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# Geotechnical Characterization of In-filled Materials used in Trench Wave Barriers for Vibration Screening

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**ABSTRACT:**

In-filled materials play a significant role in performance of trench wave barriers for vibration screening. Using waste materials in trench wave barriers as in-filled materials is an eco-friendly and sustainable step in services and application of geotechnical engineering techniques. But how these materials have suitable application in engineering domain, safety and stability, is an important concern. To know its application and comparison with other materials as in-filled materials in vibration isolation, it is required to ascertain its geotechnical properties. In the present paper, the geotechnical characterization of in-filled materials i.e. rice husk, saw dust and crumbed tyre rubber had been carried out. Several laboratory tests had been carried out such as particle size distribution, specific gravity, bulk density, relative density and permeability. Since trench wave barrier is exposed to dynamic loading, its dynamic properties in addition to these properties are also important. Several dynamic tests had also been conducted such as shear modulus, damping ratio, stiffness and shear strain to curtain down the suitability of these materials as in-filled materials which was used in trench wave barriers for vibration screening. Based on the experimental study for performance of in-filled materials in trench barriers, the results indicate that the materials possessed good characteristics of in-filled materials in trench barrier for vibration isolation.

**Keywords**: Geotechnical characterization, Crumbed tyre rubber, Rice husk, Saw dust, Damping ratio, Shear wave velocity, Shear modulus, In-filled materials, Trench barrier, Vibration screening

**Notations:**

| | |
|---|---|
| $a_0$ | Attenuation coefficient |
| G | Specific gravity |
| $\rho_s$ | Density of soil |
| $\rho_b$ | Density of in-filled material in barrier |
| Vs | Shear-wave velocity |
| $A_r$ | Amplitude Reduction Ratio |
| $C_u$ | Uniformity coefficient |
| $C_c$ | Coefficient of gradation |
| $\gamma_d$ | Bulk density (dry) |
| $I_d$ | Relative Density |
| $\gamma_{d(max)}$ | Dry density (maximum) |
| $\gamma_{d(min)}$ | Dry density (minimum) |

## 1. INTRODUCTION:

The in-filled materials to be used in trench barriers for vibration isolation play a significant role in efficiency of screening. Type of in-filled materials used will finally decide the performance or efficiency of the trench wave barriers with respect to screening. In civil engineering applications, the in-filled materials should have possessed much of desired engineering properties so that suitability of materials for filling in trench wave barriers can be defined. In the experimental study carried out for investigating performance of in-filled materials in vibration screening, the materials used had shown characteristics such that the performance criteria could be ascertained by adhering in the range of the values of these properties. The in-filled materials used in the experimental study in trench wave barriers for vibration screening are saw dust, rice husk and crumbed tyre rubber.

## 2. MATERIALS AND METHODS:

Based on the factors such as; suitability for purpose, availability of materials, waste nature, economy and handling, following three types of material were selected under this research study. Considering the above factors, the materials selected as in-filled materials were (i) Saw Dust (ii) Rice Husk and (iii) Crumbed Tyre Rubber as shown in Figure-1:

1) Saw dust 2) Rice husk 3) Crumbed tyre rubber

Figure-1: Three types of In-filled materials used in Trench wave barriers for Vibration screening

### (i) Saw Dust:

Sawdust (or wood dust) is dark brown in colour and angular in shape [13], a waste obtained or by-product obtained after carrying out operations on wood i.e. routing, sawing, milling, sanding and planing. It consists of small sized chippings or even fine powder from wood. These operations generally performed by wood-working portable power tool machinery or hand tools. In some manufacturing industries, the saw dust can be a significant fire hazard and as a source of occupational dust exposure. The particulates are the chief component of particleboard. Dust and chips are the two waste products forms at the working area during wood working operations as stated above. Dust is created by shattering of wood cells, while degradation out of whole groups of wood cells generates chips. Finer dust particles will be formed as more cell-shattering occurs [11]. For example, sawing and milling are mixed cell shattering and chip forming processes, whereas sanding is almost exclusively cell shattering. Sawdust is a waste produced from various sawmills in the country. It is mostly disposed off in the open environment and thus become factor pollution [12]. Hence using sawdust as filling materials in trench barriers for vibration isolation can enhance the utilization of saw dust waste in the longer run and help in sustaining the environment to a little extent.

### (ii) Rice Husk:

The rice husk is also known as rice hull, is flaky particles brown in colour, is the rice seed coating or grain coating. It is produced from hard materials, which includes silica and lignin which protects the seed in season of growing. In 1 Kg of milled white rice results in about 0.28 kg of rice husk obtained as a by-product in rice production during milling. Common by products produced from rice husk are: like solid fuel (in loose form or as briquettes and pellets), carbonized rice husk generated after burning, and the rice husk ash at the end after combustion. In its loosest form, Rice husk is mostly utilized for energy production. When the density of rice husk increased the product forms are rice husk briquettes and pellets which have higher combustion performance. These forms of densified rice husks are utilized in boilers which help in saving fossil fuels. Produced during rice milling, the rice husk is already dried and accumulated at the factory. Since long, rice husk was treated as a waste after milling process and their disposal was a cumbersome task. Because the rice husk is collected easily and is not costly, rice husk has been in application as an energy source.

