



# International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



**Impact Factor: 9.935**

**Volume 15, Issue 5, May 2026**

# An Exploratory Search for Optimum Use of Natural / Waste Rubber Products in Roads: A Case Study with Alluvial Soil of Gorakhpur District in Uttar Pradesh

Ajai Kumar Rai, Dr. Brajesh Mishra

Assistant Professor, Department of Civil Engineering, ITM, GIDA, Gorakhpur, UP, India

Senior Engineer, UPSSCL, Lucknow, U.P. India

**ABSTRACT:** The development of new roads in developing countries like India is an ongoing process to meet the requirements of an increasing population, which subsequently increases vehicular traffic. Almost all vehicles moving on roads contact the road surface in the form of a rubber tire, which produces wear and tear on the road as well as on tires. As a consequence of it, a large no of scrap tires, i.e. about twenty percent of tires produced in a year, are being generated as waste lying in the landfills or stockpiles. As these tires are not biodegradable, the presence of these waste and worn-out tires in landfill/stock piles poses not only an environmental threat but also generates adverse conditions for human health of the surrounding population in the form of leaching toxic chemicals in the surrounding, breeding ground for mosquitoes and fuel for fire that cannot be stopped or extinguished. This paper is an attempt through experimental investigation with alluvial soil of Gorakhpur District mixed with various percentages of rubber shredding or powder in context to road embankment soil quality improvement or sub grade specific to Indian Conditions for finding the optimal percentage.

**KEYWORDS:** Rubber Latex, Gorakhpur, Rubberized Roads, Crumb Rubber, Composite Soil Tests

## I. INTRODUCTION

One of the most important industrial fields, i.e., vehicle manufacturing, which utilizes rubber for the manufacturing of tires and other parts as a prime ingredient, but after completing its life cycle, the generation of worn-out/scrap tires recycling / disposal is problematic due to fuel production of low quality / high cost as compared to petroleum products and regarded as hazardous waste in the context to environmental pollution. Last two decades researches on the use of rubber as modified bitumen /asphalt and as concrete mixes (partial replacement of coarse or fine aggregate) for enhancing the characteristics of concrete in context to durability, ductility, sound absorption and energy dissipation resulted global adoption of rubber use in road construction but limited to technologically advanced countries and proves insufficient to resolve the problem or complete and safe disposal of waste tyres. The present study is concentrated on the literature survey, experimental analysis, and review in context to optimize the use of rubber tire waste as a reinforcing or mixing material for the subgrade of roads or ground improvement to solve the problem of waste tire disposal and find a vital material for all components of the road.

### 1.1-Selection of Site:

The selected site for the collection of soil samples covers the whole area of Gorakhpur District, having its boundary districts, i.e., Kushinagar and Deoria in east, Santkabir nagar in west, Siddharth Nagar and Maharajganj in the north, and Ambedkar Nagar, Azamgarh & Mau in the south, situated at the confluence of Rapti and Rohin rivers originating from Nepal, is famous for its pleasant climate due to its location features, i.e., the foothills of the Himalayan hill range, which ultimately made it presently the second largest city of Eastern Uttar Pradesh after Varanasi. Being the head Quarter of NE railway, passing two national highways NH-28(new NH-27) and NH-29 and wide area road network connected to almost all parts of the country even the international boundary with Nepal, Gorakhpur deserves for the capital of Eastern Uttar Pradesh if a new state is formed partly from UP and partly from Bihar due to locational features in between Patna and Lucknow the capital cities of Bihar and UP almost at equal distance in East & West while connected with road network with Nepal border distant 100 Km in North and approx.225 km south of Varanasi, the city

of cultural and religious importance, As far as topographical features are concerned, the city's low-lying elevation between Goddhoiya Nala and RamgarhTaal, and along/between Goddhoiya Nala and Rapti River covering the southern half of the city acts as natural drainage for the disposal of the surface water far from the city through interconnected nalah to Ghaghara River. The plain topographical area with a gentle slope from north(elevation 95m) to south (elevation 75m) of Gorakhpur District, except for a narrow strip area with an average elevation of about 90 m along the railway line, is a characteristic feature in the context of economic design of sewers/wastewater disposal.

Keeping in view the wide coverage of clayey soil /loamy soil, about eighty percent of the district area, excluding standing/flowing water bodies and large coverage forest areas of Kusumhi&Jungle Kauriya, all the seven tehsil headquarters, which are apart by an average distance of 27 Km to each other were selected for obtaining the true representative soil samples of the area as follows shown in figure 1 Paper is organized as follows. Section II describes automatic text detection using morphological operations, connected component analysis and set of selection or rejection criteria. The flow diagram represents the step of the algorithm. After detection of text, how text region is filled using an inpainting technique that is given in Section III. Section IV presents experimental results showing results of images tested. Finally, Section V presents conclusion



Fig. 1-Selected Study Area (Gorakhpur) Showing Tehsils & Surrounding Districts

## II. LITERATURE SURVEY

Rubber use as most versatile construction material is gaining wide adoption all over the world due to resistance of highly graded rubber against fire, weather and ultraviolet rays on one hand while flexibility, movement, vibration and stress absorption characteristics on the other hand. The journey of rubberized road from concept to reality in the form of sustainable and roads started in late 20th century from Arizona as testing ground with the experimentation of adding of scrap tires (ground up) into asphalt by an engineer of Arizona Transport Department named Charles McDonald to obtain the practical solution of mounting problem of tire waste and improvement of quality of paved surfaces simultaneously. The positive experience of Arizona were noticed and supported in 1991 by US Congress in the form of Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 to use recycled rubber tire waste in road construction, which boosted up and developed as well recognized practice of not only in the states of US but also in many other countries such as Brazil, China, Germany, Spain and many other countries to its specific needs and conditions resulting in durable, safe and long life roads along with reduced repairs/maintenance cost, noise and landfill waste. However, some problems still exist for the adoptability of rubber roads at the global level and solution of these problems given by the researchers/engineers/practitioners all over the world made the global adoption of rubberized road specially in the developed countries in the form of rubberized asphalt

