Laboratory Characterisation of Sand-Tyre Rubber mixture used as bedding material for underground pipes

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Abstract: **Underground buried pipes are essential components that serve the basic need of our daily life includes drainages, electricity, gas and underground water pipes. Recent statistics have created eye-opening situations for researchers on the failure of underground pipes. As per latest data provided by Water Services Association of Australia (WSAA), annually the average rate of failure of only pressurized pipes in Australia was around 20% per 100km of water main underground pipes that are causing billions of Australian dollars to be spent as maintenance cost. Among the many causes (i.e. design and installation), it was identified that such failures were essentially due to vibrations induced by massive traffic flows and/or intense construction activities. Improving the damping characteristics of surrounding soil using tyre crumb specifically at bedding portion could potentially be the solution to mitigate the failure caused by vibrations. In this paper, 10%, 20% and 30% of tyre crumb mixed with sand were used and tested in the laboratory as per Australian Standards (AS) for characterisation of Sand-Tyre Rubber mixture. In this paper, basic test-gradation, compaction, shear strength, and permeability are presented.**

Keywords: Bedding Material, Sand, Tyre-Rubber, Underground Pipes.

I. INTRODUCTION

Proper specification and installation of bedding and backfill is essential for achieving the intended structural performance of the buried pipelines [1]. As per Australian standard the requirement for Flexible and Rigid pipelines are different and based on many factors mainly such as Induced load, Type of pipeline and its usage, soil condition and thermal stress etc. Pipelines are refer as Lifeline as it is essential to our day to day life in relation to the fluids they transport: gas, liquid fuels, potable water, sewage, etc. so it is essential to understand the safety of these underground pipelines for a normal and healthy life.

Australian Standards has provided the guidelines and codes for Design and installation of buried pipes as shown in Fig. 1 [2].

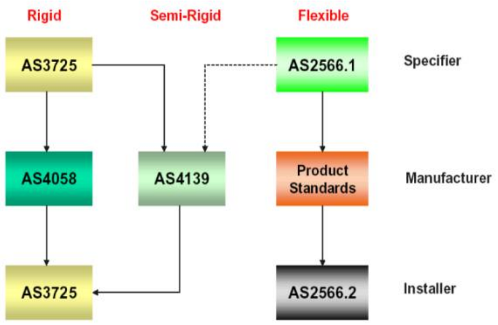

Fig. 1: Australian Standards for Pipe Design and Installation

- AS4058 (1992) is Australian Standard regarding the guideline for manufacture and assessment rigid pipe-pressure and non-pressure Precast concrete pipes.

- AS3725 (1989) allows the selection of a suitable loading class and the proper use of concrete rigid pipes and also specifies the material (bedding, Side and fill) details required to achieve the minimum pressure levels that correspond to different types of recommended support for reinforced concrete pipes.

- AS4139 (2003) is an Australian Standard for preparation and performance assessment of Semi-Rigid pipes, also known as fiber reinforced pipes.

- AS2566.1 (1998) is the Part one of Australian/New Zealand standard that tells us the design perspective for flexible underground pipes

- AS2566.2 (2002), Part 2 of buried flexible pipelines; Installation. The three AS2566 documents provide designers with the guidelines regarding installation and structural design of flexible buried pipes.

New South Wales (NSW), Victoria and Western Australia (WA) are the most populous states of Australia and where Australian Standards (AS) are being strictly followed. It is seen that in despite of proper installation and design of pipelines as per guidelines in AS Standards, the failure rate is increasing every year, statistic is shown in Fig. 2 of the states of NSW, Victoria and WA [3]–[5]. In 2016 it was also reported in a blog that “Every Single Day an Underground Gas Pipe Is Being hit and Damaged in Australia [6]."

