processing conditions, the researchers were able to achieve a more uniform and stable network structure within the CRMA, resulting in improved storage stability [26]. Gray-level co-occurrence matrix (GLCM) provides valuable insights into the microstructure and texture characteristics of the composite material, as well as its rheological behavior [27]. The utilization of palm oil waste as a sustainable alternative in asphalt mixtures can reduce environmental impacts and promote the circular economy by converting waste materials into valuable resources [28]. Asphalt-aggregate separation technology contributes to the sustainable and cost-effective use of reclaimed asphalt pavement in asphalt pavement construction, offering opportunities for resource conservation and environmental preservation in the road engineering industry [29]. Microscopic mechanism of this modification and found that the interaction between waste cooking oil and waste crumb rubber enhances the elastic and viscous behaviors of the modified asphalt and it enhances the performance and sustainability of asphalt pavements, offering potential benefits such as improved rutting resistance and increased durability [30]. Synthetic fibers can improve the overall performance and durability of asphalt mixtures by enhancing their strength, stiffness, and resistance to deformation [31]. By employing appropriate techniques such as gradation optimization, aggregate blending, and the use of additives, the negative effects of inferior quality aggregates can be mitigated, leading to the acceptable performance of the asphalt mixes [32]. The addition of printed circuit boards to the asphalt mixture resulted in improved aging resistance, with enhanced performance in terms of viscosity, ductility, and penetration [33]. Incorporating Portland cement as a filler improved the rutting resistance and stiffness of the asphalt mixture. Additionally, it helped reduce moisture susceptibility and increased the durability of the pavement [34]. Utilizing granite cutting waste and tunnel excavation rock as fine aggregates can be a viable approach for sustainable construction, reducing waste generation and enhancing the performance of cement-based materials in building engineering applications [35]. Using cement as a mineral filler can enhance the mechanical performance of the asphalt mixture, resulting in improved stability and resistance to rutting [36].

The use of fillers, such as hydrated lime and Portland cement, improved the compatibility, stability, and moisture susceptibility of the mixtures [37]. Incorporation of phase change material as a functional filler in the asphalt mixture significantly reduced pavement surface temperatures during daytime hours, contributing to the mitigation of urban heat island effects [38]. It enhances the thermal performance and energy efficiency of asphalt pavements, contributing to the development of cooler and more comfortable urban environments. The use of brake pad waste as an aggregate did not significantly affect the mechanical properties and performance of the asphalt mixtures, including stability, rutting resistance, and moisture susceptibility [39, 40]. Utilizing waste vegetable oil as a rejuvenator offers a promising approach to enhance the durability and sustainability of asphalt pavements, contributing to the circular economy and environmental conservation in addition waste vegetable oil improved the adhesion strength between the asphalt binder and aggregates, indicating enhanced bonding and cohesion [41]. Self-healing treatment improved the resistance to water infiltration and enhanced the overall durability of the steel deck asphalt pavement [42].

Rutting depth has been reduced by increasing the amount of shredded face mask and waste saline tube in the aggregate, which acts as a binder. As a result, partial alternatives for gravel and hot mix asphalt have been offered, such as surgical face masks and saline tubes. The impact on stability has been addressed by including these waste elements inflexible pavement combinations, which has reduced their disposal costs. The use of hot mix asphalt as a substitute not only strengthens road building but also contains combinations that are more resistant to wheel load. The effects of asphalt with shredded face mask and saline tube waste in HMA, improved aggregate adhesion and stiffness. *Figure 1* shows the methodology of this research.

