Rubber Tire Environmentally Friendly Alternative to Track Oval Granules

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Abstract*— *With the increase in population, improvement in living standards, and expansion of both urban and rural areas, there has been a corresponding rise in the amount of waste generated. The adverse impact of solid and industrial wastes on the environment is a persistent concern for contemporary society, and it presents a potential hazard to future generations. Using recycling and upcycling methodologies for repurposing used tires is crucial in implementing circular economy practices. Hence, it is justifiable to enhance existing methods and explore novel approaches for the industrial use of discarded tires. This study aims to present innovative and feasible measures for waste management that prioritize sustainability and safety. The present study investigates the potential use of recycled rubber tire granules to construct rubberized track ovals. A comparative analysis of the characteristics of commercially available rubber granules and ground tire rubber accomplishes this. The compressibility and tensile properties of materials and the sustainable treatment or functionalization of waste tire rubber were considered significant. Emphasize the difficulties in utilizing waste tire rubber for potential construction and material applications.

Indexed Terms*— *Environmentally friendly, Granulated Tire Rubber, Track Oval, Universal Testing Machine.

I. INTRODUCTION

Managing used tires is a significant waste stream that requires effective and ecologically sound handling methods. Improper disposal of these items can result in environmental harm and pose potential health hazards. Hence, it is imperative to devise innovative approaches for the industrial utilization of utilized tires, ensuring their appropriate recycling or upcycling aligns with the tenets of a circular economy. The abundance of used tires and their potential to cause adverse environmental impacts when not managed appropriately present a significant challenge as a waste stream. Improper disposal of tires can result in a range of adverse consequences, such as jeopardizing public health and causing ecological deterioration. Improper disposal or landfilling of tires can lead to water accumulation, creating a conducive environment for mosquitoes to breed and spread diseases, posing a potential fire hazard.

Furthermore, as tires undergo gradual decomposition, they emit harmful compounds into the environment, exacerbating the ecosystem's damage. Developing effective and sustainable management systems for utilized tires is imperative to tackle the abovementioned issues. Recycling tire rubber as construction material necessitates the implementation of state-of-the-art methodologies that adhere to the principles of a circular economy. Let us revise our perception of tires as mere waste because they hold significant potential for repurposing as valuable resources through recycling or upcycling processes. This approach would obviate the necessity for virgin materials and result in a negligible adverse environmental impact.

Moreover, applying circular economy principles can benefit the economy and the environment in managing used tires. The domains of recycling and upcycling on utilized tires possess the capacity to enhance both employment opportunities and the economy. Adopting recycled tire products not only aids in resource conservation but also facilitates cost savings for businesses by reducing the demand for fresh materials. This study investigates the utilization of discarded rubber tire granules in manufacturing rubberized track ovals. Using rubberized track ovals presents a viable solution for repurposing recycled tire materials, owing to their inherent advantages, such as durability and versatility. Utilizing discarded tire granules for track surfaces presents a viable solution to simultaneously tackle the problem of tire waste and provide a high-performance athletic surface. We evaluate the suitability of recycled tire materials for producing rubberized track ovals. This evaluation involves comparing commercially available rubber granules with ground tire rubber. This examination evaluates both materials' qualities, composition, particle size distribution, resilience, and durability. The evaluation of the performance and durability of materials utilized in the construction of track surfaces is of interest to researchers. The examination of the tensile properties of materials is a critical component. We utilize the tensile properties of a material to quantify its ability to withstand tearing or fracturing when subjected to tension. Researchers can study the tensile strength and elasticity of tire granules to evaluate their durability and ability to withstand prolonged usage, as well as environmental factors such as fluctuations in temperature and moisture.

Furthermore, scholars can assess the shock attenuation properties of tire granules by quantifying their ability to undergo deformation when subjected to pressure. Ensuring a safe surface is crucial in mitigating the likelihood of injuries and safeguarding athletes. The findings obtained from this inquiry will aid in recognizing the capabilities of rubber tire granules as materials for Track Oval surfaces.

1.2 Objective of the Study

Compared to commercially available rubber granules, this study aims to determine whether using granulated rubber tire material as a track oval material is feasible.

The study specifically seeks to:

1. Analyze the traits and qualities of the rubber granules sold in stores and the granulated rubber tire material.
2. Compare these materials' capabilities and suitability for rubberized track oval construction.
3. To evaluate the materials' robustness and durability, examine their tensile and compressibility qualities.
4. Examine the possibility of enhancing the qualities of used tire waste as a material for a track oval by sustainable treatment or functionalization.
5. Draw attention to the drawbacks and difficulties of using recycled tire rubber to build track ovals.
6. Provide analysis and suggestions for enhancing tire recycling and upcycling practices within the framework of circular economy principles.
7. Support the creation of workable, sustainable solutions for efficient waste management and environmental protection.
8. By attaining these goals, the project hopes to promote waste management tactics, circular economy practices, and the creation of more durable and resilient track surfaces.

1.3 Statement of the Problem

The escalation of population, enhancement of living standards, and expansion of both urban and rural regions have resulted in a substantial surge in the generation of solid and industrial refuse. Disposing of used tires presents a significant environmental challenge due to their improper disposal methods and the potential for environmental degradation. To effectively tackle this matter and advance the tenets of a circular economy, it is imperative to investigate recycling and upcycling methodologies for utilized tires, particularly in industrial contexts.

Nonetheless, further research is necessary to explore the feasibility and suitability of using granulated rubber tire material as a track oval material compared to commercially available rubber granules. The comprehension of the characteristics and efficacy of these substances regarding compressibility, tensile potency, and robustness to erect rubberized track ovals needs to be improved.

The present study aims to investigate the viability of employing granulated rubber tire material as a track oval material and to conduct a comparative analysis of its properties vis-à-vis those of commercially available rubber granules. Furthermore, it is imperative to investigate the compressibility and tensile characteristics of said materials and examine eco-friendly techniques for treating or functionalizing discarded tire rubber. Identifying and resolving challenges related to using waste tire rubber as a construction material for track ovals are imperative in advancing efficient waste management and ecological sustainability.

1.4 Significant of Study

The study's significance is rooted in its potential to contribute to multiple facets.