### (iii) Crumbed Tyre Rubber:

Crumb tyre rubber is a form of recycled rubber of fibrous in shape and black in colour which is produced after scrapping the automotive tyres. In

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the recycling process, its components such as steel wires and tyre cord (fluff) are separated, leaving tyre rubber part with a granular consistency. Further, in a granulator, with the help of of cryogenics or by mechanical means, the size of particles is further reduced. The particles are then separated as per size of grains and grouped on the basis criteria including colour. The crumbed tyre rubber used in this research study has been collected from recycle tyre factory located at Mayapuri, New Delhi. The factory produces three different grades of crumb tyre rubber graded as 40, 20 and 16. As shown in Figure-2, the various stages in producing crumb tyre rubber, from the waste tyre when cut into chipped tyre by means of cutting machine and then undergo shredding. It is then sieved using sieve machine and rubber crumb and steel wire are separated. In this research, crumbed tyre rubber has been characterized by carrying out testing on the selected material [14]. It is important to note that though the waste rubber tyre is separated from its metallic wire component, even remnant of metallic element may present in crumb tyre rubber undergoing processes.

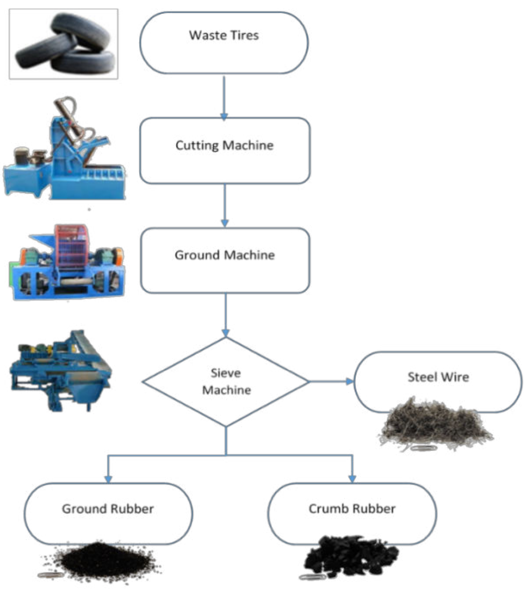


**Figure-2:** Layout of the process for formation of Crumbed Tyre Rubber from waste Tyres (Source: Journal of Engineering Science and Technology, No. 1(2021) 510-526), Volume-16

A fact that the tyres are one of the industrial wastes, which makes interest to the researchers to explore its utilization. Pelisser et al. [14] mixed rubber in concrete mix to develop concrete products in form of rubcrete with enhanced properties like thermal insulation, sound-proofing and low density. The addition of rubber content in concrete has decreased the density of the concrete. Nadal Gisbert et al. also observed that adding rubber content in form of fibres or aggregate to concrete mix can produce concrete of lower density. Other than particular applications in civil engineering, concrete with rubber particles has the property of occluding a large volume of air, which enhances workability. Also, the enhanced characteristic of rubber to dissipate and absorb energy the utility may be found in production of sound barriers.

## 3. EFFECT OF VARIOUS PROPERTIES ON ATTENUATION OF WAVE MOTION:

Screening performance of in-filled materials in trench barrier depends on the property of attenuation of waves. Wave attenuation is affected by number of factors such as particle size, specific gravity, saturation, stiffness and dynamic properties such as Damping ratio, Shear modulus and Shear wave velocity. Though, there is less availability of resources revealing much about the dependence of the factors on wave attenuation, the influence of these factors on the attenuation of wave is dealt herewith:

### (i) Effect of particle size of soil on Wave attenuation:

M. Sadeghi et al. [7] observed that when particle size of soil increases, soil reflectance, R, decreases This occurrence has been derived by using model of analytical radiative transfer. reflectivity (ρ), and Absorptivity (k) are the two parameters which the

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optical properties of soil depends and are used in the model. This assumed model has been deduced for surface and volume reflectance using two different models for beam tracing.

(ii) **Effect of specific gravity on wave attenuation:**

Though not many studies are available to show the effect of specific gravity on wave attenuation, one of the research papers by John Ahrens [1]. The study showed that for the width of the tested zone, the low specific gravity is not much effective in attenuating wave energy.

(iii) **Effect of Saturation on wave attenuation:**

The correlation between permeability and attenuation is not well defined. Study revealed that attenuation coefficient is high with permeability less than 50 md and attenuation coefficient is low with permeability more than 50 md preferably greater than 1dB/cm [2].