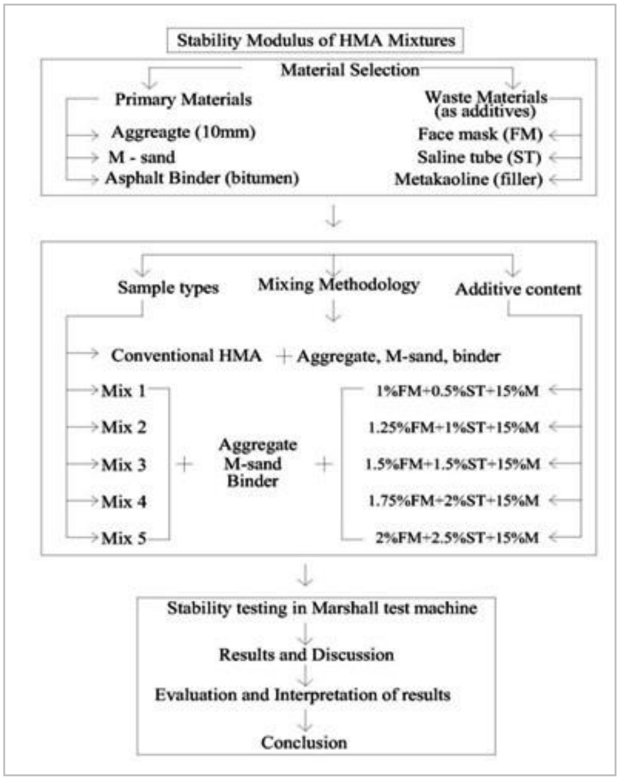


Figure 1 Research methodology

3.Materials and methods

Aggregate is a material that is used to form concrete or mortar when it is mixed with cement, bitumen, lime, gypsum, or another adhesive. The aggregate provides volume, stability, wear and erosion resistance, and other physical properties to the finished product. When employed on a bituminous surface, the aggregate serves three primary roles. The load is transferred from the surface to the base course. This is accomplished in the pavement through the mechanical interlocking of aggregate particles (10-12mm). It can withstand the abrasive assault of traffic. For the bituminous surface, stone aggregate should be firm, robust, resilient, and hydrophobic. The extremely adhesive characteristic of bitumen allows the elements in the road mix to bind together in strong connections. When the mix is suitable for vehicle movement, these get stronger. Bitumen is a binding organic substance derived from processed crude oil by-products. It is utilized in road building because it is simple to make, reusable, non-toxic, and has a strong binding ability. Bituminous roads have a surface made of bituminous materials, which are also known as asphalt. It is a viscous, sticky dark liquid derived from natural resources such as crude petroleum. In HMA, SFM was utilized as an additive. Polypropylene makes up most of the structure. This material was melted at 160°C and then shredded into little pieces using a paper shredder. The required gradations, 40mm x 5mm shredded particles were sieved. Furthermore, throwaway face masks might take up to 450 years to degrade in the environment because they are usually made of non-biodegradable polymers. To solve these important environmental issues, efforts must be made to dispose of worn face masks by sustainable principles to reduce environmental risks. The saline tube, which is made of polyvinyl chloride (PVC), is collected on a large scale, shred and cut into little pieces with a paper shredder, and then used as aggregates mix substitute. The primary advantage of using PVC-based goods is their strength and flexibility. Sealing accountability is straightforward, and sterilizing is not an issue. Manufactured sand (M-Sand) is a construction aggregate manufactured by crushing hard stones into small angular-shaped particles the size of sand, then washing and accurately grading them. It is a river sand-based alternative to concrete construction. M-sand is made from crushed hard granite stone. For use as a building material, crushed sand is cubical with grounded edges, washed, and graded. The particle size of the M-Sand is less than 4.75mm. Metakaolin (filler material) is a type of calcite clay with pozzolanic properties. It is made by baking high-quality kaolin clay for 90 minutes at temperatures between 650 and 800°C. Metakaolin is added at a rate of 15% by weight of aggregate, with a specific gravity of 2.6. Metakaolin is a dehydroxylated version of kaolinite, a clay mineral. In comparison, metakaolin has a smaller particle size (1-2m) and a greater surface area, and all materials are shown in *Figure 2.*

Figure 2 Photograph of material in HMA

3.1Preparation of waste material

Waste materials from society and hospitals are collected. This can include a variety of items such as discarded items, packaging, and medical waste like face masks. Boiling water treatment: To remove chemical contaminants and contaminated minerals from the waste materials, boiling water is used. Boiling water helps in killing microorganisms and break down certain chemical compounds. The waste materials are immersed in boiling water, allowing the contaminants to be released and dissolved. Removal of ear knot from shredded face mask: In the case of shredded face masks, which typically have ear loops, the ear knot needs to be removed before further processing. This step ensures that only the mask material is processed and any non-biodegradable components like plastic ear loops are separated. After the boiling water treatment, the waste materials are dried to remove moisture and facilitate further processing. There are two common methods mentioned in the description for drying: sun drying and oven drying. Sun drying: Waste materials are spread out in the sun, allowing them to dry naturally through exposure to sunlight. Sun drying is an eco-friendly and cost-effective method, utilizing solar energy to evaporate the moisture present in the waste materials. Oven drying: Alternatively, waste materials can be dried in an oven. The temperature range mentioned in the description is from 50 to 80 degrees Celsius. This controlled heating process accelerates drying by providing a consistent heat source. It is important to ensure that the temperature is set at a level that will not cause the waste materials to burn or release harmful fumes. Once the drying process is completed, the dried waste materials are chopped into smaller pieces. This step can help facilitate further processing, recycling, or repurposing of the waste materials. Chopping the waste into smaller pieces increases its surface area, making it easier to handle and process *Figure 3*.

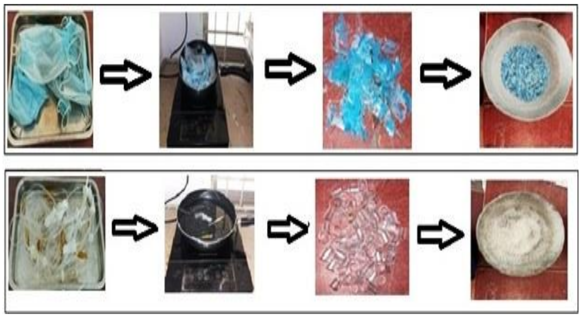


Figure 3 Preparation of shredded face mask and saline tube

3.2Test on materials

3.2.1 Specific gravity test on aggregate

The specific gravity of an aggregate is analyzed by comparing the weight of that aggregate to the weight of the same volume of water. For a variety of reasons, specific gravity is significant. Aggregate has a specific gravity between 2.5 and 3.0. The aggregate with the best performance has an average specific gravity of 2.60 (*Figure 4*).

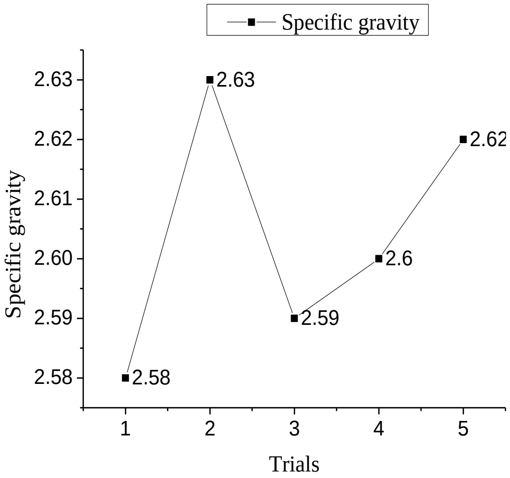


Figure 4 Results on specific Gravity Aggregate

It is formally defined as the mass of a unit volume of aggregate divided by the mass of an equal volume of gas-free distilled water at the stated temperature, including the weight of water within the voids filled to the extent obtained by sinking in water for around 15 hours.