The study centers on investigating recycling and upcycling methodologies for utilized tires to mitigate environmental contamination and lessen the adverse effects of tire refuse on ecological systems. The study investigates the viability of utilizing granulated rubber tires as a track oval material, thereby advancing the cause of sustainable waste tire management and bolstering environmental conservation endeavors.

The research aligns with the tenets of a circular economy as it explores novel uses for discarded tire materials. The study's employment of waste tires for alternative purposes enhances resource efficiency, diminishes the demand for primary materials, and advances the notion of circular material usage.

Managing waste tires is a significant global challenge that requires practical solutions. The present research provides valuable perspectives on viable and enduring recycling strategies and upcycling tire rubber waste. It furnishes direction for decision-makers, waste management entities, and sectors engaged in the handling and recycling of waste tires.

The study uses granulated rubber tire material to construct rubberized track ovals in sports infrastructure. If deemed viable, this option has the potential to provide a more sustainable and economically efficient substitute for conventional track materials. The potential consequences of this phenomenon are noteworthy within the sports sector, as it may stimulate the advancement of environmentally conscious athletic surfaces and augment the general sustainability of sports infrastructure.

This study makes a valuable contribution to material science and engineering by investigating the properties and performance of granulated rubber tire material and comparing it to commercially available rubber granules. The study's results significantly contribute to understanding these materials' mechanical characteristics, compressibility, and tensile resistance, facilitating their advancement and refinement for various industrial purposes.

1.5 Scope and Limitation of the Study

This study encompasses the subsequent facets:

The present study assesses and compares granulated rubber tire material with commercially available rubber granules. This study aims to determine their suitability for employment in constructing rubberized track ovals.

The present study conducts a performance analysis of materials by evaluating their compressibility and tensile properties, intending to ascertain their resilience, durability, and appropriateness for use on track surfaces.

This study investigates prospective sustainable treatment or functionalization techniques for waste tire rubber intending to improve its characteristics as a material for track ovals.

This study compares the properties and performance of granulated rubber tire material and commercially available rubber granules to assess their advantages and limitations.

The investigation incorporates the essential criteria for tensile potency and elongation at rupture as prescribed by the International Association of Athletics Federations (IAAF) for track surfaces.

The present study has certain limitations, which we outline below:

We conducted the experimentation and analysis on a laboratory scale, which may only partially encompass the conditions and fluctuations that can arise when constructing larger-scale tracks. This study centers on using granulated rubber tire material and commercially available rubber granules as track oval materials in single-track material application. The exploration of alternative track materials and potential applications still needs to be improved.

The Environmental Assessment has limited scope as it solely focuses on the environmental implications of waste tire disposal. It needs to comprehensively evaluate the environmental effects of using granulated rubber tires throughout its life cycle as a track oval material.

The scope of the study is limited to the examination of track oval applications. It does not encompass an evaluation of the practicability or appropriateness of utilizing granulated rubber tire material for other categories of athletic or industrial surfaces.

The generalizability of the research findings and conclusions may be limited to the particular granulated rubber tire material and commercially available rubber granules utilized in the study. These findings may not universally apply to all waste tire rubber or track materials.

It is imperative to consider these constraints while interpreting the outcomes and contemplating the broader generalizability of the discoveries.

1.6 Framework

We are investigating using rubber tires as a sustainable substitute for track oval material. We are conducting this research within a comprehensive framework encompassing several essential components for effective implementation. The framework above offers a methodical methodology for conducting research, which guarantees a comprehensive exploration of the topic at hand. The study's framework comprises essential elements, which are:

The primary aim of this study is to evaluate the feasibility and potential consequences of utilizing rubber tire material as a sustainable substitute for traditional track oval surfaces. The research objective is a fundamental basis for the methodology and data collection, guiding the entire research process.

A literature review thoroughly examines existing scholarly works to ascertain the present understanding of a particular subject matter. This stage facilitates the identification of lacunae in research, comprehension of prior discoveries, and assessment of the potential impact of the research on the field.

The material selection and preparation process involve carefully identifying and curating appropriate rubber tire samples deemed suitable for subsequent testing procedures. The process entails the acquisition of discarded rubber tires followed by their transformation into the intended configuration for assessment. The selection criteria consider various factors, including but not limited to the tire's composition, size, and condition.

Evaluation and Examination: The rubber tire specimens are subjected to a sequence of evaluations and examinations to gauge their mechanical characteristics, resilience, and ecological ramifications.

We evaluate the strength and elasticity of the material through tensile Testing following the ASTM D412 guidelines. Supplementary examinations may encompass impact durability assessments, environmental elements exposure, and chemical scrutiny to appraise efficacy across various circumstances.

The study places significant importance on consultation and collaboration with experts in the field, exemplified by the involvement of Dr. Leslie Diaz, as well as engagement with materials research and development facilities, such as the Materials R&D and Consulting Facilities (MRCF). The interactions above offer significant perspectives, direction, and assets to examine and affirm the material's characteristics.

Establishing a clearly defined timeline is crucial for ensuring the seamless progression of a research project through effective project management. We meticulously strategize and supervise critical project stages to uphold project efficacy, including endorsing the research title, deliberating on material specifications, sanctioning testing procedures, and disseminating outcomes.

The implications and recommendations of the study are evaluated and discussed in light of the findings and analysis. This study identifies the potential benefits, challenges, and practical applications of rubber tire material as a sustainable substitute for track oval surfaces. The paper offers suggestions for potential avenues of future research and practical approaches for implementation.

II. REVIEW OF RELATED LITERATURE

2.1 Related Literature

Because of the limitations on polycyclic aromatic hydrocarbons PAH's emission and the partial market saturation brought on by these types of facilities, the use of Granulated Tire Rubber as a filler material in artificial playgrounds or football fields may be considerably limited. Therefore, during a further study in this area, it should be taken into consideration to look for and develop other applications of Granulated Tire Rubber, including those in construction and hydro construction, asphalt pavements, anti-shock, and anti-vibration slabs, as well as other solutions (Grynkiewicz-Bylina, 2022).