**2.1-Use of Rubber Latex As Bitumen or Asphalt Modifier:**

Natural rubber, which in pure form known as chemical polyisoprenes derived from milky latex found in the sap of plants. performance as superior reactivity with bitumen in context to improvement in cohesion with coarse aggregate(stone grit/ballast/chips) and adhesive property of bitumen resulting the stiffness of the bitumen at high temperature as compared with the other form of rubber use as additive to modify bitumen was first applied in Singapore in 1929 and recognized /widely adopted as most common thermoplastic elastomeric at global level specially in United States, South Africa and United Kingdom as it acts as preventer in the formation of cracks through maintaining the stiffness of asphalt surfaces at cold weather while acts as bitumen shear resistance improver through formation of filmy layer in turn preventing bitumen flow in case of temperature increase ultimately resulting the enhancement in the life span and reducing maintenance cost/formation of ruts/wear and tear of the asphalt surfaces. Most commonly used rubber latex form is highly concentrated dry natural rubber of about average 80 percent concentration ranging from 60-100 percent obtained through centrifugation treated with ammonia to avoid bacteria attack due to quality of latex dependency on quantity of latex content and direct use of raw natural rubber latex adverse effects by its higher water content/susceptibility to bacteria attack/variable composition or density governed by several factors such as age of tree, season, soil condition tapping method and frequency of tapping. Most critical identified problems and solutions during the development of rubber asphalt and adoptability as road construction material are summarized as follows in table-1

**Table 1 - Problems and possible solution for adoptability of Rubberized Road**

| S.No. | Particulars  | Identified Problems   | Possible Solutions   |
|-------|--|---|--|
| 1     | <b>Lacking of Uniformity in Segregation &amp; Distribution</b> | Rubber material bonding with aggregate/bitumen were not upto marks and lack of uniformity in context to distribution and segregation of rubber material were observed in normal temperature / working conditions during the incorporation of rubber material use either as aggregate or as bitumen modifier in the first half of nineteenth century.  | This problem was recognized as process or equipment limitation and attempts to develop process / equipment with metering, pumping and agitation of highly viscous fluids lead to Asphalt Rubber placement or distributed lorries (Band-Aid Type) using as a diluents (kerosene) after approx.25 years i.e.in year 1972   |
| 2     | <b>Survival in Too Hot / Too Cold Situation Or Location</b>    | Asphalt rubber loses its specific characteristics required as binding with aggregate due to change in the state liquid in too hot / high temperature and stiff in in too cold/low temperature resulting in break of bonding with aggregates and development of cracks.  | Mix design suiting to local climate conditions i.e. the quantity of crumb rubber as per grade of the asphalt and optimal temperature range are the key factors to obtain performance as per expectation. Mixing of rubber in asphalt at plant level gives uniform mixture  |
| 3     | <b>Depositing in Separate Bottom Portion</b>                   | Additional equipment/energy for constant stirring of asphalt rubber mixture in the storage tank before application is required to avoid the rubber ingredient settling.   | An agitator equipped storage tank ensures the free and fluent flow of mixture uniform and lying of recent rubber road pavement in band-aid form is taking place.   |
| 4     | <b>Implementation Problem</b>                                  | The application of rubber as a road material right from the preparation and rubber ingredient mixing with bitumen or concrete requirement of higher temperature or controlled climatic conditions creates complexity in terms of laying and compaction as compared to traditional asphalt or concrete constructed road. The problems were considered as equipment limitation and specific equipments were developed . | Recent advancement in technology has made the process of implementation as easy and adoptable through development of specific equipment, logical planning and training to the workers. Now a days, rubber roads are preferred and widely adopted road in developing countries due to lesser traffic efforts of vehicles wear and tear reduction of both vehicle as well as road and above all reduced maintenance and enhanced safety/life span. |

**2.2 -Different forms of Rubberized Product (Waste Tire) Used in Road Construction:**

The waste tire in different forms is used in almost all components of roads of both types of roads whether it is a concrete/rigid pavement or traditional bituminous pavement as per requirement of the different sizes/forms of the rubber suiting to the other materials or site. These forms may be crumb rubber, tire chips, rubber shedding, granules, powder identification given to recycled rubber on the basis of the produced sizes and characteristic features suiting to the application or use.

**2.2.1-Bitumen/Asphalt Modifier:**

Previous researches in this context reveals that optimum mixing of 18 percent waste rubber product of the binding material(bitumen in the form of crumb rubber) provides a better performance in context to durable and finished surface with reduced cracking/maintenance.

**2.2.2-Aggregate in Concrete/Bituminous Concrete:**As decrease in mechanical strength of concrete range one-third to two third for six to twenty four percent rubber fine aggregate content and maximum rubber aggregate content in aggregate permissible is twenty percent ,nine percent as fine aggregate and twelve percent as coarse aggregate replacement is possible as the ductility, impact and fatigue resistance of rubberised concrete were found better than the normal concrete in past researches.

**2.2.3-Aggregates in Base /Sub Base Course:**Direct utilization of low processed tires in the form of scrap tires, completely buried tires and tire tied bales requires fewer resources and less energy than use of recycled tire as rubber shredding/crumb rubber / powder form and past researches indicate that low process tires in burial forms have greater potential to use as structure layer due to negligible or no adverse effect/impact on environmental health. The tire reinforced structural layer though have the higher initial sensitivity but more recovery from deformation as compared to the traditional material used in base course /sub base course due to hyper elastic nature of rubber material enables it to control permanent deformation ultimately leading to better performance and enhanced durability of the layer under dynamic condition. For placing/incorporating the tires into the base layer four categories i.e.fulltire,half tire ,one-third tire and one fourth tire arranged in alternate layers starting from either full tire or one third tire maintaining the spacing between tires as 1.5 to 2 times diameter of the tires used for uniform distribution of load. The past research findings in this context suggest that though the tire-reinforced structure exhibits greater initial sensitivity to load application, the hyperelastic nature of the rubber material enables it to recover more effectively from deformation. This enhanced resilience ultimately leads to a reduction in permanent deformation, highlighting the potential benefits of incorporating tires into pavement structures for improved durability and performance under dynamic loading conditions.

**III. METHODOLOGY**

After defining and identification of the problem, research methodology in the form of survey analysis was designed to cover the use of rubber latex /waste tire rubber as modifier of bitumen or asphalt performance and as partial replacement of road aggregates through secondary data of previous researches keeping in view much researches conversion in widely adopted practices through standardization of processes /procedures based on previous researches in developed countries such as various states of United States, European &African Countries etc. The most important part of the road sub grade / embankment, which is responsible for road failure / maintenance frequency, stabilization experimental investigation through use of cement coated rubber tire shredding /powder was considered as supportive part of this review as waste tire rubber most environmental adverse effect originates with its stockpiling/haphazard disposal in landfills and cement acts as well recognized soil stabilizer/binding material. To achieve the experimental investigation objective and analysis of finding changes related to soil stabilization or characteristics due to mixing/reinforcing cement coated waste tire shredding/powder, research methodology consisting of seven steps as shown in figure 2 below :