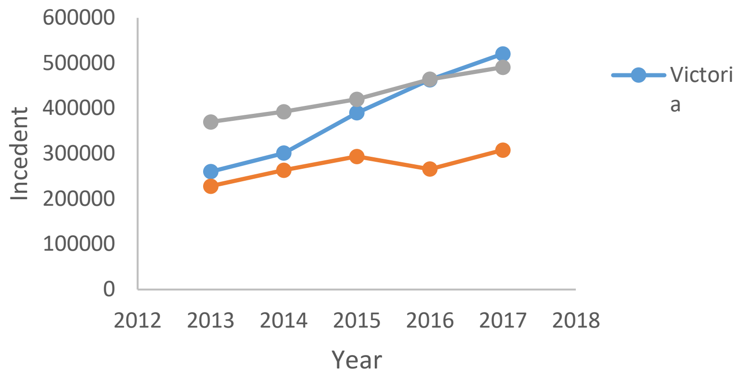

Fig. 2: Number of Incident per year

The increase in underground pipelines failures is now a real time problem for researcher to study the cause of failure and give solution to its safety considering the cost, quality, time and also environment. The cause of failure can be s Safety of buried pipe is most important concern under different loadings and conditions, and it cannot be achieved until and unless the actual behaviour of buried pipe is be studied and well understood [7]. Many researchers are currently working on the safety of underground pipelines. Marston and Anderson (1913) developed a method for buried conduit, in which he developed design parameters considering his experimental work on different External Loadings [8]. Recently one of researchers presents the results from testing a new method to set up separate sewer pipelines when buried in parallel in sand [9].

Kleiner and Rajani (2002) reported that pipe failure rates were affected by the numerous characteristics-Static and Dynamic of the pipe and its environment [10]. Dial Before you Dig (DBYB) is the National organisation to report in case of incident of pipelines and is operating at all the states within Australia including Tasmania. Infrastructure Damage Reporting System (ISRS) is the system DBYD has developed to gather the detailed reports of incidents occurring in Australia reported that, many factors are causing the failure of underground pipelines mainly includes; Vertical Boring, Transportation Activity, Mechanical and Manual Excavation, Horizontal Boring, Construction and others[3]–[5]. Among the many causes (i.e. design and installation), it was identified that such failures were essentially due to vibrations induced by massive traffic flows and/or intense construction activities [11].

A report of the European Gas Pipeline Incident Data Group incidents has indicated that ground movement represents the fourth major cause of gas pipeline failure with close to half of the reported cases resulting in pipe rupture [12]. Also, United Kingdom indicates approximately 21% of the failure in underground pipes is caused by ground movement is mentioned in the European report. The failure of buried reticulation pipes has been reported to peak during winter months in a number of countries, including Canada and the United Kingdom, prompting much research. In Australia, the number of pipe failures has been reported to peak during summer [13]

A comparable pipe which crosses under a road will be subject to continuous loading, the magnitude of which is dependent on the traffic on road. The load is being transferred from backfill to bedding experienced by the pipe is dependent on pipe depth [14]. As suggested by Rajeev and at all, the failure of pipeline caused by Heavy traffic loading and intense construction activities can be controlled by improving the damping characteristics of soil-Fill and Bedding soil [11].

Several researchers have evaluated some basic geometrical properties of soil and tire crumbs mixture, such as compaction properties, compression and permeability, shear strength, elastic modulus and poison's ratio. Rao and Dutta (2006) after series of triaxail and compressibility test on tyre chips and sand reported that addition of upto 20% tyre chips in sand could be potential material for road and dam construction, furthermore he claimed it is due to stress-strain behaviour of tyre chip-sand mixture. [15]. In addition, the shear strength and energy absorption of the rubber and soil mix is highly dependent on the size of the rubber and the proportion in the soil [15], [14], [15], [16], [17], [18].