Seghar et al. studied the Mechanical disintegration of waste tires as the basis for used tire recycling. Ground tire rubber (Granulated Tire Rubber) is the starting material for further applications dependent on dimensions, surface properties, and purity. The cost of grinding rubber using a knife mill is estimated to be 120 €/ton for particles of 1–3 mm in size and 300 €/ton for particles with dimensions under 0.8 mm. We characterize commercially available granulated tire rubber based on sieve analysis. However, social and environmental concerns about using Granulated Tire Rubber in artificial turf football pitches, playgrounds, or other rubber goods require more complex characteristics. Analytical protocols significantly impact the determined type and concentration of volatile compounds, so without standardization of used analytical techniques, the results of Granulated Tire Rubber analysis regarding volatile organic compounds emission profile can significantly differ between laboratories (Isayev, 2014).

Low-quality ground rubber with unknown composition can easily pass assessment based on current PAHs emission limits and expose potential users to other harmful chemicals. Searching and developing alternative applications of Granulated Tire Rubber, such as construction and hydro construction, asphalt pavements, anti-shock, and anti-vibration slabs, should be considered during further research in this field. Waste tire composition significantly impacts Granulated Tire Rubber degradation, reclaiming, or devulcanization mechanisms. Other studies suggest the degradation mechanisms of natural rubber (NR) and styrene–butadiene rubber (SBR) during light pyrolysis. Styrene–butadiene rubber tends to secondary cross-linking, making it difficult for reclaiming/devulcanization.

Garcia et al. studied the physical and chemical changes in microwave devulcanization of GRANULATED TIRE RUBBER as a function of treatment time—thermogravimetric analysis (TGA) to evaluate rubber composition, following the ASTM D6370 standards. Nadal et al. research performed comprehensive studies focused on the thermal degradation kinetics of GRANULATED TIRE RUBBER, and obtained results are summarized; GRANULATED TIRE RUBBER is composed of 7.0 0.2 wt.% of volatile compounds, 56.3 2.1 wt.% of rubbers, and 36.7 2.2 wt.% of carbon black + ash. Derivative thermogravimetry (DTG) curves indicate the presence of NR and BR. At the same time, TGA combined with other analytical techniques provides exciting information about volatile organic compounds (VOCs) emitted from Granulated Tire Rubber or Granulated Tire Rubber-based materials.

Gogol et al. investigated examples of volatile compounds that can serve as "markers" in recycling technologies for GRANULATED TIRE RUBBER. Other research studied the volatile low molecular weight compounds formed during the continuous reclaiming of ground tire rubber and found that benzothiazole showed the highest concentration among detected compounds. The literature suggests that limonene concentration is for assessing natural rubber degradation while evaluating aromatic compounds of styrene–butadiene rubber. During Granulated Tire Rubber processing and application, it is crucial to consider monitoring volatile organic compounds (VOCs) to assess the quality of Granulated Rubber-based products and their impact on the environment and human health (Formela, 2022).

2.2 Synthesis

This study illuminates commercial rubber granules and granulated tire rubber performance. This research will consider the constraints on granulated tire rubber use in particular applications due to polycyclic aromatic hydrocarbon (PAH) emissions and market saturation.

The study recommends utilizing granulated tire rubber in construction and hydro construction and incorporating it into asphalt pavements and anti-shock and anti-vibration slabs. The research supports finding new uses for waste tires and maximizing their potential in diverse industries. The research also stresses the need for granulated tire rubber properties analysis that addresses social, environmental, and health problems. The volatile chemicals emission profile and analytical protocol standardization are essential for accurate assessment and user safety.

Granulated tire rubber recycling and devulcanization depend on its composition and degradation mechanisms. The study discusses reclaiming and devulcanizing natural rubber (NR) and styrene-butadiene rubber (SBR). It recommends TGA and DTG for assessing rubber composition, volatile organic compound (VOC) emissions, and granulated tire rubber-based material quality.

This research improves our understanding of commercial rubber granules, tire performance, and applications. It stresses detailed investigation, standardization, and alternate uses in numerous industries to overcome granulated tire rubber's limitations and environmental issues. These findings can inform future studies and enhance waste tire recycling and management.

III. MATH

3.1 Research Design

The present study employs a combination of Experimental Design and Comparative analysis using Quantitative Analysis and Quantitative Analysis.

Material Selection: Select appropriate specimens of granulated rubber tire material and rubber granules that are commercially available to ensure representativeness.

The process of sample preparation involves the creation of thin sheets or samples of materials with precise dimensions and thickness.

Procedures for Testing: Performing standardized tests, such as ASTM D412 tensile tests, is recommended to evaluate the mechanical characteristics of a material. These tests can measure parameters such as tensile strength, elongation at break, and other relevant properties.

The process of gathering and recording information for research is commonly called data collection. Document and compile the experiment's outcomes, encompassing stress-strain diagrams, load-displacement figures, and other pertinent metrics.

The comparative analysis examines and evaluates two or more objects, ideas, or phenomena to identify their similarities and differences. This approach is often used in academic research to gain a deeper understanding of a particular topic or to make informed decisions based on the findings. Researchers can conclude and make recommendations based on their observations by comparing various aspects of the analyzed objects.

Conduct a quantitative analysis utilizing statistical methods to compare the mechanical properties of granulated rubber tire material with those of commercially available rubber granules. The analytical process may encompass the computation of means and standard deviations and the execution of hypothesis testing to ascertain noteworthy distinctions among the materials.

The methodology involves performing visual inspections and qualitative assessments of the materials' texture, appearance, and other visual characteristics as part of the qualitative analysis. The present analysis has the potential to offer supplementary perspectives regarding the appropriateness of the materials for utilization in track oval settings.

3.2 Data Collection Instrument

This study's primary data collection tool is a universal testing machine, a widely utilized apparatus in materials testing. The researchers utilize the Universal Testing Machine to apply controlled forces to samples and measure their response, thereby obtaining quantitative data on the mechanical properties of the samples. The instruments that are involved can be specified as follows:

The researchers outfitted the Universal Testing Machine with grips or fixtures designed to hold the specimens during the testing process securely. The method involves the application of tension to the specimens, followed by the measurement of the resultant force and displacement. The apparatus facilitates meticulous regulation of the experimental variables and furnishes precise measurements of the specimens' tensile potency, elongation at fracture, and additional mechanical attributes.

The researchers equipped the universal testing machine with a load cell that functions as a transducer, converting the applied force into an electrical signal. The load cell precisely quantifies the magnitude of the force exerted on the specimens throughout the tensile testing procedure.