(iv) **Effect of Stiffness of soil on attenuation of wave motion:**

Bornitz equation of attenuation [8] has been used to evaluate the frequency independent attenuation coefficient, $a_0$, caused by damping of material. The equation adequately related the attenuation of Rayleigh wave varying with distance. It was based on the analytical value of attenuation coefficient caused by radiation and material damping. Attenuation of amplitude of Rayleigh wave over a distance increases exponentially with respect to frequency of waves propagating. The frequency and wavelength of the waves transmitting, affects the vibration by a source. Attenuation in stiffer material is lesser than the soft soils.

(v) **Effect of Wave attenuation on Shear wave velocity:**

In Bender element test, Ingale et al. [15] concluded the factors affecting the attenuation of wave. The absorbing attenuation is related to damping characteristics of soil which in turn dependent on soul type, stress stage and water content as shown in Figure-3. It has been observed that attenuation decreases with increase in confining pressure in Bender element test. Higher length to thickness ration also reduces wave attenuation. The attenuation of waves may be minimized by adopting suitable excitation frequency or efficient testing system.

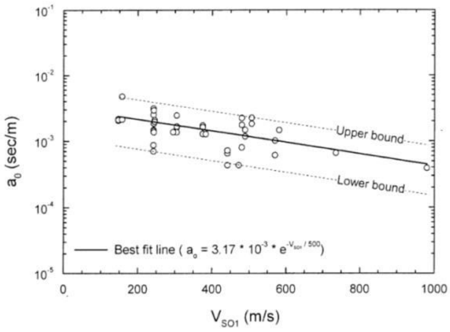


**Figure-3:** Frequency-independent attenuation coefficient, $a_0$, as a function of low-amplitude Shear wave velocity of soil (Source: Soil Dynamic and Earthquake Engineering 19 (2000) 277-288))

(vi) **Effect of Density ratio on Wave attenuation:**

Zhifei Shi [4] observed that relation between density of soil and higher filling part should be in parallel to get a comparatively wider attenuation zone in the region of low-frequency. Dry density of the soil sample when increased, the frequency of the attenuation zone can get reduced. It was concluded that an appropriate porosity of soil is advantageous for attenuation of waves. Density ratio is defined by finding the ratio of barrier density to that of the soil sample. Hossein observed while study on effect of density ratio on performance of screening with various normalized cross section area that by keeping all parameters constant, if density ration increases, it will increase the efficiency of barrier for screening as shown in Figure-4 [5].

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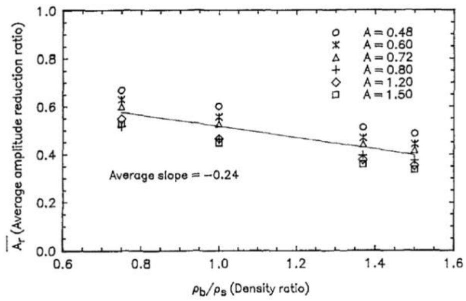


**Figure-4:** Effect of density ratio of material used for filling and soil (Source: Arab J Geosci (2017) 10:513, http://doi.org/10.1007/s12517-017-3279-3)

## 4. CHARACTERIZATION OF SAW DUST, RICE HUSK & CRUMBED TYRE RUBBER USED AS IN-FILLED MATERIALS:

The detailed Characterization of three waste materials has been done to focus on its geotechnical properties while using for in-filled materials in trench barriers for vibration isolation. The various properties to be considered for characterization of these three in-filled materials are as follows:

1. Particle size analysis
2. Specific Gravity
3. Bulk Density
4. Relative Density
5. Permeability
6. Young's modulus

**Dynamic Properties:**

1. Shear Modulus
2. Damping Ratio
3. Stiffness
4. Shear wave velocity
5. Density ratio

### 4.1. PARTICLE SIZE DISTRIBUTION: (As per IS: 2720-Part 4-1985)

Particle size is the significant property used for finding suitability as in-filled materials in trench barriers for vibration isolation. This test is carried out to find distribution of particle sizes of soil in a given sample in order to classify the soil with respect to size of particles [9]. The grain size analysis is performed to find out the % age of size of each grain contained in the given soil sample as shown in Figure-5 and the test results obtained is used to draw particle size distribution curve. This is used to classify the soil and to predict its behavior. The sieve analysis was done as per IS:2720 Part-4 (1985) and the sieves used were in the order to 4.75 mm, 2.36 mm, 1.18 mm, 600 μ, 300 μ, 150 μ and 75 μ.