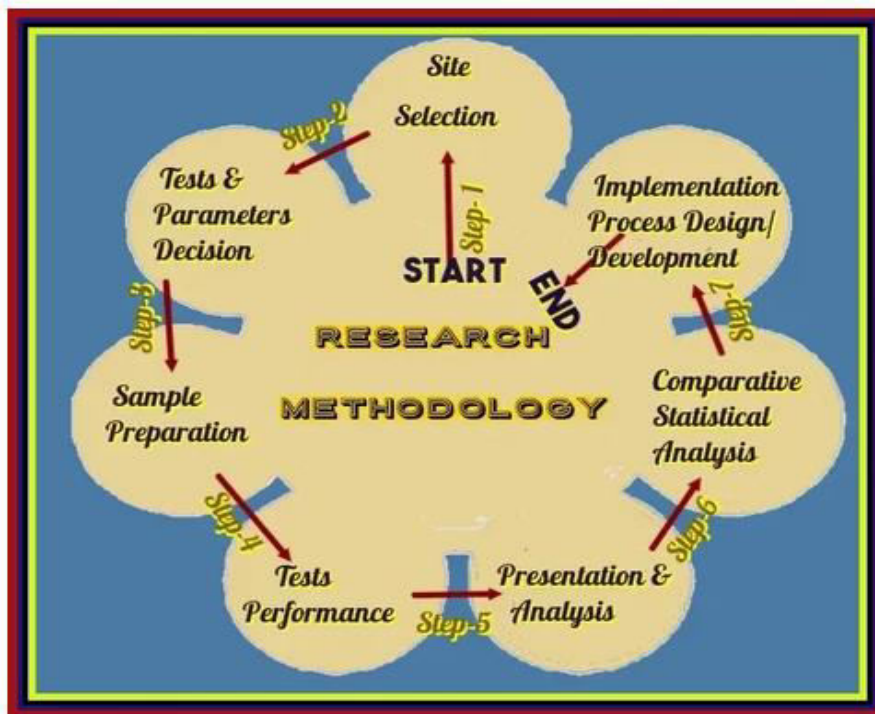


Fig.2. Experimental Research Methodology

IV. EXPEIMENTAL ANALYSIS

Further four sampling points surrounding the main sampling point (headquarter in each tehsil) covering the whole area of tehsil along with distance from tehsil headquarter (Total 35 numbers sample points)/elevation of the selected locations based on blocks, distributed area around the main sampling location and sampling point selected in the adjacent tehsil to achieve well coverage and proper distribution of area as per details provided in table 2 shown below:

Table 2-Details in Context to Sampling Point Location &Elevation

| S.No. | Centre Sampling Point                                      | Sample Points Location | Distance / Direction from Centre SP | Elevation |
|-------|--|------------------------|-------------------------------------|-----------|
| 1     | Campiereganj<br>39.0 Km(North)<br>Elevation-85m            | Chaumukha,             | 03.5 Km (South-West)                | 80.5 m    |
|       |  | Pipiganj               | 12.0 Km (South)                     | 84.0 m    |
|       |  | Thakur Nagar           | 08.0 Km (North)                     | 88.0 m    |
|       |  | Rajpur                 | 02.5 Km (East)                      | 87.5 m    |
| 2     | Gorakhpur Sadar<br>Starting Point(00.0Km)<br>Elevation-86m | Pipraich,              | 17.0 Km (North- East)               | 82.0 m    |
|       |  | Bhauapar,              | 12.0 Km (South)                     | 78.0 m    |
|       |  | Kalesar                | 09.0 Km (West)                      | 93.0 m    |
|       |  | Maniram                | 20.0 Km (North)                     | 91.0 m    |
| 3     | Chaurichaura<br>27.0 Km<br>(South East)<br>Elevation-86m   | Khorabar,              | 17.0 Km (North-West)                | 87.0 m    |
|       |  | Saradarnagar,          | 07.0 Km (North)                     | 86.0 m    |
|       |  | Brahmpur,              | 09.0 Km (South)                     | 84.5 m    |
|       |  | RampuraBujurg          | 13.0 Km (East)                      | 86.5 m    |
| 4     | Bansgaon<br>27.0 Km(South)<br>Elevation-84.3m              | Kauriram,              | 08.0 Km (South-West)                | 84.8 m    |
|       |  | Gagaha,                | 19.0 Km (South-East)                | 82.3 m    |
|       |  | Unawal,                | 13.0 Km (North-West)                | 84.8 m    |
|       |  | Malaon                 | 16.0 Km (South-West)                | 85.3 m    |

|   |   |  |  |  |
|---|---|--|--|--|
| 5 | <b>Khajni</b><br><b>24.0Km</b><br><b>(South-West)</b><br><b>Elevation-82m</b> | Sikriganj,<br>Jhudiya,<br>Ashapar,<br>Belaghat       | <b>21.0 Km</b> (South)<br><b>08.0 Km</b> (South)<br><b>06.5 Km</b> (North)<br><b>32.0 Km</b> (South)               | <b>81.0 m</b><br><b>80.5 m</b><br><b>84.5 m</b><br><b>81.0 m</b> |
| 6 | <b>Sahjanwa</b><br><b>19.0 Km (West)</b><br><b>Elevation-82m</b>              | Adilapar,<br>Anantpur,<br>Baidauli,<br>Tinahara      | <b>08.0 Km</b> (South-West)<br><b>12.0 Km</b> (South)<br><b>16.0 Km</b> (South-East)<br><b>08.0 Km</b> (South)     | <b>83.5 m</b><br><b>82.5 m</b><br><b>79.5 m</b><br><b>82.5 m</b> |
| 7 | <b>Golabazar</b><br><b>53.0 Km (South)</b><br><b>Elevation-79m</b>            | Unchagaon<br>Dhuriyapar,<br>Bharauli,<br>Bairiyakhas | <b>11.0 Km</b> (North-West)<br><b>17.0 Km</b> (North-West)<br><b>18.0 Km</b> (West)<br><b>32.0 Km</b> (North-East) | <b>79.5m</b><br><b>80.0m</b><br><b>79.5m</b><br><b>77.5m</b>     |

#### 4.1-Selected Parameters:

Besides particle size and hydrometer analysis of the soil samples, to identify sand, silt & clay percentage, taken from different tehsils of Gorakhpur District (Uttar Pradesh) as standard/control test parameter to compare the composite soil mix with different proportion of rubber shredding/powder content, acknowledgement of soil characteristic features in light of soil requirements as embankment construction material / different soil properties testing requirements, the various parameters selected were grouped in following four groups:

- General Index Properties of soil- **Specific Gravity, Toughness Index, Permeability & Compression Index**
- **Hydraulic Properties- Plasticity Index & Flow Index**
- **Compressibility – Optimum Moisture Content, Maximum Dry Density, CBR Value & Free Swell Index**
- **Shear Strength of Soil**

**4.1.1-Specific Gravity:** The first selected foremost and fundamental soil characteristic specific gravity of soil, which falls near around 2.72 (+/-0.10) with coarser soil lower specific gravity as compared to finer soil, provides a comparison of masses of soil solids and water at same volume. In other words, it is the average specific gravity of all individual soil particles content in a soil mass. As specific gravity represents porosity / void content within soil mass and soil saturation status, it is an important engineering property for the prediction of soil stability and proper drainage allowing, which plays key role in soil selection for construction and structural design of road embankments.