The researchers equipped the universal testing machine with a displacement sensor, an extensometer, or an encoder to accurately measure the specimen's displacement during Testing. This sensor is responsible for measuring the displacement or deformation of the samples as they undergo Testing. The sensor facilitates the acquisition of information regarding the extension of the specimens, thereby enabling the determination of parameters such as strain and stress-strain curves.

The Vernier Caliper or Digital Caliper is a precision instrument utilized to measure and document sample dimensions. The provision of this data guarantees homogeneity and coherence in the preparation of samples and facilitates the computation of variables such as the cross-sectional area for stress analysis.

Utilizing documentation tools is imperative in ensuring the precise recording of data. Documentation tools utilized in recording and organizing collected data may encompass a range of options, such as data sheets, spreadsheets, or specialized software used by the Universal Testing Machine.

We conducted the laboratory testing at the Materials R&D and Consulting Facility (MRCF) of the Department of Mining, Metallurgical, and Materials Engineering at the University of the Philippines, Diliman Quezon City, Philippines.

3.3 Subject of the Study

The two types of samples that make up the subject of this study are granulated tire rubber bonded with polyurethane glue and rubber granules that are readily accessible in the market. We chose these samples to facilitate easier comparison and direct analysis of their qualities and suitability as track oval materials.

The samples of granulated tire rubber are taken from recycled tires and put through a polyurethane adhesive bonding procedure to create cohesive sheets. These examples show a creative way to recycle and repurpose used tires that align with the circular economy and sustainable waste management concepts.

On the other hand, the commercially available rubber granule sample is an example of a standard track oval material. This sample acts as a standard for comparison and a point of comparison for assessing the functionality and attributes of the samples of granulated tire rubber.

3.4 Data Gathering Procedure

The present study focuses on using refurbished tires as track oval material. We sourced the materials used in this research from vulcanizing shops or junk shops, where previously utilized rubber tires are typically discarded. The chosen tire undergoes manual processing whereby it is cut into granules of 1mm size using a sharp cutting knife. Eliminate extraneous substances such as metals, fibers, debris, and the like, and cleanse the granulated rubber tire particles. Ensuring that the granules are devoid of impurities such as dirt, dust, and other contaminants is imperative. Ensure complete drying of the object.

To create the desired mixture, combine the polyurethane adhesive and rubber granules. Blend the constituents vigorously with a mixing paddle or other appropriate implements until achieving homogeneity for a uniform mixture. Ensure uniform coating of adhesive on the rubber material.

Ensure the granules are evenly dispersed over the intended area to achieve the desired thickness before drying. Apply gentle pressure to the granules to promote optimal adhesion with the adhesive.

Use a roller or other appropriate tool to compress and smooth the granulated rubber and adhesive layers. Exert uniform pressure to guarantee the granules' secure integration into the adhesive. This procedure facilitates the sheet's compaction and eradicates any air voids.

Curing: Facilitate the process of solidification of the polyurethane adhesive by allowing it to cure. The duration of the curing process is subject to variation. However, it typically spans from a few hours to an entire night. To guarantee a robust adhesion, imperative to maintain the sheet undisturbed throughout the curing phase.

After the adhesive has completely cured, we recommend meticulously removing any excess rubber or uneven edges to achieve the desired dimensions and configuration for the thin sheet. For this purpose, it is possible to utilize a sharp-edged knife or a pair of scissors. Execute supplementary final procedures to section the sample into the specified dimensions of ASTM D412.

In the context of this study, material Testing is a crucial component.

The present study utilizes rubber tire granules obtained from recycled tires and commercially available track oval rubber granules. We recommend subjecting these materials to Testing according to the ASTM D412 standard. The ASTM D412 standard is a widely accepted and validated approach for evaluating the tensile properties of rubber substances, encompassing both vulcanized rubber and rubber compounds.

The ASTM D412 standard outlines the techniques to determine rubber materials' tensile strength, elongation at break, and elastic modulus. The Testing, as mentioned above methodology, provides a reliable basis for conducting experiments, ensuring accurate and consistent outcomes across various research facilities and undertakings.

The sample preparation process involves the creation of test specimens using granules obtained from discarded rubber tires following established standards. It may be necessary to mold or shape the granules into appropriate configurations, such as dumbbell-shaped specimens, following the dimensions and tolerances outlined in the established standard.

Following ASTM D412, the die size pertains to the cutting die dimensions employed in fabricating dumbbell-shaped specimens from rubber substances. Employing a cutting die ensures the maintenance of uniform and accurate dimensions of the specimens. The following information outlines the specifications for the size of the die cutter. It is advised by The University of the Philippines, Materials R&D and Consulting Facility (MRCF), Department of Mining, Metallurgical, and Materials Engineering at Diliman, Quezon City, Philippines, following the ASTM D412 die C dimension when preparing the specimens to ensure that the specified dimensions.

The cutting die's width is directly proportional to the intended width of the specimen at its most constricted point, also known as the neck. As previously stated, specimens with a thickness below 6.4 mm (0.25 inches) must have a width of 6.4 mm (0.25 inches). Align the width of the cutting die with the thickness of the material when working with materials that have a thickness of 6.4 mm (0.25 inches) or more.

Typically, the cutting die length exceeds the specimen's desired gauge length. The gauge length refers to the spatial separation between the grips of the apparatus employed for conducting tensile tests. For most elastomers or materials that demonstrate high elongation properties, the ASTM D412 standard prescribes a gauge length of 25.0 mm and a gauge length of 33.0 mm. Consequently, the cutting die's length must surpass the gauge length by a suitable margin to accommodate the intended specimen dimensions.

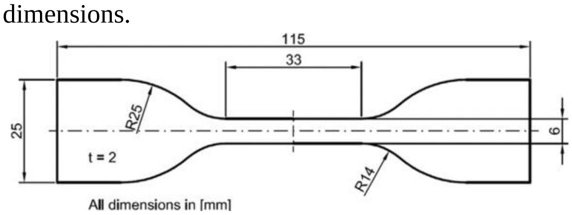

Figure 1 ASTM D412 Die C Dimension

The cutting die must possess a smooth and precise cutting edge to achieve accurate and clean specimen cuts. The die size determines the dimensions of prepared specimens, and it is imperative to maintain the prescribed dimensions to ensure uniform and comparable test outcomes. However, in this study, the research material was manually cut using a sharp cutting knife to conform to the standard dimension size of a specimen required for the ASTM D412 standard testing procedure.