3.2.2 Water absorption test on aggregate

Methods of Aggregate Testing, IS 2386(Part 3):1963 Water absorption reveals the aggregate's internal structure. The retaining capacity of coarse aggregate has been investigated using a water absorption test. The aggregate result for water absorption is 2.22 (*Figure 5*).

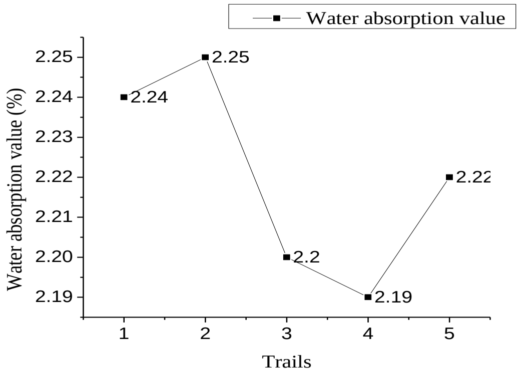


Figure 5 Water absorption value of aggregate

The permissible water absorption value varies by layer; for example, aggregates that absorb around 4% of water are allowed in the drain layer, whereas only 1% of water is permitted in the base course.

3.2.3 Impact test of aggregate

The test procedure was followed in line with IS: 2386 (Part IV) – 1963. As a result of vehicle movement on the road, aggregates are subjected to impact, which causes them to break down into smaller pieces. As a result, the aggregates must be able to withstand impact-induced disintegration. This feature is evaluated using the impact value test. The optimal impact value of aggregate findings is 29.26 percent (*Figure 6*).

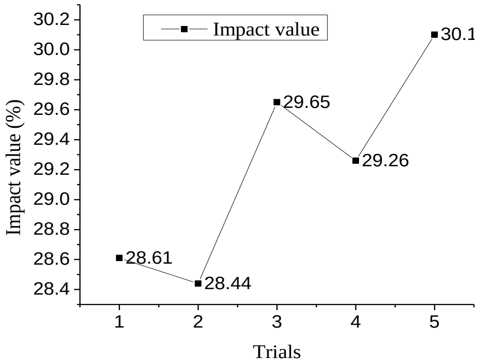


Figure 6 Impact value of aggregate

The impact value of the aggregates used for the wearing course should not exceed 30%. The maximum percentage of bituminous macadam that can be used is

35 percent. According to the Indian road congress (IRC), the maximum allowable value for water-bound macadam base courses is 40%.

3.2.4 Crushing value test on aggregate

The aggregate crushing value test, according to IS: 2386 – part 4, provides a relative indication of an aggregate's resistance to crushing under a gradually applied compressive stress. The aggregate crushing value is defined as the proportion by weight of crushed (or finer) material obtained when test aggregates are exposed to a specified load under standardized conditions, and the strength of aggregate used in road construction is signified by a numerical index. The crushing value of bituminous macadam roads is typically between 40 and 45 percent. The ideal number for aggregate crushing is 43 percent as shown in *Figure 7*. For the crushing value of road work, this number is adequate. Its applicability in various layers of roads can be determined based on the crushing percentage.

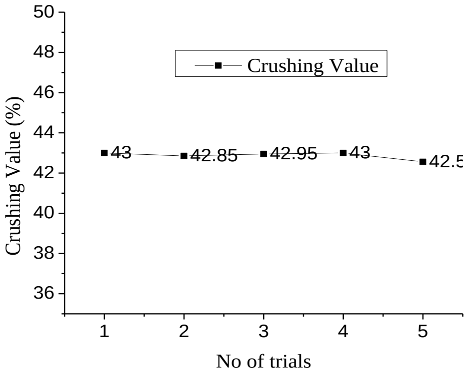


Figure 7 Crushing strength value of bitumen

3.2.5 Specific gravity test on bitumen

The mass of a bituminous binder is divided by the mass of an equal volume of water to determine its specific gravity. The specific gravity of bitumen is calculated to estimate the specific gravity of semi-solid bitumen road tars according to IS 1202-1978.The specific gravity of bitumen ranges from 0.97 to 1.02. The specific gravity of the best-performing coarse aggregate is 1.0 (*Figure 8*). At 25°C, the mass of a specific volume of semi-solid bituminous material, asphalt cement, and soft tar pitches is the same as the mass of an identical volume of water.

3.2.6 Bitumen softening point test

Bitumen is a viscoelastic material with no clearly defined melting point; as the temperature rises, it becomes softer and less viscous. A ring and ball device immersed in distilled wastewater or lycerin (above 80 to 157°c) can be used to measure the softening point of bitumen. On bitumen, the softening point test ranges from 35 to 70 0C. The ideal softening point test result is 450C (*Figure 9*).

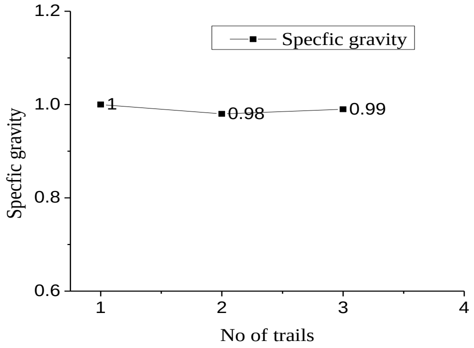


Figure 8 Value of bitumen's specific gravity

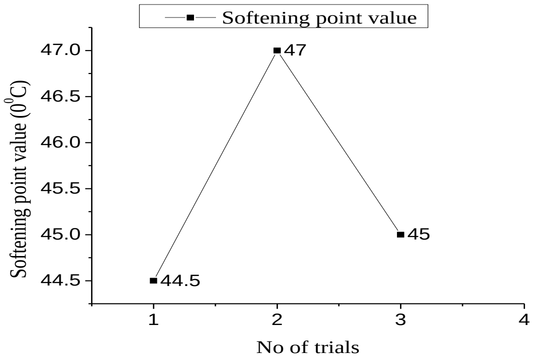


Figure 9 Softening point results on bitumen

The percentage of modifiers increases the softening point. The findings reveal that bitumen modified with a lower amount of modifier can be used in road building but not in roofing.