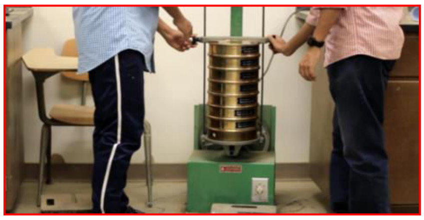

**Figure-5**: Pouring the soil sample on sieves and vibrating on sieve shaker

The % age of soil retained on each size of sieve has been obtained taking the basis of the total mass of in-filled material used and from the results of the % age sample passing each of the sieves has been obtained and tabulated in Table-1 below:

$$\%\text{age of sample passing through sieve} = \frac{\text{Weight of sample retained on IS sieve in g}}{\text{Total Wight in g}} \text{ x } 100$$

(a)

| Sieve Number | Sieve Size (mm) | Mass of Sieve (g) | Mass of Sieve & Soil (g) | Soil Retained (g) | Soil Retained (%) | Cumulative % age retained | % Finer |
|---|---|---|---|---|---|---|---|
| #1 | 4.750 | 1022.50 | 1032.00 | 9.50 | 2.35 | 2.35 | 97.65 |
| #2 | 2.360 | 875.15 | 883.15 | 8.00 | 1.98 | 4.32 | 93.33 |
| #3 | 1.180 | 441.95 | 466.90 | 24.95 | 6.16 | 10.48 | 89.52 |
| #4 | 0.600 | 824.30 | 918.95 | 94.65 | 23.37 | 33.85 | 66.15 |
| #5 | 0.425 | 314.50 | 411.80 | 97.30 | 24.02 | 57.88 | 42.12 |
| #6 | 0.300 | 756.95 | 830.75 | 73.80 | 18.22 | 76.10 | 23.90 |
| #7 | 0.150 | 370.55 | 428.65 | 58.10 | 14.35 | 90.44 | 9.56 |
| #8 | 0.075 | 303.90 | 325.85 | 21.95 | 5.42 | 95.86 | 4.14 |
| Pan | | 958.95 | 963.25 | 4.30 | - | - | - |

(b)

| Sieve Number | Sieve Size (mm) | Mass of Sieve (g) | Mass of Sieve & Soil (g) | Soil Retained (g) | Soil Retained (%) | Cumulative % age retained | % Finer |
|---|---|---|---|---|---|---|---|
| #1 | 4.750 | 1022.50 | 1023.45 | 0.95 | 0.20 | 0.20 | 99.80 |
| #2 | 2.360 | 875.15 | 877.35 | 2.20 | 0.47 | 0.68 | 99.32 |
| #3 | 1.180 | 441.95 | 566.95 | 125.00 | 26.88 | 27.56 | 72.44 |
| #4 | 0.600 | 824.30 | 1012.90 | 188.60 | 40.56 | 68.12 | 31.88 |
| #5 | 0.425 | 314.50 | 377.40 | 62.90 | 13.53 | 81.65 | 18.35 |
| #6 | 0.300 | 756.95 | 790.95 | 34.00 | 7.31 | 88.96 | 11.04 |
| #7 | 0.150 | 370.55 | 402.30 | 31.75 | 6.83 | 95.78 | 4.22 |
| #8 | 0.075 | 303.90 | 316.55 | 12.65 | 2.72 | 98.51 | 1.49 |
| Pan | | 958.95 | 964.65 | 5.70 | - | - | - |
| | | | TOTAL: | 463.75 | 98.5 | | |

(c)

| Sieve Number | Sieve Size (mm) | Mass of Sieve (g) | Mass of Sieve & Soil (g) | Soil Retained (g) | Soil Retained (%) | Cumulative % age retained | % Finer |
|---|---|---|---|---|---|---|---|
| #1 | 4.750 | 1022.50 | 1097.25 | 74.75 | 15.25 | 15.25 | 84.75 |
| #2 | 2.360 | 875.15 | 933.95 | 58.80 | 12.00 | 27.25 | 72.75 |
| #3 | 1.180 | 441.95 | 612.09 | 170.14 | 34.72 | 61.96 | 38.04 |
| #4 | 0.600 | 824.30 | 912.00 | 87.70 | 17.89 | 79.86 | 20.14 |
| #5 | 0.425 | 314.50 | 378.55 | 64.05 | 13.07 | 92.93 | 7.07 |
| #6 | 0.300 | 756.95 | 770.25 | 13.30 | 2.71 | 95.64 | 4.36 |
| #7 | 0.150 | 370.55 | 374.85 | 4.30 | 0.88 | 96.52 | 3.48 |
| #8 | 0.075 | 303.90 | 315.90 | 12.00 | 2.45 | 98.97 | 1.03 |
| Pan | | 958.95 | 962.95 | 4.00 | - | - | - |
| | | | TOTAL: | 489.04 | 99.0 | | |

**Table-1:** Sieve Analysis Data sheet for (a) Saw Dust (b) Rice Husk and (c) Crumbed Tyre Rubber

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Based in these data, $D_{10}$, $D_{30}$ and $D_{60}$ has been derived then the value of $C_u$ & $C_c$ has calculated

For Saw Dust: $D_{10} = 0.17$, $D_{30} = 0.35$, $D_{60} = 0.55$, $C_u = 3.23$ & $C_c = 1.31$

For Rice Husk: $D_{10} = 0.15$, $D_{30} = 0.35$, $D_{60} = 0.55$, $C_u = 3.66$ & $C_c = 1.48$

For Crumbed Tyre Rubber: $D_{10} = 0.47$, $D_{30} = 0.95$, $D_{60} = 1.80$, $C_u = 3.82$ & $C_c = 1.06$

Based on the values of particle sizes and coefficients, it has been found that all the sample of in-filled materials belonged to poorly graded soil.