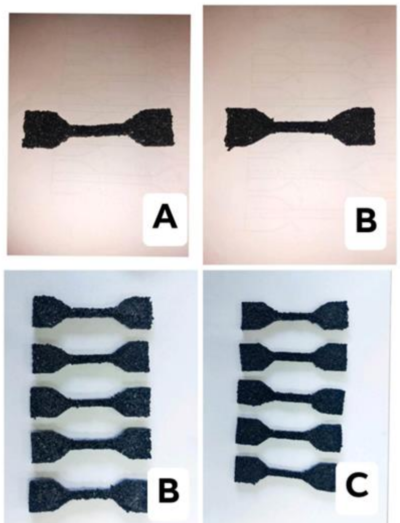

Figure 2 Actual Specimen for testing a. Granulated Rubber granules b. Commercially available rubber granules c. five pieces of Granulated Tire Rubber sample tested and c. Commercially available rubber granules sample tested.

Experimental arrangement: Following the prescribed specifications, establish the experimental setup, encompassing the universal testing machine (tensile testing machine), grips, and extensometers. It is imperative to ensure that the tools are accurately aligned and calibrated.

The experimental protocol involves the application of a controlled tensile load on the specimen under investigation until it reaches its breaking point, thereby facilitating the execution of a tensile test. The experiment measures the ultimate tensile strength and elongation at the break of the specimen, along with the required force for its elongation. During the testing process, the apparatus records load and displacement data. The standard testing procedure utilized in this study is ASTM D412. The rate of grip separation, commonly referred to as testing speed, pertains to the velocity at which the grips of the tensile testing apparatus undergo separation while conducting the test. The prescribed norm suggests a range of testing velocities that are advisable. However, the precise velocity may fluctuate contingent on the substance under examination and any prerequisites of the testing methodology.

As per the guidelines outlined in ASTM D412, researchers generally consider the optimal speed for separating grips to be 500 mm/min (20 in/min). This velocity is frequently employed to evaluate a diverse array of rubber substances. Notably, the standard provides provisions for alternative testing velocities falling within the 50 to 500 mm/min (2 to 20 in/min) range, subject to mutual agreement among all relevant parties. However, in this research, the agreed speed for the test is identified as 500mm/min.

The velocity of Testing is a significant parameter that can impact the mechanical characteristics and conduct of the rubber substance throughout the examination. Maintaining a consistent testing speed during the entire test is crucial to guarantee dependable and comparable outcomes.

We will use the mentioned data to calculate various tensile characteristics, including tensile strength, elongation at fracture, and modulus of elasticity. Researchers will utilize the mentioned data to calculate various tensile characteristics, including tensile strength, elongation at fracture, and modulus of elasticity.

The collected data shall be analyzed using the proper calculations and formulas stipulated in the ASTM D412 standard for data analysis. The computations entail the determination of significant parameters, namely stress, strain, and Young's modulus, which offer valuable insights into the mechanical characteristics and efficacy of the evaluated rubber substances.

Young's modulus (E) is a fundamental material property that characterizes its ability to undergo deformation and elongation and is mathematically expressed as the ratio of tensile stress (σ) to tensile strain (ε). Stress can be defined as the magnitude of the force exerted on a given surface area, expressed as $\sigma = F/A$. Meanwhile, strain refers to the degree of elongation or compression per unit length, expressed as $\varepsilon = dl/l$.

$$E = \frac{\sigma}{\epsilon} = \frac{F/A}{dl/l}$$

3.5 Data Analysis

Data preprocessing for this research entails systematically arranging and preparing the gathered data from the universal testing machine. The process may encompass various techniques such as data cleansing and arranging the data collected from the testing process of specimens presented to the testing facilities.

Descriptive statistics offer a concise overview of data, facilitating comprehension of its central tendencies, variations, and distributions. Frequently employed descriptive statistics encompass mean, standard deviation, median, and range measures.

Using suitable statistical techniques, researchers can compare two distinct sample types, granulated tire rubber, and commercially available rubber granules. The process may entail the comparison of means, the execution of t-tests, or the implementation of an analysis of variance (ANOVA) to ascertain the presence of statistically significant distinctions between the samples.

Researchers can compare the evaluation of the gathered data with the minimum standards outlined by the International Association of Athletics Federations (IAAF) for both tensile strength and elongation at break. This evaluation aims to ascertain whether the specimens conform to the established criteria and whether additional enhancements are required.

Interpreting results becomes crucial in data analysis, as researchers must contextualize them within the research objectives and questions. The discussion should center on examining the results, emphasizing the research's importance, consequences, and constraints.

3.6 TIME SCHEDULE

The timeline below details the research project "Rubber Tire as Environmentally Friendly Alternative to Track Oval Material." This research investigates rubber tire material as a sustainable track oval surface. The timetable shows approval, testing arrangements, consultations, specimen submission, Testing, and results. Collaboration, standardization, and expert assistance are essential for successful research and data collection. Let us examine this crucial study's timeframe.

March 6, 2023: The "Rubber Tire as Environmentally Friendly Alternative to Track Oval Material" research project receives approval. This update marks a significant milestone in exploring sustainable options for the Track Oval surfaces.

April 13, 2023: A letter is addressed to Dr. Leslie Diaz, a respected expert in the field, seeking assistance in testing the material. Dr. Diaz's expertise and guidance will be invaluable in ensuring accurate and reliable results.

April 18, 2023: The research team forwards the request for testing the material to the Materials R&D and Consulting Facilities (MRCF), an extension arm of the Department of Mining and Metallurgical and Materials Engineering. MRCF's specialized facilities and knowledgeable staff make them an ideal partner for conducting comprehensive Testing.

April 19-24, 2023: Consultations take place to discuss the material specifications and dimension requirements. These discussions are crucial to ensure that the testing process aligns with the research objectives and the desired outcomes of the study.

April 25, 2023: The research team approves the tensile Testing of the research specimen. This testing method will provide valuable insights into the material's mechanical properties, such as strength and flexibility.
May 2, 2023: The research team conducts a final inspection of the materials to ensure their integrity before delivering them to the testing facilities at the University of the Philippines Campus Diliman in Quezon City. The careful handling of the specimens is essential to maintain the accuracy and reliability of the test results.