Lee et al. (2010) studied the stress-strain and shear wave characteristic of sand-tyre rubber mixtures and stated that percentage and size of tyre rubber are important factors that influence the behaviour of rigid and soft particle mixtures [21]. The effect of mixing ratio on dynamic shear modulus and liquefaction was investigated and it was concluded that the mixing ratio significantly affects the dynamic shear modulus and liquefaction [22]. Christ et al. (2010) investigated the potential use of granular rubber as filler for buried pipes in cold areas where it was concluded due to excellent thermal properties of rubber cold temperatures progressed faster into the sand fill material in comparison to sand-rubber mixture [23]. S.N Moghaddas, et al (2012) concluded Soil surface settlement, pipe deflection, and pressure distributed over a pipe placed in a trench and subject to cyclic loading were investigated as a function of chipped and shredded rubber used as backfill [7]. Observed responses show that the mixture of rubber and soil used in the pipe is more effective in reducing the vibrations induced in the soil when they are covered with a layer of soil-rubber mixture, compared to the time when the soil itself is used only for the entire backfill

In this paper the, considering the limits as provided in Australian Standards (AS) for underground pipelines, the laboratory characterisation of Sand and Tyre Rubber is carried out. Tyre rubber with proportion of 10%, 20% and 30% by weight is mixed with sand. The laboratory test-Gradation, Compaction, Shear Strength and, Permeability test are performed and presented next.

II. EXPERIMENTAL METHODOLOGY

In order to characterisation of Tyre Rubber-Sand Mixture, Experimental set up was developed to perform series of experiments on Sand, Tyre rubber and San-Tyre Rubber mixture. Firstly Gradation test is performed as per AS1256 on Sand and Tyre rubber to access they are suitable to use as bedding Material considering the Australian Standard (AS) and previous study by prominent researchers. The soil were then tested in Standard proctor compaction devise following the AS1256. Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were obtained for Sand and Sand-tyre rubber Mixes (10%, 20% and 30%). In the next phase permeability test was conducted to determine the coefficient of permeability for all mixes and also on Sand and Tyre rubber. The test was performed according to procedure as given in AS1289.6.7. The direct shear box text were performed on Sand-tyre rubber mixes (10%, 20% and 30% TR) and sand (0% TR) itself to know the angle of coefficient of friction (ϕ) and cohesion (c) at respective optimum moisture content (OMC). The direct shear test is simple, quick and reliable test used to determine the consolidated drained strength properties because the drainage paths through the test specimen are open, thereby allowing excess pore pressure to be dissipated more rapidly than with other drained stress tests. The test was performed by deforming a specimen at a controlled strain rate (1mm/min) on or near a single shear plane determined by the configuration of the apparatus. The test results are presented and discussed next.

III. RESULT AND DISCUSSION:

A. Material

As per Australian Standard AS3725 and AS2566, Sand is one of material that can be used as bedding Material or fill material for underground buried pipes. Rubber size ranging from 0.6 mm to 2.36mm are best in order to control variation in permeability, shear strength and other characteristics when mixed with soil [24].Sand and tyre crumbs used in this study are obtained from local distributor and were tested in the laboratory as per AS standard. The particle size distribution for Sand and Tyre rubber can be shown in Fig. 3. Table 1 shows the summary of Gradation analysis performed on Sand and Tyre rubber. Tyre rubber which is by-product of the shredding process of used tyres is of range 1-3mm. The specific gravity of sand used is 2.635 and gradation curve gives uniformity coefficient (Cu) of 2.19 and coefficient of curvature (Cc) of 0.17 and classified as poorly gradated coarse sand (SP) as per Unified soil classification system (USCS).