The data sheets of Sieve analysis for Saw Dust, Rice Husk and Crumbed Tyre Rubber are illustrated in Table-. Figure-6 shows the particle distribution curve based on the available data sheet of Sieve Analysis.

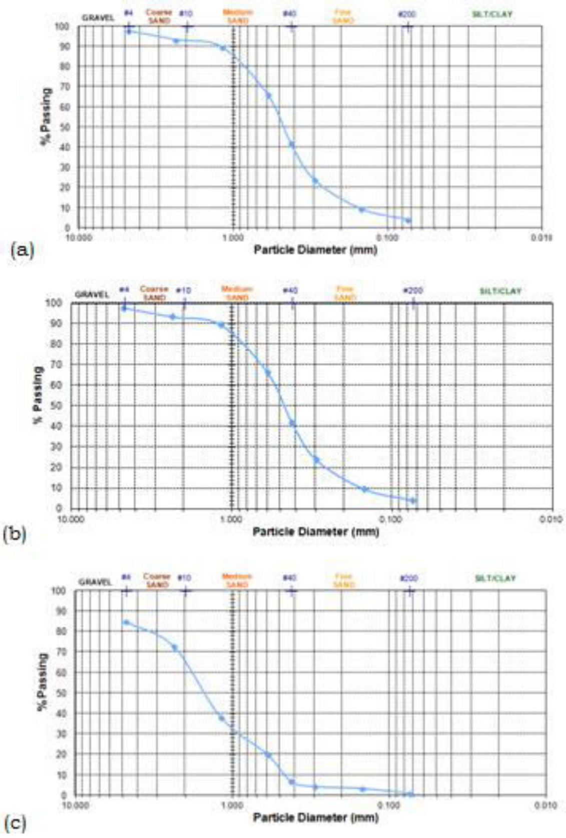


**Figure-6:** Particle size distribution curve for (a) Saw Dust (b) Rice Husk and (c) Crumbed Tyre Rubber

**4.2. SPECIFIC GRAVITY: (As per IS: 2720-Part 3-1980)**

The specific gravity ($G_s$) of any soil sample is defined as the ratio of mass of a unit volume of soil solids at a temperature (specific) to that of the mass of an equal volume of distilled water at the same temperature. The temperature specified for obtaining specific gravity of sample of soil is 20°C. The specific gravity obtained is helpful in calculation of the phase relationships of soil in terms of void ratio and degree of saturation. The specific gravity of soil has been found out as shown in Figure-7 and the density of the soil solids is calculated. The calculated values are tabulated in Table-2 below.

$$G = (m_2 - m_1) / ((m_4 - m_1) - (m_3 - m_2))$$

where,

$m_1$ = mass of density bottle in gram

$m_2$ = mass of bottle and dry sample in gram

$m_3$ = mass of bottle, soil and water in gram, and

$m_4$ = mass of bottle when full of water only in gram

**Figure-7:** Testing for Specific Gravity

**Table-2:** Value of Specific Gravity:

| **In-filled Material** | **Specific Gravity** | | | |
|---|---|---|---|---|
| | S-1 | S-2 | S-3 | Avg. Specific Gravity (G) |
| Saw Dust | 0.65 | 0.65 | 0.66 | 0.65 |
| Rice Husk | 0.72 | 0.74 | 0.75 | 0.74 |
| Crumbed Tyre Rubber | 0.73 | 0.72 | 0.72 | 0.73 |

**4.3. BULK DENSITY: (As per IS: 2720-Part 29-1975)**

The bulk density may be defined as the ratio of weight of soil sample per unit volume in gram/cubic centimeter has been calculated from the formula and is tabulated in Table-3 as below

[10]:

$\gamma_b$ (g/cm$^3$) = (Ws – Wc) / Vc $\gamma_d$ (g/cm$^3$) = 100 $\gamma_b$ / (100 + w)

$W_s$ = Weight of sample and core cutter in gram
$W_C$ = Weight of core cutter in gram
$V_C$ = Volume of core cutter in cm$^3$, and
$w$ = Water content
$\gamma_d$ = Bulk density (dry)

**Table-3:** Bulk density for the in-filled materials

| In-filled Material | Bulk Density (g/cm³) | | | | Dry Density ($\gamma_d$) (g/cm³) |
|---|---|---|---|---|---|
| | B-1 | B-2 | B-3 | Avg. Bulk Density ($\gamma$) | |
| Saw Dust | 0.26 | 0.24 | 0.24 | 0.24 | 0.23 |
| Rice Husk | 0.27 | 0.39 | 0.36 | 0.34 | 0.33 |
| Crumbed Tyre Rubber | 0.40 | 0.39 | 0.40 | 0.39 | 0.37 |

