Comparative Study on the Effect of Tyre Waste on Specific Gravity of Construction Demolition Waste

N. Srilatha and P. Anbazhagan

Abstract The use of tyre waste has become common in various engineering applications as a light weight fill material, vibration isolation, noise absorption and other environmental benefits. Several studies are available on use of recycled waste as an alternative to the natural materials in the construction field. In this study, the effect of tyre crumbs on the specific gravity of Construction Demolished Waste (CDW) is investigated. CDW is grouped into three different groups based on size of particles, Group 1 (0.075 mm–0.3 mm), Group 2 (0.3 mm–1.18 mm) and Group 3 (1.18 mm–4 mm), respectively. Locally available tyre crumbs of size range between 0.075 and 4 mm is used in the study. The tests on specific gravity of CDW are conducted using pycnometer method. Further, an attempt is made to understand the combined effect of specific gravity on composite of CDW and tyre crumbs as studies available on combined effect of these two materials are not available in the literature. To address the composite effect, experiments are conducted using water pycnometer as well as using ethyl alcohol pycnometer as tyre crumbs floats on the surface of water. The obtained values of specific gravity is compared considering the group effect and combined effect of the construction waste. Further, a correlation is predicted using the obtained values of specific gravity determined using water and ethyl alcohol pycnometer for converting the specific gravity of the composite mixture of tyre and construction waste of different proportions.

Keywords Specific gravity · Ethyl alcohol · Tyre crumbs

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1 Introduction

The use of recycled waste materials in engineering applications increases in recent times as it eliminates disposal problems to a great extent. Waste materials such as tyre of different forms and construction waste obtained from different forms can be used in various infrastructural facilities. Tyre crumbs also known as tyre crumb rubber that are derived from the recycling of used or scrap tyres. Tyre derived aggregates are used as it has significant factors such as flexible, light weight, high permeability and more economical compare to any other materials. Many researchers established that addition of tyre waste improves the properties of soil significantly, viz., Humphrey and Manion [1]; Ahmed [2]; Edil and Bosscher [3] and Trouzine et al. [4]. Sustainable development encourages the use of recycled construction demolition waste in the construction field to replace natural materials. Sharma et al. [5] reviewed the applicability of using CDW in various geotechnical applications such as backfill material for geosynthetic reinforced structures and sub-base/base material for pavement construction as a replacement of natural materials. The fundamental and important index property of the soil which plays an important role in the geotechnical investigation is specific gravity of the soil. The specific gravity of soil, Gs, is a measure of particle density and is referenced to an equivalent volume of distilled water. It is used for obtaining the degree of saturation and void ratio of the soil. Several standards have been developed to determine the specific gravity of soil particles and some of them are mentioned below. ASTM (D 854-10) [6] code to be followed when grain size is less than 4.75 mm. In the case of particles, which can be readily dissolved in water or float in water, ASTM (D 550-06) [7] should be used and recommended to use only gas pycnometer. AASHTO T 100 [8] and California test 209 [9] may also be used for determination of specific gravity of the soil. California test 206 [10] or ASTM C127-12 [11] can be used when soil particles greater than 4.75 mm size. The specific gravity measurement following the above mentioned standards using water pycnometer is recommended where as in case of tyre crumbs it is not applicable. Therefore, a liquid with a density lower than the material density should be used for specific gravity measurement as the density of tyre crumbs is very close to density of water. Specific gravity measurement is highlighted in Florida method (FM 5-559) [12] for testing of ground tyre rubber using ethyl alcohol pycnometer and hence this method is recommended for overcoming the above mentioned limitation. Hence in the present study, an attempt is made to understand the effect of tyre waste on specific gravity of construction waste using both water pycnometer and Alcohol pycnometer. There are limited studies available in the literature on computation of combined effect of specific gravity of soil/sand tyre mixtures. However, the following Table 1 gives the details of the published work available in the literature for calculation of specific gravity of composite material.