3.2.7 Viscosity tests on bitumen

This test has been completed according to IS 1206-PART-2. Grades of viscosity (degree of fluidity) grading is used to classify bitumen. Viscosity tests are carried out at 60°C and 135°C, which correspond to the temperature of the road surface during the summer and the mixing temperature, respectively. In this test,60 ml of liquid bitumen flowed through an orifice of a specified size in seconds at a specified temperature. The higher the viscosity of the bitumen, the longer it will take to flow out an amount. Bitumen viscosity tests range from 250 to 267. The ideal result of a bitumen viscosity test is 251 as shown in *Figure 10*.

It is a measurement of flow resistance. The higher the viscosity of liquid bitumen, the closer it comes to a semi-solid form. The viscosity of a thick liquid is higher than that of a thin liquid on road pavement.

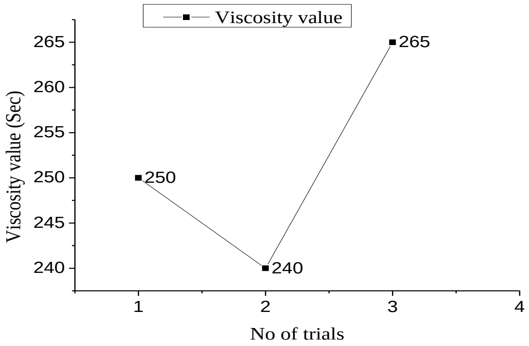


Figure 10 Viscosity Test results of bitumen

3.2.8 Penetration test of bitumen

To determine the consistency of bituminous material, penetration tests on bitumen were done according to IS:1203-1978. The bitumen's hardness was determined by measuring the vertical depth (in millimeters) that a standard rod needle could penetrate for 5 seconds while maintaining a temperature of 25 ° C in the bitumen sample. The range of penetration tests on bitumen is 35 to 40. The optimum result of the specific gravity of bitumen is 36 (*Figure 11*). This value is adopted on bitumen to grade the material in terms of its hardness.

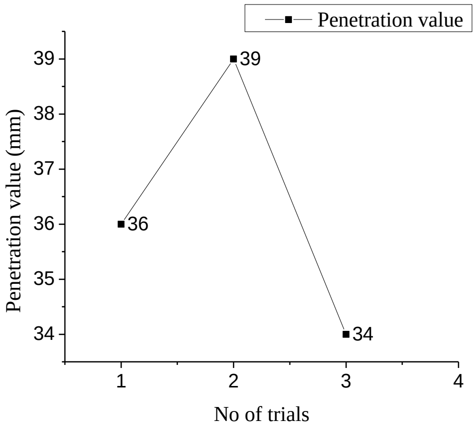


Figure 11 Penetration value of bitumen

3.2.9 Binder content test on bitumen

The Bitumen Extraction Test uses cold solvent extraction to detect the percentage of bitumen content in the asphaltic pavement. The furnace is a cost-effective method for determining the amount of bitumen in a bituminous mixture. It has a maximum sample weight of 4000 grams that it can handle. It can function at temperatures ranging from 200 to 650 degrees Celsius. The bitumen content test on bitumen yields an optimal value of 8.67 as shown in (*Figure 12*).

The difference between the initial mass of the HMA and the mass of the residual aggregate, correction factor, and moisture content are used to compute asphalt binder content. The amount of asphalt binder in the mix is reported as a percentage of the moisture-free bulk.

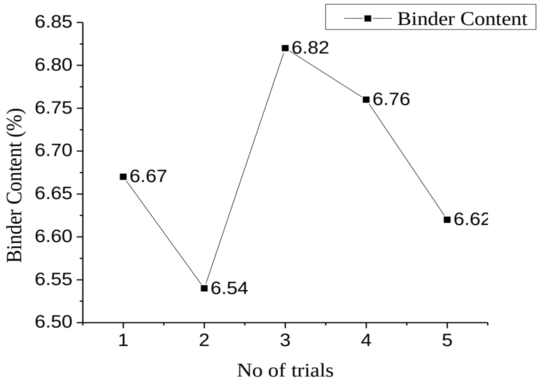


Figure 12 Binder content results of bitumen

3.2.10 Ductility test on bitumen

The feature of bitumen that permits it to undergo deformation or elongation is called ductility of bitumen, according to IS:1208-1978. The distance in mm (millimeter) to which a bitumen sample will stretch before breaking when pushed by a standard specimen at a specific speed and temperature is used to determine bitumen ductility. The ductility test determines bitumen's adhesive properties as well as its capacity to stretch. In flexible pavement design, the binder must provide a thin ductile layer surrounding the aggregates to improve physical interlocking.

The optimum value of the ductility test on bitumen is 75cm (*Figure 13*).