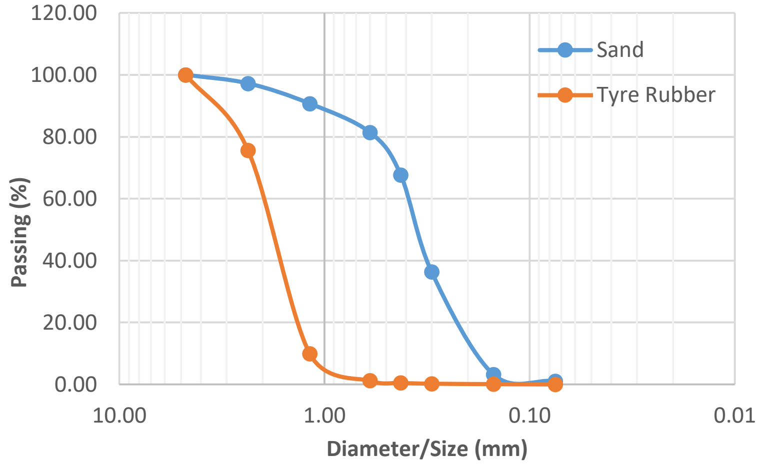

Fig. 3: Particle Size Distribution of Sand and Tyre Rubber

Table 1: Summary of Gradation and Specific Gravity of Sand and Tyre Rubber

Description	**Sand (value)**	**Rubber (value)**
Effective Size, D10	0.18	1.3
D30	0.28	1.75
D60	0.395	2
Coefficient of Uniformity (Cu)	2.19	1.54
Coefficient of Curvature (Cc)	0.17	4.71
Passed Sieve No 200 (%)	1.5	0
Unified Soil classification	SP	SP
Specific Gravity	2.635	1.08

B. Compaction

The obtained parameters i.e. Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are plotted against percentage of Tyre rubber as shown in Fig. 4. From figure it can be seen that with increase in percentage of Tyre rubber (10%, 20% and 30%) the value of Optimum Moisture content (OMC) and Maximum Dry Density (MDD) is decreasing with the almost same trend.

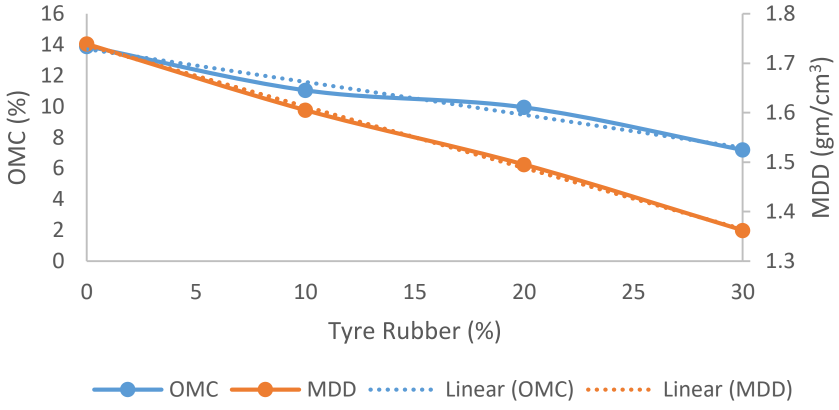

Fig. 4: Variation of OMC and MDD with Tyre Rubber (%)

C. Permeability

From the result of permeability, it is concluded that the coefficient of permeability decreases significantly with addition of 10% of tyre rubber in sand and after that no significant variation is found when 20% and 30% tyre rubber is added as shown in Fig. 5. The value of coefficient of permeability of tyre chips itself found equivalent to the typical coarse mineral aggregate.

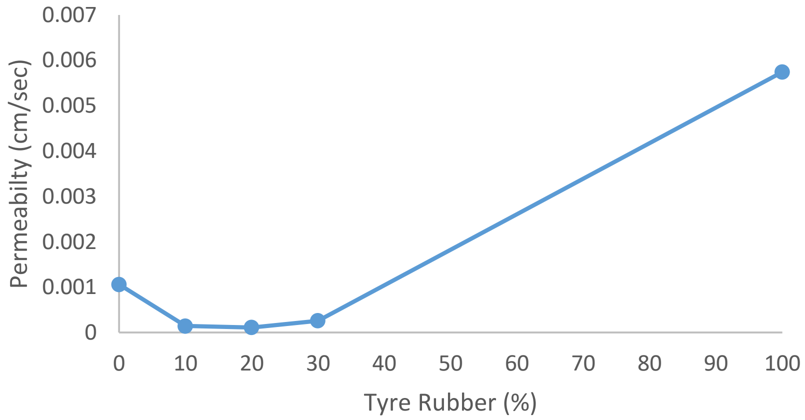

Fig. 5: Variation of Co-efficient of permeability with Tyre Rubber (%)