Table 1 Studies available on soil/sand tyre mixtures for combined specific gravity computation

References	Materials used	Method	Conclusions
Amanta and Dasaka [13]	Sand tyre mixtures	Laboratory and theoretical equations	Presented both the theoretically calculated and experimentally obtained values of specific gravity. It is observed that the experimental results showed close agreement with the theoretical ones. It can be observed that with increase in percentage of tire chips, the specific gravity decreases
Reddy et al. [14]	Sand tyre chips mixtures	Laboratory and theoretical equations	Specific gravity of composite mixture is calculated based on theoretical and laboratory methods. The specific gravity of composite mixture is observed to be decreased with increase in percentage of tyre content
Arefnia et al. [15]	Soil-kaolin mixtures	Laboratory determination	Proposed a correlation for converting the specific gravity of the Kaolin-TDA mixture by means of water pycnometer to the alcohol pycnometer from the laboratory studies
Sellaf et al. [16]	Dredged soil tyre mixtures	Theoretical equations	The specific gravity of composite mixture is observed to be decreases with increase in percentage of tyre content
Trouzine et al. [4]	Soil tyre mixture	Theoretical equations	It is observed from the results that the specific gravity of the composite mixture decreases with increase in rubber content to reach half its value for the sample with **50%** scrap tyre rubber content (For soil—**2.55,** and for composite mixture, it is calculated as **1.25**)

2 Materials and Methodology

The construction waste and tyre waste was collected from the local recycled industries. The tyre crumbs used in the study varying from 0 to 100%, respectively. Construction waste was made into three different groups such as: Group 3 (1.18–4 mm), Group 2 (0.3–1.18 mm) and Group 1 (0.075–0.3 mm) and tyre waste of size between 0.075 mm and 4 mm, respectively. The specific gravity of composite mixture was determined using both water pycnometer and ethyl alcohol pycnometer, and the tests were performed as per ASTM D 854 [6] and Florida method FM5-559 [12], respectively. The apparatus for the experiment includes pycnometer, weighing balance accurate to 0.001 g, drying oven, thermometric device, de-aired water, ethyl alcohol, vacuum pump with desiccator, funnel, sieve and material, etc. The pictures of construction waste and tyre crumbs are shown in Fig. 1. The samples kept in vacuum desiccator and during vacuum are shown in Fig. 2. The grain size distribution of construction waste and tyre waste was conducted as per IS: 2720 (part 4) [17]

are shown in Figs. 3 and 4, respectively. The specific gravity of each material was calculated using the following Eq. (1).

$$G_s = M_2/(M_4 - (M_3 - M_2)) \tag{1}$$

where, M_2 is mass of oven dry soil, M_4 is mass of pycnometer and water, M_3 is Mass of pycnometer, water and material, G_s is specific gravity of material (g/ml).

The gradation properties of construction waste of size smaller than 6 mm and tyre waste of size between 0.075 and 4 mm and corresponding specific gravity using water pycnometer are given in Table 2. The test matrix of composite mixture of construction waste and tyre crumbs are given in Table 3.

To check the particle size effect on specific gravity, specific gravity of three groups such as Group 1, Group 2 and Group 3 along with the combined effect (size less than 6 mm) of construction waste are calculated and shown in Fig. 5. From the figure, it is clear that the specific gravity of group increases substantially with increase in particle size. The obtained average value of specific gravity of tyre crumbs is 1.16 and is in close agreement with the studies available in literature and the value is between 1.01

