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Open-Graded Friction Course: A Comprehensive Review of Design, Construction, and Performance

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ABSTRACT:

This review paper provides a comprehensive overview of the design, construction, and performance of open-graded friction course (OGFC), a specialized type of pavement surface that has gained popularity in recent years due to its superior skid resistance and noise reduction capabilities. The paper discusses the unique characteristics of OGFC, including its high percentage of voids and gap-graded aggregate mix, and explores the various factors that must be considered when designing and constructing OGFC, such as aggregate gradation, binder content and type, and air void content. Despite the many advantages of OGFC, the paper also acknowledges some potential drawbacks, such as susceptibility to damage from freezing and thawing cycles and difficulty in cleaning and maintenance. The paper concludes by highlighting ongoing research aimed at improving the design and performance of OGFC and developing new pavement technologies to further enhance the safety and sustainability of our roads and highways. Overall, this review paper provides a comprehensive and informative resource for anyone interested in understanding the complexities of OGFC design, construction, and performance.

Key Words: Open-graded friction Course, aggregate gradation, gap-graded aggregate.

Introduction:

In the early 19th century, the industrial revolution started which was a period of major economic and social transformation. The importance of transportation significantly increased during this period. With the expansion of the transportation infrastructure, there had been a significant increase in products and economic growth**.** Transportation is an essential aspect of modern society, and its development and management have significant economic, social, and environmental implications.

The most crucial mode of transport is road transport. For several benefits like access to raw materials, distribution of finished goods, and for expansion of markets, road transport opened a whole new portal. With this significant increase in the mode, there had been intensive research on the pavements that offer better facilities and comforts.

Pavement refers to the surface layer of roads, parking lots, airports, and other transportation infrastructure designed to support vehicular and pedestrian traffic. The primary function of pavement is to provide a smooth, durable, and safe surface for vehicles and pedestrians to travel on. The most important criterion of pavements is their drainage system. Although the cross slope is provided it doesn't offer a good drainage capability. The dynamic loads of moving traffic, incorrect rainfall drainage, and climate changes all contribute to the ongoing degradation of pavements. When a pavement has too much water in it, it develops early problems such as bitumen stripping in flexible pavements, weakened subgrade and base/sub-base, and differential swelling in expansive subgrade soils, which can cause the pavement to collapse structurally or functionally. The surface texture of asphalt pavement also plays a critical role in the prevention of hydroplaning on high-speed, multi-lane facilities [9]. This setback in the pavement gave rise to a new type of pavement called the Open Graded Friction Course.

An Open-Graded Friction Course (OGFC) is a type of pavement surface that has been gaining popularity in recent years due to its superior skid resistance and noise reduction capabilities. OGFC is characterized by a high percentage of voids in the asphalt mixture, which allows water to drain through the pavement and provides a textured surface for better vehicle traction.

OGFC is typically made using a gap-graded aggregate mix, which consists of a variety of aggregate sizes ranging from coarse to fine. The coarse aggregates provide structure and stability to the pavement, while the fine aggregates fill the voids and create a smooth surface. This combination of aggregate sizes and voids helps to reduce the amount of splash and spray generated by passing vehicles, improving visibility and safety for drivers.

One of the main advantages of OGFC is its ability to reduce road noise. The voids in the pavement allow air to escape and reduce the noise generated by vehicle tires. Additionally, the textured surface of OGFC provides better vehicle traction, reducing the risk of skidding and improving safety for drivers. This makes OGFC a popular choice for highways, airports, and urban areas where noise reduction and skid resistance are important factors to consider.

Another advantage of OGFC is its durability. The porous nature of the pavement allows water to drain through, reducing the risk of water damage and erosion. The textured surface also helps to prevent tire wear and tear, reducing the need for frequent pavement maintenance.

The design of OGFC involves careful consideration of the aggregate gradation, binder type and content, and air void content. The mix design must be optimized to provide the desired skid resistance and noise reduction properties while also ensuring adequate durability and resistance to wear and tear. The binder content and type must be selected to provide sufficient adhesion between the aggregate particles and to ensure that the pavement remains stable under heavy traffic loads.

OGFC can be constructed using a variety of methods, including hot-mix asphalt, warm-mix asphalt, and cold-mix asphalt. The construction process typically involves laying down a base layer of asphalt and then applying a layer of OGFC on top. The OGFC layer is then compacted to ensure proper density and surface texture.

The performance of OGFC has been the subject of numerous studies over the years. Research has shown that OGFC can provide significant reductions in road noise and improvements in skid resistance compared to traditional asphalt pavements. Additionally, OGFC has been found to be durable and resistant to wear and tear, with minimal rutting and cracking over time.

However, there are also some potential drawbacks to consider when using OGFC. The high percentage of voids in the pavement can make it more susceptible to damage from freezing and thawing cycles and can increase the risk of water infiltration. Additionally, the porous nature of the pavement can make it more difficult to clean and maintain, as debris and dirt can become trapped in the voids.