May 3, 2023: The research team submits the specimen for Testing, following a thorough discussion with the testing facility regarding the proper testing process. ASTM D412, a standard test method for the tensile properties of rubber, will be employed to evaluate the material's performance under tension.

May 4, 2023: An acknowledgment letter from the testing facility confirms the testing process's initiation. This communication ensures that both parties are on the same page regarding the timeline and expectations.

May 16, 2023: The testing facility sends a billing statement, signifying the completion of the testing process. The research team compiles the data and results for analysis at this milestone.

May 18, 2023: The research team receives the eagerly anticipated testing results from the facility. These findings will shed light on the material's characteristics, further advancing the understanding of rubber tires as an environmentally friendly alternative for Track Oval surfaces.

June 6, 2023: A Testing certification is prepared and sent to relevant parties. This document serves as an official confirmation of the conducted tests, their accuracy, and the quality of the research conducted.

IV. TESTING AND RESULTS

The research employs a specimen sample that undergoes Testing at the Materials Research and Development and Consulting Facility (MRCF) of the University of the Philippines. The MRCF is an extension arm of the Department of Mining, Metallurgical, and Materials Engineering in Quezon City, Philippines.

Units	mm	mm	mm
Commercially	4.7533	6.7166	33.0000
Commercially	4.1933	8.9366	33.0000
Commercially	5.4660	5.2366	33.0000
Commercially	4.6400	6.9800	33.0000
Commercially	4.5766	7.9700	33.0000
Rubber Tire - 1	6.9866	9.4766	33.0000
Rubber Tire - 2	6.7266	7.3866	33.0000
Rubber Tire - 3	6.4866	7.8100	33.0000
Rubber Tire - 4	8.2800	9.4566	33.0000
Rubber Tire - 5	7.2266	8.6366	33.0000

Table 1 Prepared Material Dimensions

Table 1 Displays the dimensions of the prepared materials.

Thickness: The commercially available rubber granules have an average thickness ranging from 4.1933 mm to 5.4660 mm, with an overall mean thickness of approximately 4.82 mm. On the other hand, rubber tire specimens have an average thickness ranging from 6.4866 mm to 8.2800 mm, with an overall mean thickness of approximately 7.31 mm. These measurements indicate that the rubber tire specimens generally have a greater thickness than the commercially available rubber granules.

Width: The commercially available rubber granules have an average width ranging from 5.2366 mm to 8.9366 mm, with an overall mean width of approximately 7.26 mm. The rubber tire specimens have an average width ranging from 7.3866 mm to 9.4766 mm, with an overall mean width of approximately 8.46 mm. These measurements suggest that the rubber tire specimens generally exhibit a greater width than the commercially available rubber granules.

Gauge Length: Both the commercially available rubber granules and the rubber tire specimens have the same gauge length of 33.0000 mm. There is no significant difference observed in this parameter between the two groups.

Based on the data analysis, the granulated tire rubber specimens generally have greater thickness and width than the commercially available rubber granules. However, both groups exhibit the same gauge length. These findings provide insights into the dimensional characteristics of the specimens and can be significant for their specific applications or further research in the field.

Name	Max_Force	Max_Disp	Max_Stress	Max_Strain
Units	kN	mm	N/mm2	%
Commercially	0.02819	12.7130	0.88290	38.5242
Commercially	0.01044	8.69600	0.27853	26.3515
Commercially	0.00763	7.25300	0.26639	21.9788
Commercially	0.01447	10.7305	0.44674	32.5167
Commercially	0.03034	13.3620	0.83189	40.4909
Rubber Tire - 1	0.05341	10.5880	0.80663	32.0849
Rubber Tire - 2	0.04119	4.79400	0.82894	14.5273
Rubber Tire - 3	0.04709	7.65400	0.92960	23.1939
Rubber Tire - 4	0.03419	5.62800	0.43662	17.0545
Rubber Tire - 5	0.05775	7.94600	0.92528	24.0788

Table 2 Gathered raw data during Testing.

Table 2 presents the raw data collected during the testing phase.

The data allows observing commercially available rubber granule and tire specimens' maximum force, displacement, stress, and strain.

Commercially Available Rubber Granules:
The upper limit of force varies between 0.00763 kN and 0.03034 kN. The range of maximum displacement spans from 7.253 mm to 13.362 mm. The stress values range from 0.26639 N/mm² to 0.88290 N/mm² at maximum. The range of maximum strain varies between 21.9788% and 40.4909%.

Granulated Tire Rubber:
The upper limit of the force varies between 0.03419 kN and 0.05775 kN. The range of maximum displacement varies between 4.794 mm and 10.588 mm. The upper limit of stress ranges from 0.43662 N/mm² to 0.92960 N/mm². The range of maximum strain observed is between 14.5273% and 32.0849%.

The values mentioned above offer valuable insights into the specimens' physical attributes. Compared to rubber tire samples, commercially available rubber granule samples typically demonstrate low values concerning maximum force, displacement, stress, and strain. The above observation indicates that rubber tire specimens exhibit superior strength and resilience when subjected to external loads.

It is imperative to acknowledge that the data presented depicts distinct measurements for every sample, thereby signifying the diversity in the physical characteristics among the specimens subjected to Testing.

SUMMARY	Max Force	Max Disp	Max Stress	Max Strain	Total
Commercial					
Count	5	5	5	5	20
Sum	0.09107	52.7545	2.70645	159.8621	215.41412
Average	0.018214	10.5509	0.54129	31.97242	10.770706
Variance	0.000108259	6.73150355	0.088674571	61.81343644	190.7171067
Rubber Tire					
Count	5	5	5	5	20
Sum	0.23363	36.61	3.92707	110.9394	151.7101
Average	0.046726	7.322	0.785414	22.18788	7.585505
Variance	8.85339E-05	5.106694	0.041088497	46.89368393	94.21222656
Total					
Count	10	10	10	10	
Sum	0.3247	89.3645	6.63352	270.8015	
Average	0.03247	8.93645	0.663352	27.08015	
Variance	0.000313278	8.157475358	0.074227065	74.90794878	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F*
Sample	101.4550541	1	101.4550541	6.725821956	0.014212549	4.149
Columns	4766.852705	3	1588.950902	105.337294	1.15272E-16	2.901
Interaction	164.1035151	3	54.7011717	3.626338233	0.023272098	2.901
Within	482.7011111	32	15.08440972			
Total	5515.112386	39				

Table 3 Anova: Two-Factor with Replication

This ANOVA table analyzed the relationship between the calculated F-value and the critical F-value (F crit) as follows:

From the sample's source of variance, the Sum of Squares (SS) value is 101.4550541. The statistical parameter, Degrees of Freedom (df), is 1. Additionally, we calculate the Mean Square (MS) to be 101.4550541 based on our analysis. The computed F-value is 6.725821956. The obtained p-value is 0.014212549. The computed F statistic is 4.149097446.