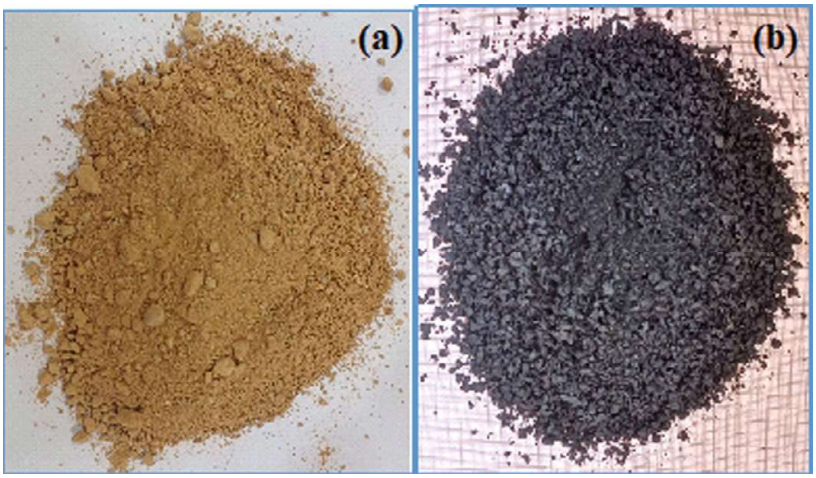

Fig. 1 Photographs of **a** construction waste **b** tyre crumbs

Fig. 2 Pictures showing samples before vacuum and samples during vacuum

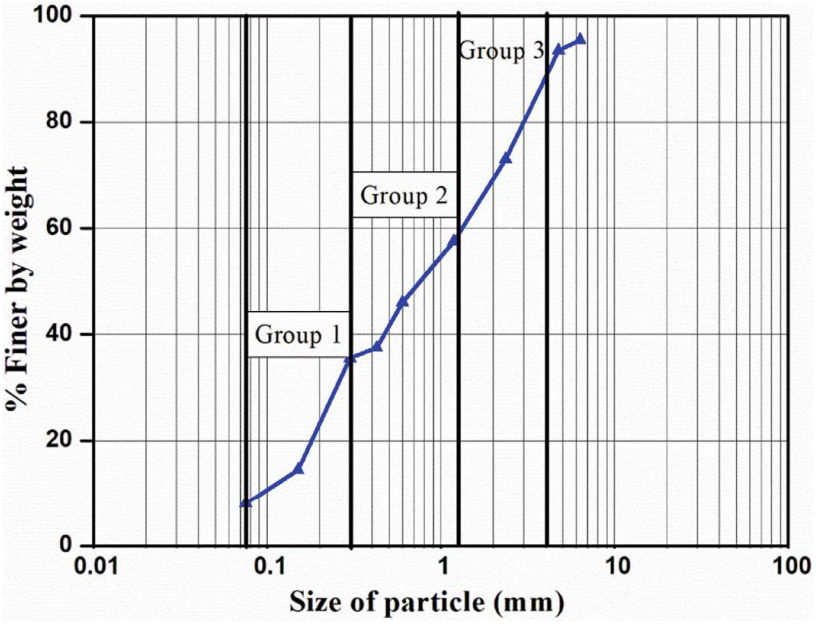

Fig. 3 Particle size distribution curve of construction waste

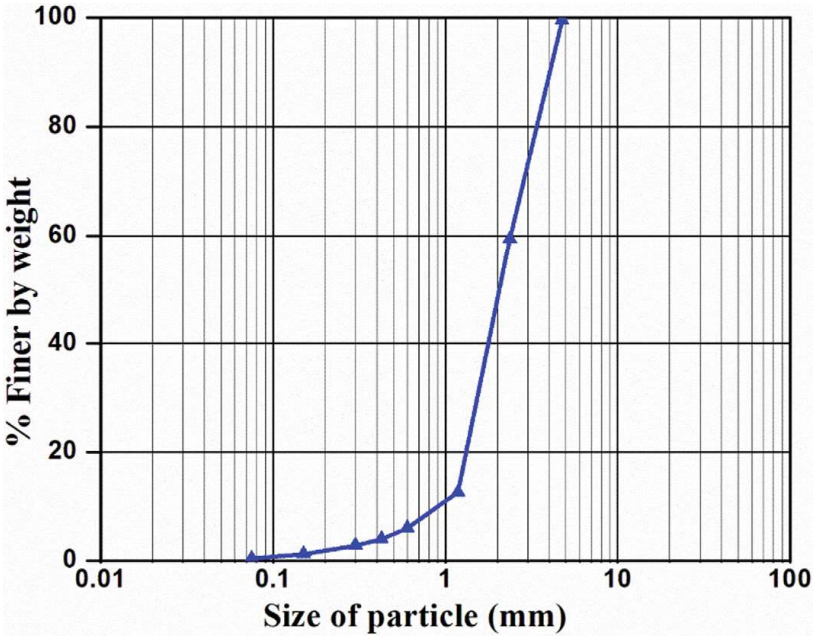

Fig. 4 Particle size distribution curve of tyre crumbs

and 1.36 (Ahmed [2], Edil and Bosscher [3], Bressette [18] and Zimmerman [19]), respectively.