**4.4. RELATIVE DENSITY: (As per IS: 2720-Part 14-1983)**

Relative density or density index may be defined as the ratio of the difference between the void ratio of cohesionless soil in its loosest state and in natural state to the difference of void ratio in the loosest and densest states. Porosity of soil is affected by shape of grain, uniformity of grain size and condition of sedimentation. Porosity itself cannot indicate whether the soil is in a loose state or in denser state. This observation can only be obtained by comparing the porosity or void ratio of the given sample with that of the same sample in its loosest and densest possible state. Hence the term, relative density has been introduced. Relative density is an unpredictable feature of sandy deposits. Actually, relative density presents the ratio of actual decrease in volume of voids in a sandy soil to the maximum possible decrease in the volume of voids, which represents how further the sand under investigation are capable of densification beyond its natural state. Relative density determination is helpful in compaction of cohesionless soils and in finding safe bearing capacity in the case of sandy soils. For very dense gravel sand, it is possible to obtain relative density more than one. The relative density of samples has been calculated by using the formula and tabulated in Table-4 as below:

$$I_d = (e_{max} – e) / (e_{max} – e_{min})$$

$e_{max}$ = void ratio of cohesionless soil in its loosest state
$e_{min}$ = void ratio of cohesionless soil in its densest state
$e$ = void ratio of cohesionless soil in its natural existing state in the field.

**Table-4:** Relative density for the in-filled materials

| In-filled Material | Relative Density (%age) | | | |
|---|---|---|---|---|
| | R-1 | R-2 | R-3 | Avg. Relative Density ($I_d$) |
| Saw Dust | 40.99 | 40.13 | 40.20 | 40.44 |
| Rice Husk | 19.27 | 18.66 | 19.71 | 19.21 |
| Crumbed Tyre Rubber | 36.37 | 35.90 | 35.97 | 36.08 |

**4.5. PERMEABILITY TEST: (As per IS: 2720-Part 17-1986)**

Soil permeability also termed as hydraulic conductivity in soil. It is the rate at which water flows through voids in soil materials. It is an important characteristic of soil in the domain of engineering and earth-sciences. The coefficient of permeability (k) is a constant of proportionality expressing the ease with which fluid flows through a porous medium. In this test, falling head test method was adopted. Information related to the permeability of soil is necessary to calculate the amount of flow through earthen dams, from waste storage facilities (landfills, ponds, etc.) and the settlement in case of clayey soil deposits. Geotechnical engineers, hydro-geologists and soil & environmental scientists use these type of

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information related to projects such as structural foundations, embankments, earthen dams, flood management and more.

**Figure-8:** Permeability Test for in-filled materials

Under falling head permeability test as shown in Figure-8, the permeability of the sample at temperature can be given by:

$$kT = ((2.30aL) / (At)Log_{10} (h_1/h_2)$$

Based on the calculations, the values of permeability for in-fill materials are tabulated in Table-5 as below:

**Table-5:** Permeability values for the materials

| **In-filled Material** | **Permeability (cm/sec)** | | | |
|---|---|---|---|---|
| | P-1 | P-2 | P-3 | Avg. permeability kT |
| Saw Dust | 0.017 | 0.017 | 0.016 | 0.016 |
| Rice Husk | 0.010 | 0.010 | 0.012 | 0.010 |
| Crumbed Tyre Rubber | 0.031 | 0.032 | 0.032 | 0.031 |

**4.5 DYNAMIC PROPERTIES SUCH AS DAMPING RATIO, SHEAR MODULUS, RESILIENT MODULUS & STIFFNESS:** As per A**STM D5311-13 & ASTM D3999-**11

Dynamic Tri-axial testing is carried out on soil when it is required to evaluate the strength and deformation characteristics under cyclic loading conditions. These dynamic loading conditions may include dynamic loading effects arising due to earthquakes, moving of high speed vehicles and trains with high speed, movement of sea waves, high speed wind, operation of vibration machines etc. There are variations in outcome of dynamic Tri-axial tests and thus selecting the test should the one that is accurately simulating the nearest conditions at site. Cyclic loading are applied to the soil specimen by using the mechanical or hydraulic actuator component of the testing system. The amount of cyclic loading to be applied is decided by various factors, such as the establishment of effective stresses after the isotropic consolidation (the difference between the cell and Back Pressure), the type of soil, state of the soil (density, moisture etc.) and the characteristics of loading (frequency, waveform type). Based on the general rule, the cyclic loading is usually kept double the isotropic effective stress, multiplied by a factor (i.e. Stress Factor). The range of stress Factors usually in between 0 and 1. Its effect on number of cycles that a soil can withstand has a significant role. In cohesionless soils, the applied negative axial stress during the cyclic loading must not exceed the effective stress which has been applied during process of consolidation, otherwise it may detach the top platen from the top surface of the specimen.