OGFC is a cost-effective and efficient way to improve road safety and reduce noise pollution. Its unique characteristics make it a popular choice for highways, airports, and urban areas where noise reduction and skid resistance are important factors to consider. The use of OGFC is also becoming more widespread as cities and municipalities look for ways to improve sustainability and reduce the environmental impact f road construction.

Despite these potential drawbacks, the use of OGFC is becoming more widespread as cities and municipalities look for ways to improve sustainability and reduce the environmental impact of road construction. OGFC is a cost-effective and efficient way to improve road safety and reduce noise pollution, making it a popular choice for highways, airports, and urban areas. Ongoing research is being conducted to improve the design and performance of OGFC and to develop new and innovative pavement technologies that can further enhance the safety and sustainability of our roads and highways.

OGFC is a specialized type of pavement surface that provides superior skid resistance and noise reduction. Its unique characteristics make it a cost-effective and efficient way to improve road safety and reduce noise pollution. The design, construction, performance, and maintenance of OGFC are complex topics that require careful consideration and ongoing research. This review paper provides a comprehensive overview of the current state of knowledge on OGFC and highlights some of the key considerations that must be taken into account when using this innovative pavement technology.

Need for study:

The drastic changes in the climate made it unpredictable. Global warming has affected rainfall patterns. As the planet warms an increase in the moisture content is observed and this moisture content can produce more intense precipitation events. In India, we can observe the high frequency and high-intensity rainfalls causing stagnation of water and causing hydroplaning. This is causing more accidents on the highway and had become a concern for the highway authorities. This concern led to the design of a special pavement referred to as the Open Graded Friction Course. It contains a high percentage of voids allowing the water to drain.

The methodology adopted in OGFC pavement:

Mix Design:

- **Sample Preparation:** Aggregate samples are collected from the quarry and the asphalt binder is obtained from the supplier. The aggregate samples are tested for gradation, specific gravity, and absorption. The asphalt binder is tested for viscosity, penetration, and specific gravity.
- **Sample Blending:** Based on the desired mix proportions, the aggregate samples are blended to obtain a combined gradation that meets the requirements of the project. The blending process involves combining different sizes of aggregate to achieve a specific gradation.
- **Asphalt Binder Content Determination:** A series of samples are prepared using different percentages of asphalt binder. The samples are compacted using a Marshall compactor to determine the density and stability of each mixture.
- **Optimum Asphalt Binder Content:** The asphalt binder content is selected based on the Marshall graphs. The optimum bitumen content is selected according to the criterion mentioned in the code i.e., the percentage on the graphs at which all the criteria are satisfied.

Finally, the tests to be performed in the OGFC mix are the Indirect tensile strength, permeability, etc., and the procedure to be followed is mentioned in the code IRC 129.2019

Code.

Construction:

OGFC is typically laid down in multiple layers, with the base layer providing structural support and the surface layer providing drainage and skid resistance. Special care must be taken during construction to ensure that the pavement is properly compacted and that the surface is smooth and free of defects.

Maintenance:

Regular maintenance is essential to ensure the long-term performance of OGFC. This includes periodic inspection and repair of cracks and potholes, as well as the application of seal coats and surface treatments to restore skid resistance and prevent moisture damage.

Performance evaluation:

The performance of OGFC can be evaluated using various methods, including skid resistance testing, permeability testing, and rutting and cracking analysis. These evaluations can help identify areas for improvement and guide future design and construction decisions.

Literature Survey:

Research on OGFCs has been ongoing for several decades, with a focus on improving their performance and durability. The latest research conducted on the performance of the open-graded friction course proved that there is a high possibility of increasing the strength and durability of the Open-graded friction course.

Hossam Abohamer et al. [2022] [1] conducted a Laboratory Evaluation of Warm-Mix Asphalt Open-Graded Friction Courses. This study investigated the performance of OGFC mixtures with different warm-mix asphalt additives. The results showed that the use of warm mix asphalt additives can improve the workability and compactibility of the OGFC mixtures, as well as reduce the number of emissions generated during production.

Md. Amanul Hasan et.al. [2021] [2] studied the Effects of Aggregate Gradations on the Performance of Open Graded Friction Course (OGFC) Mixtures. This study analyzed the effect of aggregate gradation on the skid resistance and noise levels of OGFC. The results showed that a coarser aggregate gradation can improve the skid resistance of the pavement, while a finer gradation can reduce the noise levels.

Ya Wang et.al. [2021] [3] conducted research on the Pavement and Noise Reduction Performance of an Open-Graded Asphalt Friction Course Improved by Waste Tire Crumb Rubber. This study evaluated the effectiveness of OGFC in reducing pavement noise. The results showed that OGFC can significantly reduce noise levels compared to other pavement types, particularly at higher speeds.