The specific gravity of composite mixture of construction waste and tyre crumbs is calculated using the following Eq. (2).

Table 2 Properties of construction waste and tyre waste

Parameter	Construction waste	Tyre waste
Specific gravity	2.60	1.16
Coefficient of uniformity, Cu	13.90	2.99
Coefficient of curvature, Cc	0.50	1.40
Effective size of particle, D_{10} (mm)	0.10	0.77
Mean size of particle, D_{50} (mm)	0.72	2.05

Table 3 Test matrix for specific gravity determination

Test No.	Tyre crumbs (size: 1–4 mm)	CD waste (%)		
		Group 1 (0.075–0.3 mm)	Group 2 (0.3–1.18 mm)	Group 3 (1.18–4 mm)
1	0	100	100	100
2	10	90	90	90
3	20	80	80	80
4	30	70	70	70
5	40	60	60	60
6	50	50	50	50
7	60	40	40	40
8	70	30	30	30
9	80	20	20	20
10	90	10	10	10
11	100	0	0	0

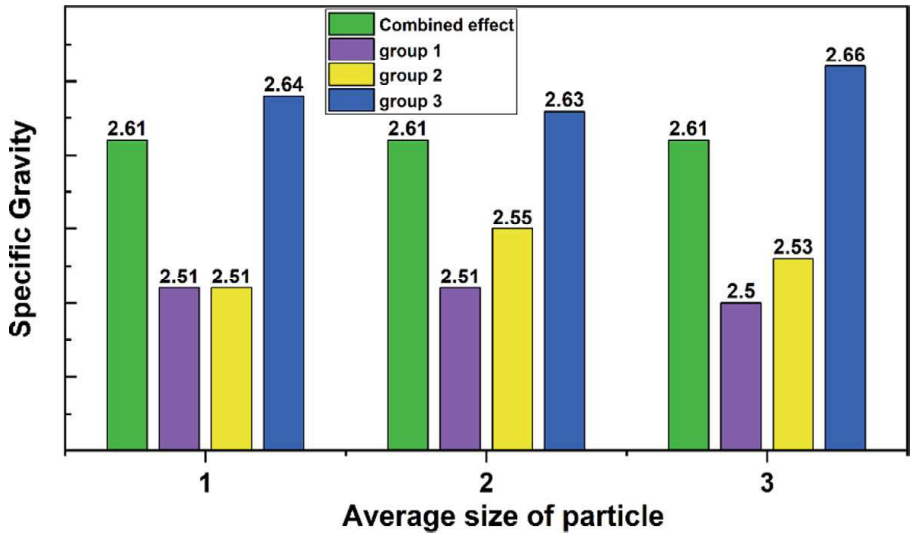

Fig. 5 Combined and group effect in variation of specific gravity of construction waste

$$G_s = ((0.9971 * M_a) * D)/(M_a - (M_b - M_c)) \quad (2)$$

where M_a is mass of original sample, M_b is mass of pycnometer filled with rubber and alcohol, M_c is mass of pycnometer filled with alcohol, G_s is specific gravity of composite mixture (g/ml) and D is density of ethyl alcohol, g/cc = 0.78 g/cc, respectively.

3 Results and Discussion

To understand the effect of tyre crumbs on specific gravity of construction waste, around 62 specific gravity tests are conducted and results are given in Tables 4 and 5. It is observed from the results that the range of specific gravities using both the methods are in consistent with the studies available in literature [15, 20]. Further, the specific gravity of composite mixture is observed to be decreased either by increasing the percentage of tyre crumbs or decreasing from Group 3 to Group 1, respectively. The difference in specific gravities for the case of tyre crumbs and three different particle size ranges using water pycnometer and alcohol pycnometer is shown in Figs. 6, 7 and 8, respectively. From the figures, it is clear that the obtained specific gravities of three different groups of CD waste are almost constant using both water and alcohol pycnometer methods. Further, as the percentage of tyre crumbs increases, the difference in specific gravities is observed to be increased. This could be due to the fact that the water and tyre crumbs densities are quite close each other leading to improper calculation of specific gravity, while in case of ethyl alcohol, the density is much lower.