The obtained F-value of 6.725821956 surpasses the critical F-value of 4.149097446, thus implying that the variances between the groups under examination are statistically significant. The p-value (0.014212549) is observed to be less than the predetermined level of significance (α), thereby providing additional evidence in favor of rejecting the null hypothesis.

From the source of variance in the column, the sum of squares (SS) is 4766.852705. The statistical parameter, Degrees of Freedom (df), is 3. Additionally, we calculated the Mean Square (MS) to be 1588.950902 and obtained an F-value of 105.337294 through our analysis. The obtained p-value is 1.15272E-16, and the critical F value is 2.901119584.

Considering that the computed F-value of 105.337294 exceeds the F-critical value of 2.901119584, it is statistically significant. The result suggests that the variances observed among the columns are highly significant from a statistical standpoint. The statistical significance is attributed to the computed p-value of the hypothesis test (1.15272E-16), thereby providing compelling evidence to reject the null hypothesis.

The factor responsible for variation is the interaction. The value of the Sum of Squares (SS) is 164.1035151. The statistical parameter, Degrees of Freedom (df), is 3. The calculated Mean Square (MS) is 54.7011717. The statistical analysis yielded an F-value of 3.626338233, a P-value of 0.023272098, and an F-crit of 2.901119584.

The obtained F-value of 3.626338233 surpasses the critical F-value of 2.901119584, thus signifying the presence of a statistically significant interaction effect. The p-value associated with the statistical test (0.023272098) is below the predetermined significance level, indicating sufficient evidence to reject the null hypothesis.

In brief, the ANOVA table indicates that the F-values computed for the Sample, Columns, and Interaction sources of variation surpass their respective F-crit values. The data indicate the presence of statistically significant variations among the samples, columns, and an interaction effect.

Name	Max_Force	Max_Disp	Max_Stress	Max_Strain
Units	kN	mm	N/mm2	%
Commercial				
Mean	0.01821	10.5509	0.54129	31.9724
Standard Deviation	0.01040	2.59451	0.29778	7.86215
Rubber Tire				
Mean	0.04673	7.32200	0.78541	22.1879
Standard Deviation	0.00941	2.25980	0.20270	6.84790
Total Mean	0.03247	8.93645	0.66335	27.0801
Total Standard	0.01770	2.85613	0.27245	8.65494

Table 4 Mean and Standard Deviation of Test Results ASTM D412

Table 4 displays the mean and standard deviation of test results for ASTM D412.

Analyzing the provided data allows us to make the following observations regarding the maximum force, displacement, stress, and strain.

Commercially available rubber granules:
We have determined that the average maximum force is 0.01821 kilonewtons, with a corresponding standard deviation of 0.01040 kilonewtons.

We have determined that the average maximum displacement is 10.5509 mm, with a corresponding standard deviation of 2.59451 mm.

The average maximum stress is 0.54129 N/mm², with a standard deviation of 0.29778 N/mm².

The average maximum strain is 31.9724%, with a standard deviation of 7.86215%.

Granulated tire rubber:

We have determined that the average maximum force is 0.04673 kilonewtons, with a corresponding standard deviation of 0.00941 kilonewtons.

The average maximum displacement is 7.32200 mm, with a standard deviation of 2.25980 mm.

The average maximum stress is 0.78541 N/mm², with a standard deviation of 0.20270 N/mm².

We have determined that the average maximum strain is 22.1879%, with a corresponding standard deviation of 6.84790%.

Upon comparison of the two samples, it is evident that the rubber tire sample demonstrates relatively high values concerning maximum force, maximum displacement, maximum stress, and maximum strain compared to the commercial sample. The result implies that the rubber tire material exhibits superior mechanical properties in strength and resilience when subjected to external forces.

Notably, the total mean and standard deviation values denote the comprehensive average and variability encompassing commercial and rubber tire specimens. The results mentioned above offer valuable knowledge regarding the properties and conduct of the substances during the experimental circumstances, emphasizing the probable variations in efficacy between the Commercially available rubber granule and granulated rubber tire specimens.

Name	Max_Stress	Max_Strain	Modulus of Elasticity
Units	N/mm2	%	N/mm2
Commercial			
Mean	0.54129	31.9724	0.016929915
Rubber Tire			
Mean	0.78541	22.1879	0.035398122

Table 5 Modulus of Elasticity

The parameters under consideration are Max Stress, Max Strain, and Modulus of Elasticity. Table 5 displays the values of the modulus of elasticity.

The modulus of elasticity is a significant characteristic that quantifies the rigidity and resilience of a substance. The provided data indicates that the modulus of elasticity for the commercial sample is

0.016929915 N/mm², whereas, for the rubber tire sample, it is 0.035398122 N/mm².

The data indicate that the modulus of elasticity of the rubber tire material is greater than that of the commercial sample. A greater modulus of elasticity signifies that the rubber tire substance exhibits increased resistance to deformation under the influence of external stress. This observation implies that the rubber tire material exhibits higher stiffness and resilience, enabling it to recover its initial shape following deformation.

A greater modulus of elasticity can be beneficial in specific scenarios where structural integrity and rigidity are crucial. The computed data suggests that the substance can endure higher levels of force and retain its structural integrity when subjected to pressure. It is imperative to consider the precise demands of the application to ascertain whether a higher or lower modulus of elasticity is preferable.