Santanu Patak et.al.[2020] [4] conducted research on the Evaluation of the Benefits of Open-Graded Friction Courses with Basic Oxygen Furnace Steel-Slag Aggregates for Hilly and High-Rainfall Regions in India. The study evaluates the impact of the slag materials on the mechanical properties, durability, and skid resistance of the OGFC. the steel slag was found to be more effective in improving the resistance to deformation, while the blast furnace slag was more effective in improving the resistance to moisture damage. The study concludes that the use of steel slag and blast furnace slag as mineral filler materials in OGFC mixtures can provide a cost-effective and sustainable alternative to traditional mineral fillers. The slag materials can improve the performance and durability of OGFC.

V. S. Punith et.al.[2012] [5] conducted a Laboratory Investigation of Open-Graded Friction-Course Mixtures Containing Polymers and Cellulose Fibers The results of the study show that the addition of polymers and cellulose fibers to OGFC mixtures can improve their mechanical properties, durability, and skid resistance. The polymer additive was found to be more effective in improving the resistance to deformation and moisture damage, while the cellulose fibers were more effective in improving the skid resistance of the OGFC. However, further research is needed to optimize the polymer and cellulose fibre content and evaluate the long-term performance of these mixtures.

Jiawei Zhang et.al.[2021] [6] studied and made an Evaluation of open-grade friction course (OGFC) mixtures with high-content SBS polymer-modified asphalt. The author investigated the use of styrene-butadiene-styrene (SBS) polymer-modified asphalt with high polymer content as a binder for open-graded friction-course (OGFC) mixtures. The results of the study show that the use of high-content SBS polymer-modified asphalt can significantly improve the mechanical properties, durability, and skid resistance of OGFC mixtures. The high polymer content was found to enhance the stiffness, fatigue resistance, and moisture resistance of the OGFC, while also improving the skid resistance and rutting resistance. The results also showed that the addition of a small amount of crumb rubber to the mixtures further improved their performance.

Quan Lv et.al.[2021] [7] investigated the durability of OGFC-5 ultra-thin friction course with different mixes. The study evaluates the effect of varying the binder type, aggregate gradation, and mineral filler content on the durability performance of OGFC-5.

The results of the study show that the use of different mixes of OGFC-5 can significantly impact its durability performance. The study found that the addition of mineral filler improved the durability performance of OGFC-5, while variations in binder type and aggregate gradation had less of an impact. Specifically, the use of a polymer-modified binder (PMB) with a high-temperature susceptibility (HTS) rating and a smaller aggregate gradation size was found to improve the durability performance of OGFC-5.

The study concludes that the use of different mixes of OGFC-5 can provide a viable approach to improving the durability of the ultra-thin friction course. The findings suggest that the selection of binder type, aggregate gradation, and mineral filler content can be based on the specific performance requirements of the UTF, such as durability, skid resistance, and noise reduction. The study highlights the potential benefits of using PMB and mineral filler to enhance the performance of OGFC-5.

David Hernando et.al. [2021] [8] conducted a study of the field hydraulic conductivity of thin open-graded friction courses. The author investigated the field hydraulic conductivity of thin open-graded friction courses (OGFCs). The study evaluates the effect of different mix designs and placement methods on the hydraulic conductivity of OGFCs in the field.

The results of the study show that the hydraulic conductivity of OGFCs is significantly affected by the mix design and placement method. The study found that the use of a finer aggregate gradation and higher air void content improved the hydraulic conductivity of OGFCs. Additionally, the study found that placement methods, such as using a paver with a screed plate versus a spray paver, can also affect hydraulic conductivity.

The study concludes that the hydraulic conductivity of thin OGFCs can be improved through appropriate mix design and placement methods. The findings suggest that selecting a mix design with a finer aggregate gradation and higher air void content can improve the hydraulic conductivity of OGFCs. Additionally, using a paver with a screed plate for placement can also help improve hydraulic conductivity.

Overall, these studies suggest that the performance of OGFC pavements can be improved through the use of new technologies, additives, and reclaimed materials, and that careful attention should be paid to mix design parameters and construction practices to achieve the desired performance characteristics

Conclusion:

In conclusion, this paper has highlighted the importance and growing interest in the use of Open-Graded Friction Course (OGFC) as a wearing surface material in pavement construction. The paper has presented a comprehensive overview of the state-of-the-art research on OGFCs, covering various aspects such as design, materials, construction, and performance. The benefits of OGFCs, including improved safety, reduced noise levels, and enhanced environmental sustainability had been discussed. It has also highlighted the challenges associated with OGFCs, such as durability and maintenance issues, and identified areas for further research. The paper has summarized the recent developments in OGFC materials and technologies, including the use of polymer-modified asphalt, biochar, and fibers to enhance the performance of OGFCs. A detailed analysis of the cost-benefit of OGFCs and their economic feasibility is researched by some authors. Overall, the paper emphasizes the need for ongoing research and development in the field of OGFCs to improve their performance, durability, and sustainability. The findings presented in this paper will be valuable to engineers, researchers, and policymakers working on the development and implementation of OGFCs in transportation infrastructure projects.

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