**4.1.2-Toughness Index:** Toughness index, which values lies in between 0 to 3, is obtained by dividing plasticity index with flow index. As plasticity index shows the status of soil stability with respect to water content and flow index is inversely proportional to shear strength of soil, hence toughness index indicates the direct relationship between shear strength and provides an estimation of shear strength at plastic limit. For the road construction soil having less than 1 toughness index is not suitable as basic characteristics of soil friability i.e. easily crushable behavior at plastic limit.

**4.1.3- Permeability:** For the better road construction and efficient /effective maintenance, the soil permeability i.e. assessment of quantity of water or fluid flowing in the locality at different times/seasons as well as within soil recognition is an essential requirement as the water plays as crucial enemy in context to road failures in the form of water rise through capillary action, soil plasticity changes due to pressure/vibration of moving vehicle and linked voids flow allowing due to change in fluid or water energy head. Its assessment provides useful information about the rate of soil settlement and drainage characteristics of soil for designing of pavement layers in ascending order from base to subgrade permeability and high level of spatial uniformity in combination with the consideration of environmental variables such as moisture, temperature, rainfall etc.

**4.1.4- Compression Index:** Compression index, which represents soil compression or consolidation ability specially in case of the clayey soil, is given due consideration for foundation stability and settlement limit calculations/design as low compression index of clayey soil index indicates stable soil and less prone to settlement as compared to soil having high compression index

**4.1.5-Plasticity Index:** In case of soil having plastic properties in the range of water content measured by the difference between liquid limit and plastic limit known as plasticity index is used to acknowledge clay and silt as high value tend to be clay, zero value little or no silt/clay and lower value silt. It is also used to assess the expansiveness

& swelling potential of soil resulting due to wetting and drying of soil due to different water/moisture availability at site. In addition to this it acts as a measure cohesive properties of clay that is responsible for binding as deficiency of clay binder may result not only the progressive disintegration of the bituminous surface due to conversion of form of soil clay particles into gravel during summer/ dry weather but also increase in permeability during rainy season or excessive water contact situation with soil.

**4.1.6-Flow Index:** Flow index as a testing parameter is based on the fact that with the increase of water content in soil the soil becomes loose i.e. shear strength of soil decreases because if the soil starts flowing its all shear strength vanishes and assumed as zero. This may also be supported by number of blows required is less at higher water content of soil. Thus flow index is an important parameter for the measuring loss of shear strength with increased soil water content. A lower flow index value indicates the slower loss rate of shear strength with increased water content in the soil and vice-versa. Both flow index and plasticity index values are responsible for adjudging the soil toughness quality.

**4.1.7-CBR Value:** The load bearing capacity and strength evaluation of road aggregate including soil is carried out through obtaining CBR value by comparison of resistance of soil through standard plunger penetration against standard crushed rock. As higher CBR value represents the harder material, this CBR value obtained in test is used in the selection of suitable material /soil for the road pavement layer for the purpose of optimized pavement layer thickness, which will be proved as cost effective through reducing initial cost (Higher CBR Value between five to seven percent considered at 2.5mm and 5mm penetration of plunger indicates strong soil allowing the lesser thickness of the pavement layer) as well as maintenance cost (Through avoidable premature failure in near future by prevention of cracking and setting of soil sub grade) as this value is a measure of sub grade bearing capacity under standard design traffic load. The soil having CBR value between 2-5 percent requires modification through replacement of the portion of the soil by good soil whereas soil having less than 2% CBR value is not suitable for the construction of road embankment as higher thickness may lead to both cost increase i.e. initial as well as maintenance cost due to soft or weak soil.

**4.1.8-Free Swell Index:** Testing/determination of free swell index of soil is necessary to identify expansive soil, which is considered as problematic soil for the use in embankment or road construction due to characteristic features of this soil of volume change in too wet condition causing upheaval and too dry condition causing cracks leading to the settlement ultimately resulting severe damage to the road even road failure. Soils having fifty percent or more volume change in too dry or too wet conditions are not suitable for use in road construction. For determination of original volume of the soil saturated with kerosene oil is used due to ability of kerosene oil to prevent the swelling of soil i.e. non-polar activity.

**4.1.9-Optimum Moisture Content:** Compaction is an essential part of any construction activity for forming a load bearing surface through ensuring the maximum possible closeness of the soil particles. As moisture in the soil works as lubrication for improving the bonding between soil particles /supportive activator in context to reduce the void space between soil particles and neither too dry nor too wet surfaces are favorable to achievement of effective compaction, optimum moisture content knowledge, which is the ideal state of moisture content obtained in the lab at which maximum dry density of particular soil is achieved, is essential. Thus optimum moisture content ensures the right density for effective compaction of soil.

**4.1.10-Maximum Dry Density:** Maximum dry density, which is the compacted dry density upto maximum possible be in context to the particular soil through the involvement of machinery and compacting equipment, is the primary requirement of each and every construction project due to certain density need of soil to support its structures. Poor compaction means the presence of more unstable void space in soil due to lying soil particles in loose stage with weak or no binding stage which will be ultimately responsible for differential settlement of structures and development of cracks and other road surface defects leading to the failure of the road. Thus effective compaction i.e. achieving of compaction in between 92 to 96 percent as per requirement of soil type and site conditions for safety and long run survival of the structure through the use of equipment and machinery at optimum moisture content has been adopted as normal and well recognized practice of construction in every civil engineering projects. For successful implementation selection of compaction comp active efforts/loads and acknowledgement of worst moisture content of soil condition at the site must be given due importance.

**4.1.11-Shear Strength of Soil:** Shear strength, the most critical mechanical property in context to soil testing, represents maximum resistance to sliding or deformation under lateral forces/stresses responsible for producing shear stresses. It consists of action of cohesive force to hold particles together, resistance capability of soil grains sliding and the pressure carried by soil particles and provides useful information/idea about safe bearing capacity of soil in context to supporting structures without excessive settlement or structural collapse/slope stability in context to landslides, earth retaining structures/soil behavior prediction in case of liquefaction or seismic event.