**4.5.1. Brief of the Cyclic Tri-axial Test System:**

The Heico make Cyclic Tri-axial Test system as shown in Figure-9 and schematic as shown in Figure-10, has been used to determine the dynamic properties i.e. Damping Ratio, Shear Modulus. The test system is a highly advanced combination of hydraulic and pneumatic technology where $\sigma_1$ is applied by hydraulic system in dynamic tests and $\sigma_2$ & $\sigma_3$ are applied by pneumatic system. It is completely based on closed loop principle. The confining and back pressure is also controlled through computer and is operated on close loop control mechanism. Figure-9 & 10 shows the detail and layout of testing equipment [15]. The applied loads were measured using a load cell. The axial deformation was measured using two Linearly Variable Differential Transducers (LVDTs). The confining pressure has been achieved through pressurized air which was measured by a pressure sensor

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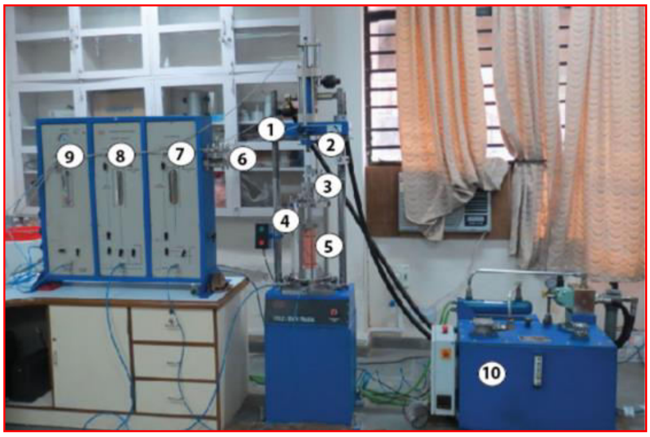
attached to one of the outlet. The sample prepared was placed on a plate base attached with the load cell. The sample was then sealed with rubber circular rings and clamped to make application of confining pressure. The various test configurations applied for testing is as follows:

The unsaturated samples were prepared by using a mould in form of cylinder of dia 50mm and height 100mm in a membrane. Then compaction of the samples has been done in four to five layers, with 9 blows each layer in order to achieve uniform density. The sample was then placed on the base plate then attached with the vertical dynamic ram for application of axial load. Water is filled in the cell for developing confining pressure. Dynamic axial load was then applied to get the required responses as shown in Figure-11 in form of various characteristics due to deformation behaviour. The results are tabulated in Table-6 as below



1. Cyclic Tri-axial frame 2. Load Cell 3. LVDT 4. Tri-axial cell 5. Sample of in-filled material 6. Volume changing device 7. Pore pressure control 8. Cell pressure control 9. Vacuum control 10. Power pack

**Figure-9**: Pictorial view of Tri-Axial Cyclic Load Test System for characterization

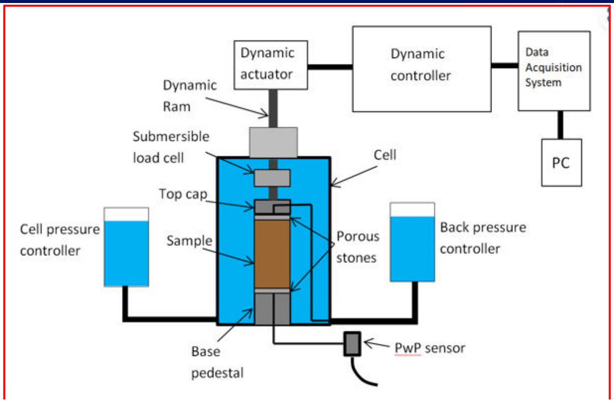



**Figure-10:** Schematic of Tri-Axial Cyclic Load Test System

### 4.5.2. Test Configuration:

Test configuration and Sample Description:

Length (cm) = 10.00
Diameter (cm) = 05.00
Area (sq.cm) =19.63
Volume (cc) =196.34
No of cycles = 100
Frequency = 1 (1 Active cycle & 9 Dead cycles)
Confining Pressure = 0.50 KPa
Pore Pressure (kN/m$^2$) =-1.96
Mass (g) = 65g (Saw Dust), 95g Rice Husk) and 95 g (Crumbed Tyre Rubber)
Sp. Gravity = 0.65 (Saw Dust), 0.74 (Rice Husk) and 0.72 (Crumbed Tyre Rubber)
Dry Density (g/cc) = 0.24 (Saw Dust), 0.34 (Rice Husk) and 0.41 (Crumbed Tyre Rubber)
Void Ratio = 0.96 (Saw Dust), 0.34 Rice Husk) and 0.51 (Crumbed Tyre Rubber)
Porosity (%)= 49.07 (Saw Dust), 33.72 Rice Husk) and 33.23 (Crumbed Tyre Rubber)