Table 4 Specific gravity using water pycnometer

Test No.	Tyre crumbs (size: 1–4 mm)	CD waste		
		Group 1 (0.075–0.3 mm)	Group 2 (0.3–1.18 mm)	Group 3 (1.18–4 mm)
1	0	2.50	2.52	2.64
2	10	2.30	2.32	2.38
3	20	2.06	2.11	2.14
4	30	1.87	1.90	1.93
5	40	1.70	1.74	1.75
6	50	1.56	1.60	1.62
7	60	1.47	1.50	1.50
8	70	1.39	1.40	1.41
9	80	1.28	1.28	1.33
10	90	1.16	1.22	1.24
11	100	1.16	1.16	1.16

Table 5 Specific gravity using alcohol pycnometer

Test No.	Tyre crumbs (size: 1–4 mm)	CD waste		
		Group 1 (0.075–0.3 mm)	Group 2 (0.3–1.18 mm)	Group 3 (1.18–4 mm)
1	0	2.55	2.58	2.68
2	10	2.46	2.49	2.53
3	20	2.20	2.23	2.33
4	30	1.99	2.07	2.15
5	40	1.76	1.93	1.95
6	50	1.60	1.75	1.77
7	60	1.57	1.65	1.67
8	70	1.42	1.53	1.59
9	80	1.33	1.38	1.49
10	90	1.30	1.35	1.39
11	100	1.28	1.28	1.28

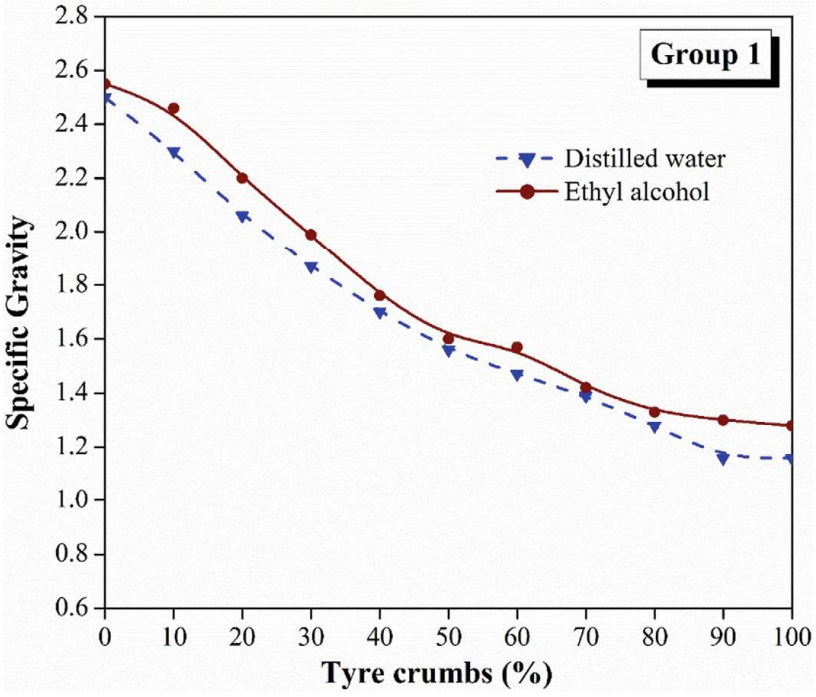

Fig. 6 Variation in specific gravity of composite mixture using water pycnometer and alcohol pycnometer for Group 1