**4.2-Particle Size & Hydrometer Analysis:**

After identification of sampling points, soil samples from each location were collected by making pit of 1m X 1m x 1m so that true natural state soil properties can be tested as the Gorakhpur lies in the flood prone zone as almost in sixty percent of area, which covers the southern half /north west portion, flood occurs at frequency of two to three years resulting soil erosion/deposition /formation of alluvial soil and assuming adverse effect of environmental/surface moisture entry in top layer upto depth of 0.60m and loose soil formation due to result of soil erosion and deposition. For the indexing of soil, basic tests i.e. particle size analysis and hydrometer analysis were carried out and various percentage of sand, silt and clay obtained from the samples test results are tabulated as shown table 3:

**Table 3: Particle Size & Hydrometer Analysis Test Results**

| S. No | Particulars     | Sand (%) | Clay(%) | Silt (%) |
|-------|-----------------|----------|---------|----------|
| 1     | Campiereganj    | 72       | 18      | 10       |
| 2     | Gorakhpur Sadar | 22       | 67      | 11       |
| 3     | Chaurichaura    | 16       | 70      | 14       |
| 4     | Bansgaon        | 08       | 27      | 65       |
| 5     | Khajni          | 12       | 20      | 68       |
| 6     | Sahjanwa        | 15       | 65      | 20       |
| 7     | Golabazar       | 10       | 18      | 72       |

The above test results were further presented in column chart form to obtain clear cut analytical interpretation in context to sand , clay and silt proportion in soil.



Fig.3: Sand, Silt & Clay Proportions for Selected Locations

As it is evident from table and pictorial presentation of data that tehsil 1 i.e Campiereganj soil has seventy two percent sand and twenty eight percent clay, hence this may be classified as sandy clay (Sample A). As samples 2, 3 and 6 have almost same sand, silt and clay proportioning hence sample B was prepared by mixing the soil samples collected from Gorakhpur Sadar tehsil, Chaurichaura and Sahjanwa classified as Clayey soil. In the same way soil samples collected from Bansgaon, Khajni and Gola bazar were mixed and designated as Silty Clay (Sample C). Further identifying the soil of tehsil three classes of soil sandy clay, Clayey and silty clay mix prepared by proper mixing of all samples prepared were tested for soil properties related to stabilization i.e. moisture absorption, dry density, natural moisture content, consistency limits, compressibility, shear strength and permeability and California bearing ratio tests as per IS code test procedure were followed not for soil mixed samples but also with mixing of varying proportions 8%, 16%, 24% and 32% of tire shredding /waste tire rubber powder

Keeping in view the benefits of composite mix samples of true/ ideal representation of soil behavior based on test performance and easy/effective analytical reasoning or decision, composite sampling procedure were adapted for the identification of general soil characteristic of Gorakhpur district in context to road as subgrade stability and long survival. Each of the three classified samples was tested and test results are presented in tabular form as follows:

Table 4 : Test Results of Soil properties of Composite Samples

| S.No. | Particulars              | Sample A<br>(Sandy Clay) | SampleB (Clayey<br>Soil) | Sample C<br>(Silty Clay) |
|-------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1     | Specific Gravity         | 2.70                     | 2.72                     | 2.64                     |
| 2     | Plasticity Index         | 8.00                     | 30.00                    | 24.00                    |
| 3     | Flow Index               | 10.00                    | 15.00                    | 20.00                    |
| 4     | Toughness Index          | 0.80                     | 2.00                     | 1.20                     |
| 5     | Permeability             | <b>2.40 cm/hr</b>        | <b>0.08 cm/hr</b>        | <b>0.30 cm/hr</b>        |
| 6     | CBR Value                | 18.00                    | 4.00                     | 9.00                     |
| 7     | Free Swell Index         | <b>10.00 %</b>           | <b>32.00 %</b>           | <b>45.00 %</b>           |
| 8     | Shear Strength           | <b>90.00 KN/m2</b>       | <b>65 KN/m2</b>          | 85.00                    |
| 9     | Optimum Moisture Content | <b>10.00 %</b>           | <b>28.00 %</b>           | <b>26.00 %</b>           |
| 10    | Maximum Dry Density      | <b>20.00 KN/m3</b>       | <b>16 KN/m3</b>          | <b>18 KN/m3</b>          |
| 11    | Compression Index        | 0.12                     | 0.46                     | 0.18                     |

#### 4.3-Test Result Presentation & Analytical Review:

The secondary data value based on test results of each parameter were used as control sample value and composite soil mixture with rubber shedding/powder for various proportional percentage by weight were further tested to obtain the data for statistical analysis and to acknowledge the effect of waste tire rubber powder / shredding percentage as soil sub grade stabilizer. In the preparation of composite mixture the waste rubber powder and shredding mixture was mixed in ratio of 1:3 of the weight of specified percentage of the composite mixed soil weight. As automobile tires have more synthetic rubber than truck tires hence two wheeler vehicle waste tires were used to prepare the rubber shredding/powder of size in between 0.425mm to 4.75mm , which were prepared through processing in cracker mill to remove the steel chord /breed wire, heating, cooling, hammering and processing in granulator. Further the wet processing and grinding process were used to reduce the maximum size .The material passing through 4.75 mm sieve and retained on 2mm sieve were grinded to obtain the powder form. The processed material were sieved and passing through 2 m m sieve were taken for testing after separating in shredding and powdered form. The various test results of soil properties on mixed soil with proportions of two wheeler waste tire shredding / powder are shown in table 5:

Table 5: Test results of Soil properties of Composite Samples With Various Proportions of Waste Tire Rubber Shredding/Powder

| S.No. | Particulars                             | Control Sample | 8%    | 16%   | 24%   | 32%   |
|-------|---|----------------|-------|-------|-------|-------|
| 1     | Specific Gravity                        | 02.70          | 02.58 | 02.47 | 02.35 | 02.25 |
| 2     | Plasticity Index                        | 21.00          | 18.00 | 15.00 | 11.00 | 10.50 |
| 3     | Flow Index                              | 15.00          | 12.00 | 10.00 | 10.00 | 10.00 |
| 4     | Toughness Index                         | 01.40          | 01.50 | 01.50 | 01.38 | 01.42 |
| 5     | Permeability(cm/hr)                     | 01.00          | 01.08 | 01.10 | 01.14 | 01.18 |
| 6     | CBR Value                               | 10.00          | 15.00 | 22.50 | 20.00 | 18.00 |
| 7     | Free Swell Index(%)                     | 29.00          | 26.00 | 20.00 | 27.00 | 32.00 |
| 8     | Shear Strength(kN/m <sup>2</sup> )      | 80.00          | 88.00 | 90.00 | 78.00 | 82.00 |
| 9     | Optimum Moisture Content (%)            | 21.00          | 20.00 | 18.00 | 14.00 | 10.00 |
| 10    | Maximum Dry density(KN/m <sup>3</sup> ) | 18.00          | 17.50 | 17.00 | 16.50 | 16.00 |
| 11    | Compression Index                       | 00.25          | 00.24 | 00.22 | 00.20 | 00.17 |

4.3.1-General Index Properties of Soil:

The specific properties selected for the comparison through vertical column bar chart of test results i.e. specific gravity, toughness index ,permeability and compression index were grouped as the parameter tests result values lie in between 0-3 are shown in vertical column bar chart format in figure as follows:

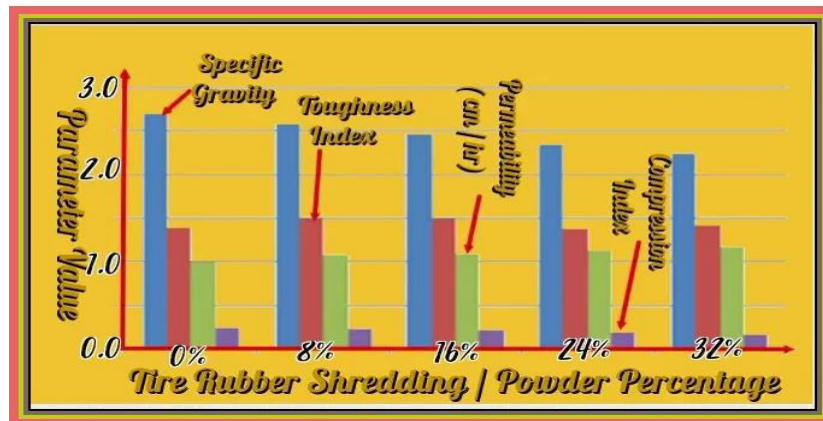


Fig. 4- Comparison of General Index Properties of Soil

As evident from the table and column bar chart that specific gravity of the composite sample decreases with the increase of proportion of rubber shredding/powder perhaps due to lower weight of rubber shredding/powder in comparison to the soil sample and higher particle size of waste tire rubber shredding than soil. It is observed that effect of mixing rubber shedding/powder in soil in context to toughness index, permeability and compression index bears almost no effect as vertical bar top level lies in almost same line and each value compared with the control value indicates a slight variation of plus/minus variation of approx. six percent.

4.3.2-Hydraulic Properties: The selected parameter presentation through line chart i.e. plasticity index and flow index based on decreasing trend and numerical value are shown in fig 5 below:

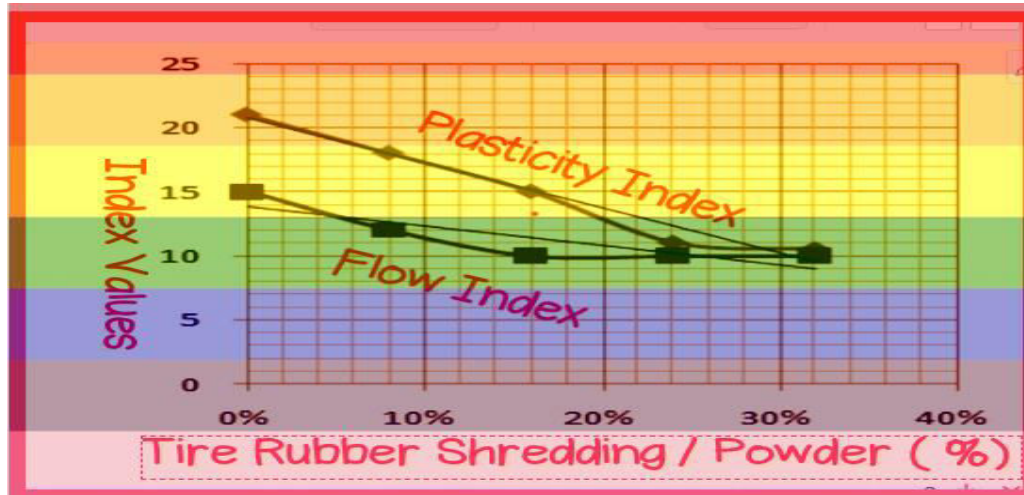


Figure 5- Comparison of Hydraulic Properties of Soil

As the liquid limit of the soil decreases with the mixing of rubber shredding and very marginal change in plastic limit depending upon soil, the plasticity index value with different proportion of rubber/soil mix shows a decrease with linear trend with almost decrease of forty five percent at thirty two percent rubber shredding/powder content in composite soil mix prepared for testing. The flow index value decreases linearly with a decrease of thirty three percent at sixteen percent of rubber shredding/powder percentage and there after the values becomes constant i.e decrease due to further increase of rubber shredding/powder percentage does not affect the flow index properties of the composite flow mix.

4.3.4-Compressibility: As compressibility characteristics of soil depends upon plasticity and water content of soil, tests for finding CBR Value, Optimum Moisture Content, Free Swell Index and Maximum Dry Density were carried out as per Indian Standard procedure for all the selected proportions of composite soil rubber shredding/powder mix ,which results are presented in figure 5 as follows:

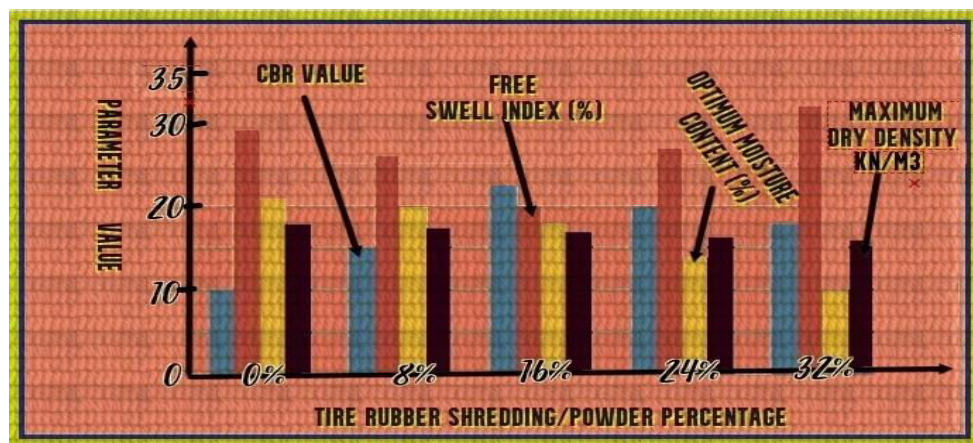


Figure 6- Comparison of Compressibility Paramters

It is observed that CBR value shows a curvilinear variation with convexity upward while swell index percentage value with concavity upward as tire rubber shredding/powder percentage increases showing maximum/minimum value at sixteen percent rubber shredding or powder content in composite soil mix. The optimum moisture content value decreases linearly twenty one percent at soil without waste tire rubber shredding mix to ten percent at thirty two percent

rubber shredding/powder mixed composite soil. Maximum dry density remains unchanged as height of the bar is almost constant showing almost slight or negligible variation

**4.3.5-Shear Strength:** The shear strength test results for various proportions of selected composite mix are graphically presented in figure 7 as follows:



Figure 7- Variation of Composite Soil Shear Strength For Different proportions

It is observed that the parabolic curve shows increasing trend followed by decreasing trend as the proportion percentage of rubber shredding / powder mix percentage increases with maximum value in between 16-24 percent rubber shredding or powder mix. This is perhaps due to larger and angular particle size of rubber shredding/powder as compared to the soil particle size, enabling large deformation before failure thus increasing flexibility up to certain limit beyond which waste tire rubber shredding / powder content in composite soil act as soil particle fundamental structure breaker due to higher percentage of it

5-Statistical Analysis: For the statistical analysis the tested soil properties were categorized in three categories based on the trend values with respect to the control sample i.e. decreasing, increasing and mixed trend values. For mixed trend values parameter toughness index, swelling index and shear strength values shows the higher values/lower values as compared to the control sample value except only one value at 24%, 32% and 24% respectively, hence mixed trend values were merged in the respective lower/higher value category ignoring the exceptional values. The categorized parameters with respective values are shown in table below:

Table 6: Higher/Lower Trend Values Parameter Compared with Control Sample

| S. No. | Particulars                  | Control Sample | 8%    | 16%   | 24%   | 32%   | 32%   |
|--------|------------------------------|----------------|-------|-------|-------|-------|-------|
| 1      | Specific Gravity             | 02.70          | 02.58 | 02.47 | 02.35 | 02.25 | 02.25 |
| 2      | Plasticity Index             | 21.00          | 18.00 | 15.00 | 11.00 | 10.50 | 10.50 |
| 3      | Flow Index                   | 15.00          | 12.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| 4      | Optimum Moisture Content (%) | 21.00          | 20.00 | 18.00 | 14.00 | 10.00 | 10.00 |
| 5      | Maximum Dry                  | 18.00          | 17.50 | 17.00 | 16.50 | 16.00 | 16.00 |

|    |   |   |   |   |   |   |       |
|----|---|---|---|---|---|---|-------|
|    | Density(KN/m3)  |   |   |   |   |   |       |
| 6  | Compression Index   | 00.25   | 00.24   | 00.22   | 00.20   | 00.17   | 00.17 |
| 7  | Free Swell Index(%)   | 29.00   | 26.00   | 20.00   | 27.00   | 32.00   | 32.00 |
|    | <b>Higher Values of Parameter as Compared to Control Sample</b> | <b>Higher Values of Parameter as Compared to Control Sample</b> | <b>Higher Values of Parameter as Compared to Control Sample</b> | <b>Higher Values of Parameter as Compared to Control Sample</b> | <b>Higher Values of Parameter as Compared to Control Sample</b> | <b>Higher Values of Parameter as Compared to Control Sample</b> |       |
| 8  | Toughness Index   | 01.40   | 01.50   | 01.50   | 01.38   | 01.42   | 01.42 |
| 9  | Permeability(cm/hr)   | 01.00   | 01.08   | 01.10   | 01.14   | 01.18   | 01.18 |
| 10 | CBR Value   | 10.00   | 15.00   | 22.50   | 20.00   | 18.00   | 18.00 |
| 11 | Shear strength (kN/m2)  | 80.00   | 88.00   | 90.00   | 78.00   | 82.00   | 82.00 |

Out of 11 parameters test result values of seven parameters values have lower values than control sample for all proportions of rubber shredding/powder mix in soil and the rest four parameters trend values are reverse of it. The percentage variation of parameters with control sample and average value were determined and tabulated in the table as follows:

**Table 7 :Percentage variation of Parameters With Control Sample and Average Value**

| Particulars / Rubber Shredding or powder mix | Percentage Variation with Control Sample Value | Percentage Variation with Control Sample Value | Percentage Variation with Control Sample Value | Percentage Variation with Control Sample Value | Percentage Variation with Average Test Value | Percentage Variation with Average Test Value | Percentage Variation with Average Test Value | Percentage Variation with Average Test Value |
|--|--|--|--|--|--|--|--|--|
| Particulars / Rubber Shredding or powder mix | 8%   | 16%  | 24%  | 32%  | 8%   | 16%  | 24%  | 32%  |
| Specific Gravity                             | 04.44  | 08.52  | 12.96  | 16.67  | 07.05  | 02.49  | 02.49  | 06.64  |
| Plasticity Index                             | 14.29  | 28.57  | 47.62  | 50.00  | 32.06  | 10.05  | 19.30  | 22.94  |
| Flow Index                                   | 20.00  | 33.33  | 33.33  | 33.33  | 14.29  | 04.76  | 04.76  | 04.76  |
| Optimum Moisture Content                     | 04.76  | 14.29  | 33.33  | 52.38  | 29.03  | 16.13  | 09.68  | 35.48  |
| Maxm Dry Density                             | 02.78  | 05.56  | 08.33  | 11.11  | 04.48  | 01.49  | 01.49  | 04.48  |
| Compression Index                            | 04.00  | 12.00  | 20.00  | 32.00  | 14.29  | 04.76  | 04.76  | 19.05  |
| Free Swell Index                             | 10.34  | 31.03  | 06.90  | -----  | 06.86  | 17.80  | 10.97  | -----  |
| Toughness Index                              | 07.14  | 07.14  | -----  | 01.43  | 02.05  | 02.05  | -----  | 03.40  |

|                |       |       |       |       |       |       |       |       |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Permeability   | 08.00 | 10.00 | 14.00 | 18.00 | 04.42 | 02.65 | 00.88 | 04.42 |
| CBR Value      | 50.00 | 125.0 | 100.0 | 80.00 | 20.55 | 19.17 | 05.93 | 04.66 |
| Shear Strength | 10.00 | 12.50 | ---   | 02.50 | 01.54 | 03.87 | ----  | 05.45 |

For each parameter the maximum, minimum, and mean values were used to determine the standard deviation / ratio of maximum and minimum values to acknowledge the variance and reliability of the data in context to obtain optimum percentage of rubber shredding /powder mix in selected soil of the study area. The data values used and determined are tabulated as follows:

**Table 8- Statistical Evaluation of Parameters**

| Parameter                | Maximum Value | Minimum Value | Mean Value | Standard Deviation | Ratio |
|--------------------------|---------------|---------------|------------|--------------------|-------|
| Specific Gravity         | 02.58         | 02.25         | 02.41      | 0.1242             | 01.15 |
| Plasticity Index         | 18.00         | 10.50         | 13.63      | 3.0695             | 01.71 |
| Flow Index               | 12.00         | 10.00         | 10.50      | 0.8660             | 01.20 |
| Optimum Moisture Content | 20.00         | 10.00         | 15.50      | 3.8406             | 02.00 |
| Maximum Dry Density      | 17.50         | 16.00         | 16.75      | 0.5590             | 01.09 |
| Compression Index        | 00.24         | 00.17         | 00.21      | 0.0259             | 01.41 |
| Free Swell Index         | 32.00         | 20.00         | 26.25      | 4.2647             | 01.60 |
| Toughness Index          | 01.50         | 01.38         | 01.45      | 0.0520             | 01.09 |
| Permeability             | 01.18         | 01.08         | 01.13      | 0.0384             | 01.09 |
| CBR Value                | 22.50         | 15.00         | 18.88      | 2.7472             | 01.50 |
| Shear Strength           | 90.00         | 78.00         | 84.50      | 4.7697             | 01.15 |