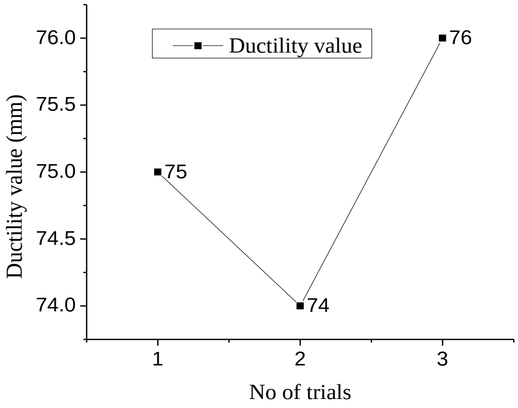
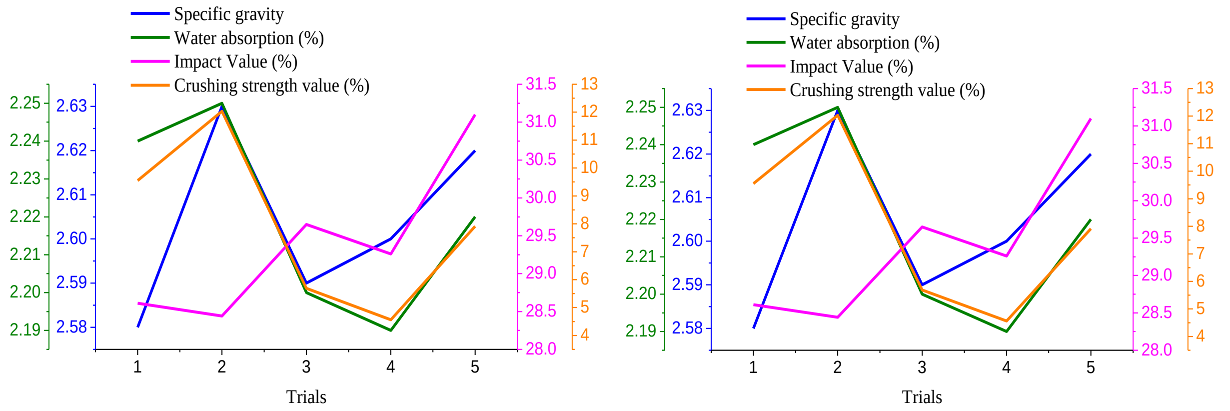


Figure 13 Ductility value of bitumen

The ductility test determines the adhesiveness and stretchability of bitumen. In flexible pavement design, the binder must create a thin ductile film around the aggregate to improve physical interlocking (*Figure 14*).

3.3Asphalt mixture preparation

Five experimental asphalt combinations as well as a standard asphalt mix were used in the study (*Table 1*). Before starting the compaction process, it is essential to ensure that the compaction hammer and mould are clean and free from any residue or debris. This helps maintain the accuracy and quality of the test samples. The mould assemblage, which includes the mould itself, is heated in an oven to a temperature of approximately 150°C. Heating the mould helps create a favorable environment for the compaction process and ensures proper bonding and curing of the test samples. Before placing the mix inside the mould, it is carefully greased. Greasing the mould helps prevent the test sample from sticking to the mould, making it easier to demold later. The mix, which consists of the material being tested, is placed inside the greased mould. The weight of each mould is specified as 1280 grams. The compaction hammer is used to provide 75 blows on each side of the samples. This process helps in achieving proper compaction and density of the test samples, ensuring consistency and accuracy in the results. After the compaction process is completed, the samples are allowed to cool for two hours at room temperature. This cooling period allows the test samples to set and solidify. Once cooled, the samples are carefully demolded, which involves removing them from the mould (*Figure 15*). Regarding the saline tubes and face masks mentioned later in the description, it states that the maximum grain size for both materials is 800 µm. This implies that the size of the particles in these waste materials does not exceed 800 µm. Furthermore, an environmental scanning electron microscope (ESEM) image (*Figure 16*) reveals that the morphologies, or physical structures, of the two waste particles (saline tubes and face masks), are distinct from each other. This observation suggests that the two materials have different appearances and characteristics when examined under the ESEM.



(a) (b)

Figure 14 Result analysis of aggregate and bitumen

Table 1 Mix proportions

Waste materials	Conventional	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Shredded face mask	0	1%	1.25%	1.5%	1.75%	2%
Saline tube	0	0.5%	1%	1.5%	2%	2.5%

Figure 15 Photograph of casted specimen in various proportions

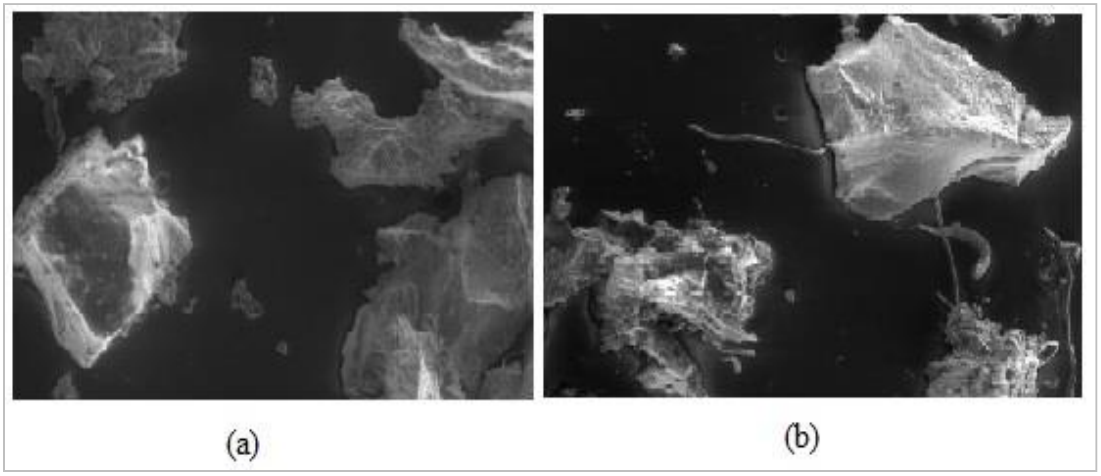

(a)
(b)