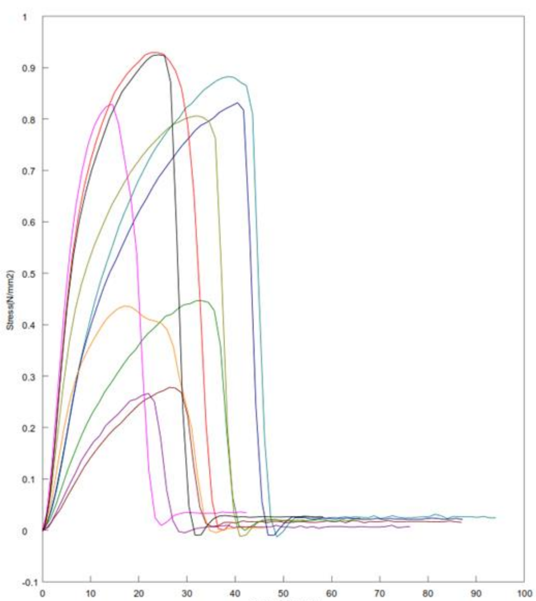

Table 6 Modulus of Elasticity graph

The graph presented in Table 6 depicts the Modulus of Elasticity.

A track surface's performance and durability evaluation necessitate the critical inclusion of tensile Testing to determine its strength. The International Association of Athletics Federations (IAAF) has stipulated minimum criteria for tensile strength and elongation at break concerning track surfaces. The above standards guide how to guarantee the quality and safety of track systems. According to the International Association of Athletics Federations (IAAF) regulations, porous surfaces must possess a minimum tensile strength of 0.4 megapascals (MPa). In contrast, non-porous surfaces must possess a minimum tensile strength of 0.5 MPa.

Furthermore, it is necessary to ensure that all surfaces demonstrate a minimum elongation at a break of 40%. The findings in Table 4 indicate that the mean stress of rubber tire granules, at 0.78541 N/mm², exceeds the minimum requirement of 0.5 N/mm² set forth by the International Athletics Association (IAAF). Similarly, the commercial rubber granule exhibits a mean stress of 0.54129 N/mm², surpassing the IAAF's minimum requirement of 0.5 N/mm². The material's elongation percentage falls short of the IAAF's requirement of 40% of the specimen's length from a 33mm gauge length. The Rubber tire granule sample exhibits a mean displacement of 7.322mm and an elongation percentage of 22.18%. The commercially available rubber granule with a gauge length of 33mm and a mean displacement of 10.5509mm displays an elongation percentage of 31.97%.

V. SUMMARY OF FINDINGS AND CONCLUSION

- *Summary*

We conducted this research to directly compare the commercially available rubber granules used in the construction of Track Ovals with the studied Granulated Tire Rubber. We aimed to determine whether the material would meet or exceed the minimum standards set by the International Association of Athletics Federations (IAAF) for track surfaces in terms of tensile strength. Submitted for testing ten (10) specimens, five (5) each for both types of samples, to Materials R&D and Consulting Facility (MRCF) of the Department of Mining, Metallurgical, and Materials Engineering at the University of the Philippines, Diliman Quezon City.

- *Findings*

The results indicate that the granulated tire rubber samples and the commercially available rubber granules exhibit mean stress values that satisfy or surpass the minimum standards established by the International Association of Athletics Federations (IAAF) for track surfaces regarding tensile strength. The results imply that both materials demonstrate adequate strength for their designated purpose.

The elongation at break values of the granulated tire rubber samples and the commercially available rubber granules are lower than the minimum requirement stipulated by the International Association of Athletics Federations (IAAF). This statement suggests that additional enhancements may be necessary to achieve the intended elongation at break for track surfaces.

The present study compared the properties of granulated tire rubber samples and commercially available rubber granules. The results indicated no significant differences between the two materials in terms of tensile strength. In contrast to the granulated tire rubber samples, the rubber granules in the market demonstrated a more significant elongation percentage.

The viability of utilizing granulated tire rubber has Although the granulated tire rubber samples exhibit a lower elongation percentage, the results indicate that they satisfy the minimum criteria for tensile strength established by the International Association of Athletics Federations (IAAF). This suggests that utilizing granulated tire rubber as a track oval material could be a viable substitute, presenting a sustainable and economically efficient alternative for track surfaces.

- *Conclusion*

As per the findings, the granulated tire material and rubber granules available in the market exhibited tensile strengths that surpassed the minimum threshold of 0.5 N/mm2 set by the International Association of Athletics Federations (IAAF) for non-porous surfaces. The rubber granules in the market exhibited an average stress value of 0.54129 N/mm2, whereas the granulated tire material demonstrated a mean stress value of 0.78541 N/mm2, as determined by measurement. The present study concludes that both materials possess the necessary tensile strength to endure the forces prevalent in track oval applications.

The elongation at the break of the granulated tire material failed to satisfy the IAAF's prescribed minimum threshold of 40%. The elongation percentage of the granulated tire material was 22.18%, while the mean displacement and gauge length was 7.322mm and 33mm, respectively. The rubber granules available for commercially available rubber granule purposes exhibited a comparable elongation percentage of 31.97% when subjected to the same gauge length and mean displacement of 10.5509mm. Neither of the materials met the minimum elongation at break requirements set by the IAAF.

The present study suggests that the tensile strength of commercially available rubber granules and granulated tire material meets the IAAF standards. However, further enhancements are necessary to achieve the necessary elongation at break. The observed reduced levels of elongation in the examined specimens indicate a possible limitation in the material's ability to withstand deformation and prevent premature failure in challenging conditions.

Despite the potential of granulated tire material as a suitable material for track ovals due to its high tensile strength, further analysis and modifications are necessary to enhance its elongation properties. This recommendation necessitates the utilization of machinery that can mechanically process the rubber tire to reduce its size. Additionally, compaction or applying pressure during the drying process may aid in improving the elongation qualities of the material under investigation. To comply with the elongation-at-break standards set by the International Association of Athletics Federations (IAAF), future research endeavors should prioritize enhancing the pliability and extensibility of the granulated tire substance.

Using granulated tire material exhibits promise to address the limitations of constructing track ovals. It may lead to developing a durable and practical solution through material enhancements. Using used tires offers advantages such as supporting the principles of a circular economy and meeting the necessary standards for track surface strength. Further investigation and advancements in the material formulation and processing techniques are necessary to fully harness the capabilities of granulated tire material as a track oval material.

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