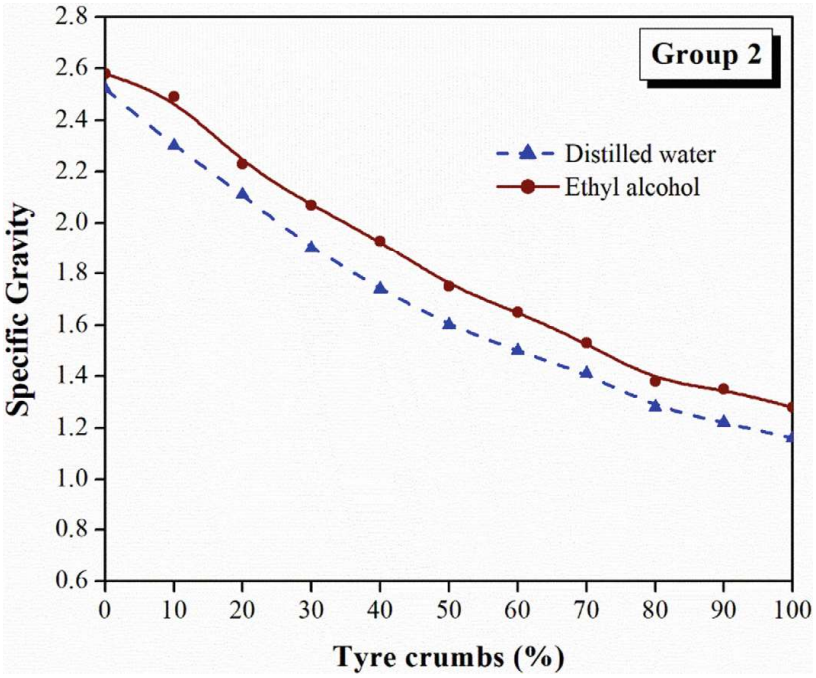

Fig. 7 Variation in specific gravity of composite mixture using water pycnometer and alcohol pycnometer for Group 2

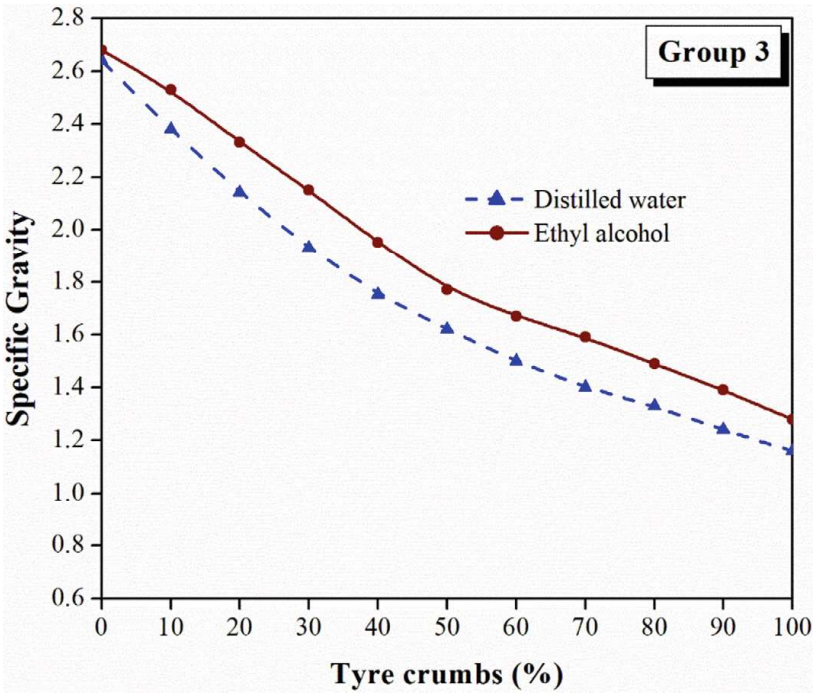

Fig. 8 Variation in specific gravity of composite mixture using water pycnometer and alcohol pycnometer for Group 3

The values of specific gravities for the case of composite mixture of tyre and construction waste of two different groups are shown in Figs. 7 and 8, respectively. It is observed from the figures that the specific gravity values calculated using water and alcohol pycnometer is observed to be increased with increase in particle size from Group 2 to Group 3, respectively. However, the specific gravity values determined using water pycnometer are observed to be lower than the alcohol pycnometer method in all the cases.