It is observed from the table that out of eleven parameters, six parameters have a standard deviation less than 1 indicating that the variation of the data from the mean is too less as compared the high deviation of three parameters optimum moisture content, free swell index and shear strength. This is perhaps either due to curvilinear variation or due to exceptional odd data not following the data trend. Based on the analysis it was concluded that optimum percentage of rubber shredding/powder mix proportion in the alluvial soil having similar characteristics of Gorakhpur District of Uttar Pradesh lies in the range 16- 24 percent and maximum dry density and shear strength parameters results favour for 20 percent rubber tire shredding/powder mix for achievement of the better strength of composite soil mix of the embankment/subgrade.

## V. CONCLUSION

- Besides use of rubber latex directly in the modification of bitumen or asphalt, the waste tire rubber shredding/ powder use prospects in different component of road as soil sub grade stabilizer, as coarse and fine aggregate in sub base/base course/top course and concrete/bituminous concrete are bright as it may constitute almost forty percent volume of the compacted road materials if used in different forms i.e. buried tires, shredding, powder, crumb rubber etc and provides better compressibility/ drainage compatibility resulting in reduced damage or material/maintenance cost with additional benefit of increased life span.
- Based on the graphical and statistical analysis it was concluded that optimum percentage of rubber shredding/powder mix proportion in the alluvial soil having similar characteristics of Gorakhpur District of Uttar Pradesh lies in the range 16- 24 percent and maximum dry density and shear strength parameters results favors for 20 percent rubber tire shredding/powder mix for achievement of the better strength of composite soil mix of the embankment/sub grade.
- As the standard procedure for use are yet to be established specially in developing countries due to high equipment cost & specific requirements, but its contribution towards the environmental pollution due to enormous waste tires will almost come to an end or the problem will be completely resolved .

## REFERENCES

1. Valentini, F.; Pegoretti, A. End-of-life options of tyres. A review. *Adv. Ind. Eng. Polym. Res.* 2022, 5, 203–213. DOI:[10.1016/j.aiepr.2022.08.006](https://doi.org/10.1016/j.aiepr.2022.08.006)
2. Duda, A.; Siwowski, T.W. Stability and Settlement Analysis of a Lightweight Embankment Filled with Waste Tyre Bales over Soft Ground. *Transp. Infrastruct. Geotech.* 2022, 9, 467–491. DOI:[10.1007/s40515-021-00184-5](https://doi.org/10.1007/s40515-021-00184-5)
3. Archibong, F.N.; Sanusi, O.M.; Médéric, P.; Hocine, N.A. An overview on the recycling of waste ground tyre rubbers in thermoplastic matrices: Effect of added fillers. *Resour. Conserv. Recycled.* 2021, 175, DOI:[10.1016/j.resconrec.2021.105894](https://doi.org/10.1016/j.resconrec.2021.105894)
4. Mendoza, A.; Guaje, J.; Enciso, C.; Beltrán, G. Mechanical behavior assessment of tire-reinforced recycled aggregates for low traffic road construction. *Transp. Geotech.* 2022, 33, DOI:[10.1016/j.trgeo.2022.100730](https://doi.org/10.1016/j.trgeo.2022.100730)
5. Anburuvel, A. Utilizing Scrap Tyre in Unbound Pavement Layers: A State-of-the-Art Review. *Int. J. Pavement Res. Technol.* 2023, 16, 1375–1392. DOI:[10.1007/s42947-022-00203-9](https://doi.org/10.1007/s42947-022-00203-9)
6. Jin, D.; Xin, K.; Yin, L.; Mohammadi, S.; Cetin, B.; You, Z. Performance of rubber modified asphalt mixture with tire-derived aggregate subgrade. *Constr. Build. Mater.* 2024, 449, DOI: [10.1016/j.conbuildmat.2024.138261](https://doi.org/10.1016/j.conbuildmat.2024.138261)
7. Duda, A.; Siwowski, T.W. Waste tyre bales in road engineering: An overview of applications. *Arch. Civ. Eng.* 2021, 67, 213–230. DOI: 10.24425/ace.2021.138052
8. Ghabchi, R.; Arshadi, A.; Zaman, M.; March, F. Technical Challenges of Utilizing Ground Tire Rubber in Asphalt Pavements in the United States. *Materials* 2021, 14 DOI: 10.3390/ma14164482.
9. Shaaban, I.G.; Rizzuto, J.P.; Elnemr, A.M.; Bohan, L.; Ahmed, H.; Tindyebwa, H. Mechanical Properties and Air Permeability of Concrete Containing Waste Tires Extracts. *J. Mater. Civ. Eng.* 2021, 33, DOI:[10.1061/\(ASCE\)MT.1943-5533.0003588](https://doi.org/10.1061/(ASCE)MT.1943-5533.0003588)
10. Gopakumar, N.; Biligiri, K.P. Can rubberized-asphalt comprising tire-derived aggregates produced through dry process be an alternative subsurface road material? *Constr. Build. Mater.* 2024, 439, 137270. [https://DOI.Org/10.1177/03611981251337668](https://doi.org/10.1177/03611981251337668)
11. Duda, A.; Kida, M.; Ziembowicz, S.; Koszelnik, P. Application of material from used car tyres in geotechnics—An environmental impact analysis. *PeerJ* 2020, 8, e9546. [https://DOI.Org/10.7717/peerj.9546](https://doi.org/10.7717/peerj.9546)
12. Duan, K.; Wang, C.; Liu, J.; Song, L.; Chen, Q.; Chen, Y. Research progress and performance evaluation of crumb-rubber-modified asphalts and their mixtures. *Constr. Build. Mater.* 2022, 361, 1296 [https:// doi.org/ 10.1016/j.conbuildmat .2022.129687](https://doi.org/10.1016/j.conbuildmat.2022.129687) <https://doi.org/10.1016/j.conbuildmat.2022.129687>
13. Jin, D.; Xin, K.; Yin, L.; Mohammadi, S.; Cetin, B.; You, Z. Performance of rubber modified asphalt mixture with tire-derived aggregate subgrade. *Constr. Build. Mater.* 2024, 449, 138261 DOI:[10.1016/j.conbuildmat.2024.138261](https://doi.org/10.1016/j.conbuildmat.2024.138261)



INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details