Figure 16 ESEM images of (a) saline tube and (b) face mask

4.Results

4.1Marshall stability test on samples

The test procedure is widely used in routine paving test programs for designing and evaluating bituminous paving mixes. The Marshall Method of mixing design focuses on determining the strength and flexibility of the mix. The mix's "Marshall's Stability," defined as the maximum load carried by a compacted specimen at a standard test temperature of 600 degrees Celsius, is used to determine its strength. For a bituminous pavement in use, this temperature represents the weakest condition. The "Flow Value," which is assessed by the change in diameter of the sample in the direction of lad application between the start of loading and the time of maximum load, is used to determine flexibility (*Table 2*). The goal of this test was to find the best binder content for the aggregate mix type and traffic intensity. The heated asphalt mix is placed in the compaction mould and compacted using the compaction hammer. The hammer is dropped a specified number of times on each side of the specimen to achieve the desired compaction level. The compacted specimen is placed on the load frame of the Marshall stability testing machine (*Figure 17*). The load is applied gradually to the specimen until failure or a predetermined deformation is reached. The applied load and deformation are recorded. The maximum load that the specimen can carry without failure is recorded as the Marshall stability value. The deformation or change in diameter of the specimen during the test is measured using a flow meter, and the value is recorded as the flow value. The optimum mix proportion is obtained in Mix 2 (*Figure 18*). It states that with the use of waste shredded face mask, a saline tube gives better results than a conventional bitumen mixture.

Figure 17 Photograph of Marshall stability test model and tested specimens

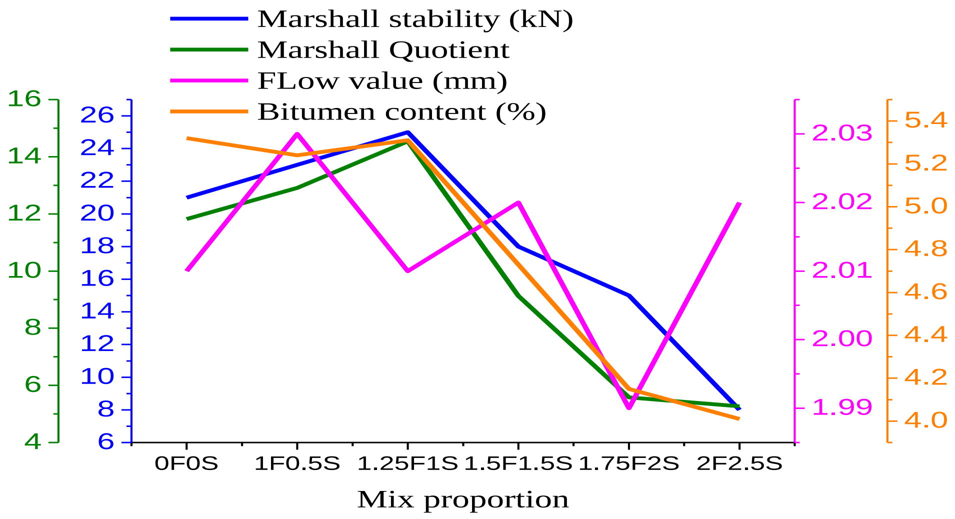


Figure 18 Shows the Marshall stability test value on specimens

Table 2 Marshall stability test results

Particulars		**Conventional**	**Mix 1**	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**
Percentage of waste materials (%)	**shredded face mask in %**	0 %	1%	1 .25%	1.5 %	1.75%	2%
	Saline tube in %	0 %	0.5%	1 %	1.5%	2%	2.5%
Weight of specimen in the air (g)		130 9	1290	1.444	1352	1410	1436
Weight of specimen in the water (g)		874	825	996	883	947	956
Weight of saturated surface dry core (g)		133 4	1295	1461	1355	1415	1430
Volume of core (cc)		460	470	465	472	468	471
Density of core (g/cc)		4.69	4.39	4.4	4.56	3.83	3.93
Marshall Stability (KN)		21	23	25	18	15	8
Flow value (mm)		2.008	2.028	2.014	2.019	1.996	2.02
Marshall Quotient		11. 82	12.91	14.54	9.13	5.58	5.27
Bitumen content (%)		5.32	5.24	5.03	4.73	4.15	4.01

4.2Spectroscopy analysis

Face masks typically consist of multiple layers, including a non-woven fabric layer, a melt-blown filter layer, and an inner absorbent layer. The non-woven fabric layer is usually made of polypropylene, while the melt-blown filter layer comprises a polypropylene microfiber web. The inner layer, designed to absorb moisture, may contain cellulose or other absorbent materials. The asphalt binder can potentially adsorb onto the surface of the face mask materials, which may lead to changes in the rheological properties of the asphalt. Face mask materials, particularly polypropylene components, are generally chemically stable and do not undergo significant reactions with the asphalt binder. Saline tubes, often made of flexible plastic materials such as PVC, are used for medical purposes and typically contain a saline solution. Plasticizers are often added to PVC to enhance its flexibility. During asphalt mixing and production, plasticizers may leach out from the saline tubes and interact with the asphalt binder. This can potentially affect the binder's rheological properties, such as its viscosity and elasticity. PVC is generally chemically stable and does not undergo significant reactions with asphalt. However, there may be minor interactions, such as weak physical adsorption or intermolecular forces that could impact the asphalt mixture's properties. The incorporation of waste materials like face masks and saline tubes into asphalt mixtures can potentially contribute to the improvement of stability. Face masks, particularly their non-woven fabric layer and melt-blown filter layer composed of polypropylene fibers, can act as reinforcement within the asphalt mixture. These fibers can provide additional structural integrity and improve the load-bearing capacity of the asphalt. The increased reinforcement can lead to enhanced resistance against deformation and rutting, thus improving stability. The interactions between the waste materials and asphalt binder can potentially modify the binder's properties. For instance, the adsorption of asphalt binder onto the surface of face mask materials can alter the binder's viscosity and improve its adhesion to aggregate particles. This improved adhesion can enhance the overall stability of the asphalt mixture by reducing aggregate-binder separation and improving resistance to moisture damage.