Therefore, from the results of the study concluded that the specific gravity of tyre and construction waste would result in under estimation of specific gravity. Attention must be required in this situation where there is an applicability of mixture of tyre and construction waste in design of any geotechnical engineering application for which the use of tyre crumbs is advised.

Precaution must be taken while using ethyl alcohol in geotechnical laboratories as it is an explosive liquid. Apart from that the use of water pycnometer in measurement of specific gravity is always more economical. From the results obtained, a linear correlation is proposed and is shown in Fig. 9. Using this correlation, specific gravity of composite of tyre and construction waste mixture obtained through water pycnometer could be converted to alcohol pycnometer specific gravity values. Further, specific gravity of composite material affects the index properties such as gradation, degree of saturation, void ratio, minimum and maximum dry densities, respectively. The void ratio of composite material is calculated using the following Eq. (3).

$$e = \frac{G.Yw}{Yd} - 1 \tag{3}$$

The void ratio corresponding to maximum and minimum dry densities of composite material can also be calculated using Eq. (3).

4 Conclusions

The present investigation presented the experimental results on effect of tyre crumbs on specific gravity of construction waste. Based on the results obtained, the following conclusions are drawn from the study.

1. From the results of the study, it is found that using water pycnometer in specific gravity determination of composite of tyre and construction waste is giving under estimated value than using alcohol pycnometer.
2. Results showed that the range of specific gravity of pure tyre crumbs is in a good agreement with the studies available in the literature.
3. The observed specific gravity of composite of tyre and construction waste is increased with increase in Group from 1 to 3 but any increase in tyre crumbs percentage would result in decrease in the specific gravity value.

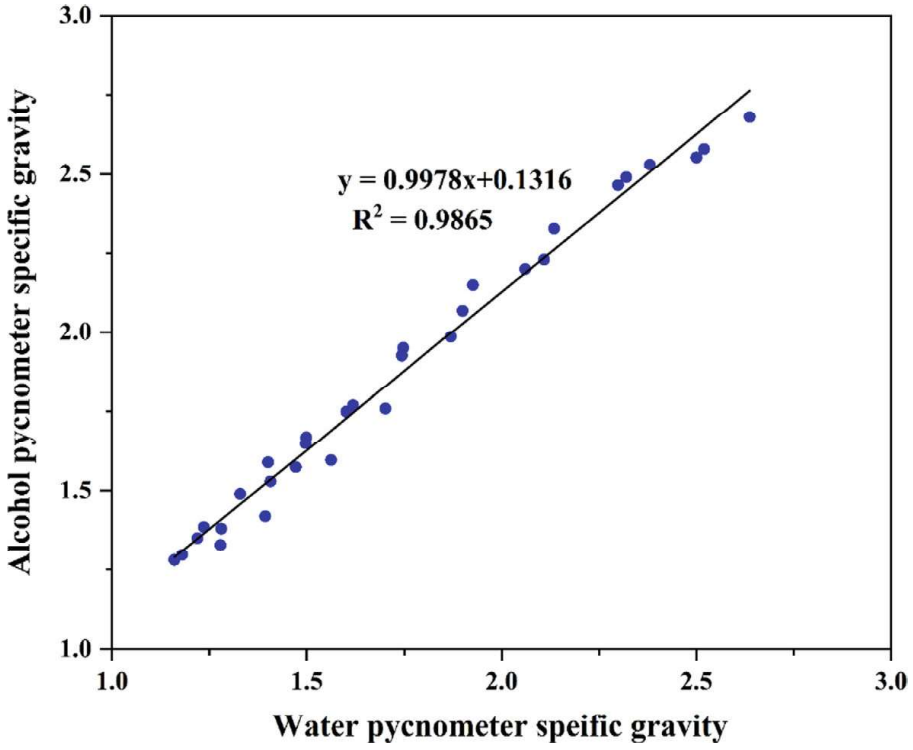

Fig. 9 Correlation between specific gravities of composite mixture of tyre and construction waste

4. A correlation is predicted for converting the specific gravity of the composite mixture of tyre and construction waste determined using water and ethyl alcohol pycnometer.

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