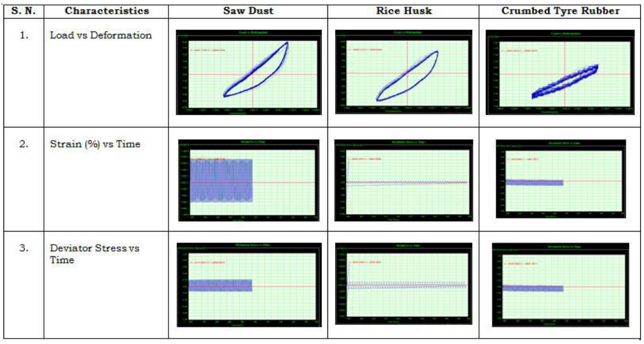



**Figure-11:** Graphs of parameters in obtaining dynamic properties of the in-filled materials

**Table-6:** Results of dynamic characterization for the in-filled materials

| Dynamic Properties | In-filled materials | | |
|---|---|---|---|
| | Saw Dust | Rice Husk | Crumbed Tyre Rubber |
| Damping Ratio (%) | 12.39 | 20.03 | 22.32 |
| Shear Modulus (kN/m$^{2}$) | 1237 | 1214 | 322 |
| Young's Modulus (kN/m$^{2}$) | 3712 | 3645 | 980 |

**5. RESULTS AND DISCUSSION:**

Based on the available data after laboratory tests for geotechnical characterization of in-filled materials, the results are discussed and analysed, the following inferences have been arrived off:

- The in-filled materials i.e. sawdust, rice husk and crumbed rubber are of sand sized and they are non-plastic in nature.
- Dry density of saw dust is low as compared to the rice husk and crumbed rubber.
- Shear modulus of crumbed rubber is quite lower than that of rice husk and saw dust.
- In case of Saw Dust, the values of particle sizes and coefficients are as; $D_{10}$ = 0.17, $D_{30}$ = 0.35, $D_{60}$ = 0.55, $C_u$ = 3.23 & $C_c$ = 1.31 whereas the values in case of Rice Husk are; $D_{10}$ = 0.15, $D_{30}$= 0.35, $D_{60}$ = 0.55, $C_u$ = 3.66 & $C_c$ = 1.48 and also for Crumbed Tyre Rubber, the values are; $D_{10}$ = 0.47, $D_{30}$ = 0.95, $D_{60}$ = 1.80, $C_u$ = 3.82 & $C_c$ = 1.06. Based on above, the samples belong to poorly graded soil with more %age of finer particles. Three samples of in-filled materials are also non-plastic in nature.
- The value of Cu & Cc for rice husk saw dust and crumbed tyre rubber is from 1 to 3 but the value of Cu for each material is not more than 6. Therefore all the materials are classified as SP-poorly graded soil.
- The in-filled materials as Saw Dust, Rice Husk and Crumbed Tyre rubber are also non-plastic in nature
- The specific gravity in case of in-filled materials is found to be as low as to in-situ soils when compared. The difference may be due to variance in composition of minerals.
- The Bulk Density of three materials used in the trench is low.
- For relative density, all the three materials have different range of density. The density range of Saw Dust and Crumbed Tyre Rubber found to be in range of 35%-40% whereas for Rice Husk, it is found to be nearly 20%.
- The permeability coefficient of three in-filled materials was found good. Out of three, the Crumbed Tyre Rubber has the maximum permeability.
- All the three in-filled materials were having Young's modulus in the range of 3628-3922 kN/m$^{2}$.
- The values of Shear modulus for all the materials are in the range of 322-1235 kN/m$^{2}$.
- One of the significant dynamic properties of in-filled materials i.e. damping ratio, which has found to be in range of 12 to 23.50%.

Moreover, this study suggested that all the in-filled materials used in this experimental study are suitable for utilization as filling material for trench barriers for vibration screening.

**6. CONCLUSION:**

This paper impetus on various investigations required for characterization of the in-filled materials which was used in filling of trench barriers for vibration isolation. The screening performance of the in-filled materials is inherently dependent on its geotechnical properties. It includes general properties to the dynamic properties of the samples. Damping ratio and the Stiffness are significant properties to be taken in consideration. The properties characterized and the performance in screening also helped in determining the suitability and deciding the range of values of properties. With respect of the existing properties of the materials, it also helps in deciding whether efficient or not for the purpose of vibration isolation. It has also supported in preparing the guidelines for selection of in-filled materials for the concerned purpose. The samples collected for characterization are heterogeneous and feathery in nature. With relation to the experimental study carried out for determining the screening performance of in-filled materials and based on available data of characterization, the efficiency of the in-filled materials has found suitable for using as in-filled material.

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