4.3Rutting stability index (RSI)

Rutting stability is typically evaluated based on performance criteria such as rut depth or rutting rate. Rut depth is the permanent deformation or indentation in the asphalt surface, measured as the vertical difference between the initial pavement surface and the deformed surface after testing. The rutting performance of the asphalt mixture with the waste materials is compared to that of the reference mixture. This allows for a relative evaluation of the impact of the waste materials on rutting stability. The RSI is calculated by comparing the performance of the asphalt mixture with the waste materials to that of the reference mixture. The index can be expressed as a ratio or percentage to quantify the relative improvement or degradation in rutting performance. A higher RSI (RSI = 8.2% for mix 2) indicates a better resistance to rutting and improved stability (*Figure 19*). The RSI provides a quantitative measure of the effect of waste materials on the rutting performance of the asphalt mixture. A higher index suggests that the inclusion of waste materials has contributed to improved rutting resistance and stability.

Implementing a wear and tear test using waste facemasks and saline tube as mixing materials in flexible pavement can have technical results that vary depending on several factors such as the type and quality of the materials, the mix design, and the testing methodology. The use of waste facemasks in flexible pavement can improve the workability and durability of the mix, reduce its permeability, and increase its resistance to deformation and cracking. Waste facemasks can also act as a filler material, helping to reduce the amount of virgin materials required in the mix.

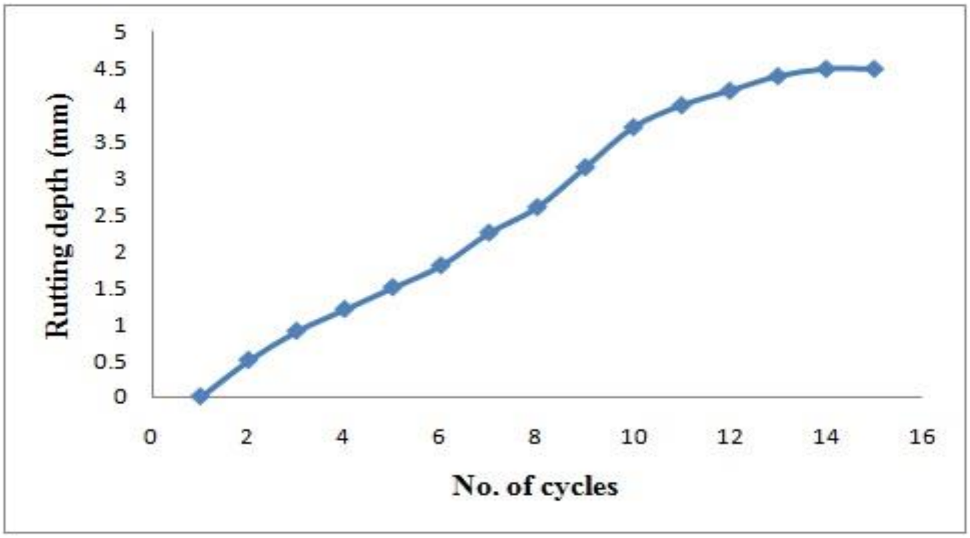


Figure 19 Shows the variables of the rutting depth

According to the Federal Highway Administration (FHWA), the maximum rut depth for flexible pavements should not exceed 12.7 mm (0.5 inches) for low-volume roads and 9.5 mm (0.375 inches) for high-volume roads. These are considered acceptable limits for maintaining good ride quality and reducing the risk of vehicle accidents. From the test of wear and tear rut depth is 4.5mm (0.177 inches). Waste facemask and saline tubes can improve the fatigue life of the flexible pavement mix, allowing it to withstand repeated loading without cracking or failing. It can reduce the stiffness of the asphalt binder and improve its resistance to cracking caused by repeated loading and enhance the cracking resistance of the pavement. A waste facemask can fill in the voids in the mix and improve its density, while crumb rubber can act as a binder modifier, improving the adhesion between the asphalt binder and the aggregate. Together, these materials can help reduce the likelihood of cracking in the pavement. Waste facemasks and saline tubes can also improve the skid resistance of the flexible pavement mix. Waste facemask can help reduce tire-pavement noise by providing a more uniform surface texture, while crumb rubber can help reduce noise levels by absorbing sound energy and reducing vibrations.

4.4Energy density

The energy density of the waste materials themselves, such as face masks and saline tubes, is an important consideration. The energy density can vary depending on the composition of the materials. For example, face masks primarily composed of non-woven fabric and melt-blown filter layers made of polypropylene may have a different energy density than saline tubes made of flexible plastic materials like PVC Understanding the energy density of the waste materials helps assess their potential impact on the overall energy density of the asphalt mixture. The quantity of waste materials (face mask and saline tube) incorporated into the asphalt mixture affects the energy density.

The presence of face mask and saline tube waste within the asphalt mixture can influence the particle packing and interlocking and properly crushed saline tubes used as an aggregate, can help fill voids and improve the overall particle packing. This leads to increased interlocking between particles, resulting in a denser mixture with improved energy density.