D. Shear Strength Test

The Tyre crumb percentage vs. angle of internal friction (ϕ) and Cohesion (c) of percentages ranging from 10-30% are represented in Fig. 6 for vertical stresses of 50, 100 and 150 kPa. It can concluded that the cohesion of soil decreases with increase in percentage of tyre rubber, while on the contrary the angle of internal friction is increasing with increase of tyre rubber content.

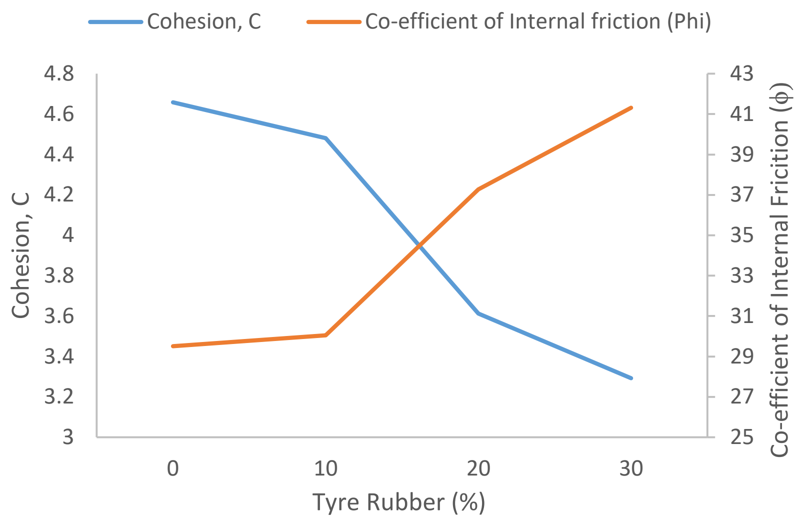

Fig. 6: Variation of c and ϕ with Tyre Rubber (%)

IV. CONCLUSION AND RECOMMENDATION:

This paper provided a summary of laboratory tests on Sand, Sand-Tyre rubber Mixture to investigate the possible use of Sand-tyre rubber mixture as bedding material for underground buried pipes. Based on preliminary study carried out the following conclusion can be drawn

1. Sand and Sand-Tyre Rubber mix lies within limits for bedding material as mentioned in Australian Standards (AS) - AS4058 and AS2566. Which show, any of mixture 10%, 20% and 30% of Tyre rubber can be used with the sand.
2. Maximum Dry Density slightly decreasing with increase in tyre rubber content and a very good linear relationship is observed. Also, with increase of Tyre rubber percentage, the optimum moisture content (OMC) decreases but remarkably. It can also be observed the decrease in Optimum Moisture content (OMC) and Maximum Dry Density (MDD) is very minimal when 10% tyre rubber by percentage is used.
3. Investigation shows, coefficient of permeability decreased slightly with addition of 10% and 20% Tyre rubber, further increase to 30% tyre rubber shown increase in the value of coefficient of permeability.
4. The direct shear box test results indicates the addition of 10% tyre rubber doesn't influence much on the shear strength parameters (c and ϕ). Further increase to 20% and 30% significantly increases the internal coefficient of friction (ϕ) and decreases the value of cohesion (c).
5. Furthermore, from the results it is conclude that, 10%, 20% and 30% tyre rubber can be used as bedding material for underground buried pipes.

Further testing can be carried out to know the dynamic response of Sand and tyre rubber with respect to damping and vibrations.

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