5.Discussion

The use of COVID-19 SFM and saline tubes has increased significantly during the pandemic, and their disposal presents environmental challenges. It is important to consider the potential effects of incorporating these waste materials into asphalt mixes, particularly in terms of stability and sustainability. Incorporating waste materials like face masks and saline tubes into asphalt mixes can potentially affect the stability of the pavement. These materials may have different physical properties compared to traditional asphalt constituents, such as aggregates and binders. The presence of foreign materials can impact the cohesive properties and overall strength of the mix. This research evaluated their effects on Marshall stability, flow value, RSI spectroscopy index, energy density, and other relevant performance indicators. The incorporation of COVID-19 waste materials into the asphalt mixer (mix 2) is very potential sustainability benefits, higher stability factor compared to other mix. This research concluded that 1.25% shredded face mask and 1% Saline tube attained a higher load carrying and stability factors is higher compared to other mixes. The inclusion of these materials can enhance the particle packing and improve the overall stability and strength of the asphalt. The fillers or aggregates can help fill voids, improve interlocking between particles, and contribute to the overall compactness of the mixture. The use of saline tubes in flexible pavement can improve the pavement's ability to withstand traffic loads, reduce noise levels, and enhance its resistance to cracking and rutting. The Saline tube can also act as a binder modifier, improving the adhesion between the asphalt binder and the aggregate.

Utilizing waste materials like face masks and saline tubes in asphalt mixes can divert them from landfills or incineration, contributing to waste reduction and promoting a circular economy approach. By incorporating waste materials into asphalt mixes, there is potential to reduce the consumption of virgin materials such as aggregates and binders, conserving natural resources and reducing the environmental impact associated with their extraction and processing. Incorporating waste materials with lower carbon footprints, such as biodegradable face masks, can contribute to lowering the overall carbon footprint of the asphalt mix. Assessing the potential environmental impact of incorporating COVID-19 waste materials into asphalt mixes requires comprehensive studies. This includes evaluating any potential leaching of contaminants, the long-term behavior of the waste materials within the pavement, and the overall sustainability and life cycle analysis of the mix.

Appendix I shows the complete list of abbreviations.

Study limitations

When considering the effect on the stability of asphalt using COVID-19 SFM and saline tube waste, it is important to acknowledge some limitations that may arise in conducting such a study. COVID-19 face masks and saline tubes can come in different compositions and materials, depending on the manufacturing processes and regulations in different regions. The variability in waste characteristics, such as particle size, chemical composition, and degradation properties, can influence their performance and behavior when incorporated into asphalt mixes.

It is important to approach the incorporation of COVID-19 face masks and saline tubes into asphalt mixes with caution and conduct further research, testing, and monitoring to fully understand their impact on mix stability and long-term performance. Collaboration among researchers, waste management experts, and regulatory bodies is crucial to address these limitations and develop robust guidelines for sustainable and effective use of these waste materials in asphalt pavement construction.

6.Conclusion and future work

Population growth, industrialization, and technological development have led to an unmanageable buildup of waste, requiring environmental engineers to utilize waste materials. Replacing 1.25% shredded face mask and 1% saline tube in aggregate enhances the performance of flexible pavement construction. Among various mix proportions, the asphalt mix 1.25F1S exhibits the highest flow value, indicating superior performance. The incorporation of 1.25% SFM and 1% ST resulted in improved stiffness of the asphalt. This enhancement can be attributed to the fact that excessive waste inclusion reduces strength and stability. In the design of flexible pavement, shredded face mask and saline tube serve as effective blending materials. The aggregate sample with a 1.25% replacement ratio exhibits higher stability compared to the conventional specimen. The aggregate sample specimen with a 2% shredded face mask and 2.5 percent Saline tube replacement has a higher flow value than the specimen. The use of COVID-19 SFM and saline tubes in asphalt mixes can have both stability and sustainability implications. Thorough research, testing, and evaluation are crucial to assess the compatibility, performance, and environmental impact of these waste materials. By considering these factors and implementing proper quality control measures, it is possible to achieve a balance between stability, sustainability, and effective waste management in asphalt pavement construction. This project aims to reduce the amount of aggregate and bitumen used in flexible pavement construction, as well as the waste disposal's environmental impact. The adoption of cutting-edge technology has not only fortified the road but has also increased its life expectancy, as well as helping to enhance the environment and generate revenue.

Future research can leverage the findings of this study on face masks and saline tube binders to explore their application in asphalt concrete mixtures using different blending methods. This research aims to assess their ability to withstand and perform effectively in real-world field conditions. By conducting such investigations, we can gain valuable insights into the survivability and durability of these waste materials as alternative binders, thereby advancing sustainable practices in asphalt pavement construction.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Author's contribution statement

Ananthakumar Ayyadurai: Conceptualization, methodology, investigation, and writing - original draft, derive the numerical analysis, writing - review & editing. **Saravanan M M and Devi M:** Supervision, investigation, analysis, and correction.

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Appendix I

S. No.	Abbreviation	Description
1	CRMA	Crumb Rubber Modified Asphalt
2	DMM	Disposable Medical Masks
3	ESEM	Environmental Scanning Electron Microscope
4	FHWA	Federal Highway Administration
5	GAWLP	Grafting-activated Waste Leather Powder
6	GLCM	Gray-Level Co-Occurrence Matrix
7	HMA	Hot Asphalt Mixtures
8	IRC	Indian Road Congress
9	M-Sand	Manufactured Sand
10	PET	Polyethylene Terephthalate
11	PPE	Personal Protective Equipment
12	PVC	Polyvinyl Chloride
13	RCA	Recycled Concrete Aggregates
14	RSI	Rutting Stability Index
15	SBS	Styrene-Butadiene-Styrene
16	SCA	Silane Coupling Agent
17	SEM	Scanning Electron Microscope
18	SFM	Single-Use Face Masks
19	WGPs	Waste Glass Powders
20	WMA	Warm Mix Asphalt