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An Experimental Study on Modified Concrete Using Partial Replacement of Gravel and Admixtures

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Abstract: This study aims to test a concrete specimen with replacement partially of 15 % of the coarse aggregate by pieces of tires and volcanic aggregates and reduce 5% of the water/cement ratio by substituting with 4% percentages of styrene butadiene rubber (SBR) and 1% of superplasticizer. The main concrete components (cement: sand: gravel) were used in weight ratios (1:1.5:3) and a water to cement 0.45 was used and it was considered as a reference sample (Mix1). A water to cement ratio 0.40 was depended for the modified mixtures. Samples were cast for testing the compression strength with sizes 150 ×150 ×150 mm for ages 7 and 28 days. the absorption rate, with a size of 100 ×100 ×100 mm at age 28 days. Moreover, 150 ×150×150 mm for depth of penetration test at the age of 28 days.

Briefly, the observed results were exhibited that the partial replacement of normal aggregate in concrete with volcanic aggregate affects negatively on the workability, so 4% of the polymer SBR and 1% of the superplasticizer have improved the workability. The improvement in the workability of concrete contributed to reducing the ratio of water to cement required for mixing compared to ordinary concrete, and this in turn led to an improvement in performance of hardened concrete. In addition, the reduction of the permeability level. The results also illustrated that the replacement of the gravel in the modified mixtures (Mix 3 and Mix 2) reduces the weight of hardened concrete by (10-12%) and (7-9%) compared with conventional concrete, respectively, which makes it suitable for use in mediumweight concrete applications.

Moreover, it can be concluded that the strength properties of the modified mix with volcanic aggregate improved by 19-20% compared to that of the unmodified concrete. While the modified concrete by cutting tires showed significant deterioration in the concrete's resistance 21% despite the reduction of concrete permeability.

Keywords: Rubber tires, permeability, aggregate; polymer.

1. Introduction

Recently, the production of rubber tires has increased on large scale due to increased vehicle demand. One of the main Global Warming hazards facing environmental organizations around the world is the disposal of expendable tires. Scrap tires are non-biodegradable in nature, therefore, major problems in the environment have been created. Many industries used it as a fuel which is not environmentally friendly Structural researchers worldwide are in the study of new alternative materials, which are required for economical and effective solutions as well as for saving natural raw material resources like aggregates etc. Partial replacement of the coarse aggregate by waste materials such as rubber tire pieces has already the advantage of saving on natural constituent which is used in the production of lightweight environmentally friendly concrete [1], [2].

On the other hand, Attempts have been made by researchers to decrease the self-weight of concrete by using partial replacement of lightweight materials such as volcanic aggregate, lightweight expanded clay aggregate, etc. Having lightweight concrete is benefit in the reduction of dead load and lower handling costs. Another most important characteristic of lightweight concrete is the relatively low thermal conductivity and high sound insulation [3]. Lightweight concrete is a multilateral that has a major interest and considerable industrial demand in recent years in more of construction projects, although its use dating back more than 2000 years [4].

Ram Prasad A, 2019 [5] showed that the advantages of using lighter concrete include reducing dead weight for members, increasing construction range and decreasing charges and costs. When placed on a wall, lightweight concrete retains its high voids and does not form laitance layer or cement film. The use of a series of lighter materials as partial replacements for the rough aggregate that composes the main weighted mass to produce lightweight concrete.

Safiuddina, 2013 [6] observed a comprehensive account of the addition of recycled aggregate in concrete, depending on the practical results in the previous studies. Recycling concrete rubble for use in construction applications offers significant potential to enhance economic and environmental impacts. substantial provision can be achieved by converting recycled aggregate in concrete into beneficial resources to produce new concrete.

Jasmin M, 2020 [7] Investigated the effect of rubber particles from scrap tire crumbs passing through a 4.75mm IS sieve used in concrete on compressive, flexural and splitting tensile strength. The results showed that a 5% partial replacement of rubber inhanced workability, mechanical strength compared to regular concrete. However, partial replacement of rubber aggregates by more than 5% leads to a reduction in concrete strength compared to conventional concrete. This reduction increased with increasing rubber aggregate content. This loss of strength is attributed to a lack of adhesion at the boundaries of the rubber aggregate, soft rubber particles behaving like voids in the hardened concrete.

Kembhavi, 2014 [8] observed that the difference in the densities between conventional concrete and lightweight aggregate concrete with LECA is around 800-1000 kg/m^3. Hence, the results conclude that concrete with lightweight aggregates can be produced for the construction industry mainly to decrease the self-weight of the concrete in the multi-storied buildings.

Menhosh, 2018 [9] studied water penetration to test permeability of concrete by pressure water to one side of 150 × 150 × 150 mm concrete cubes subjected to pressure of 0.5 MPa for 3 days. After this time, the samples were taken out and divided in half. Then the distance of the water penetration in the concrete was recorded and the maximum water penetration distance was measured and considered. In the recent time, just about all contemporary concretes have one or more admixtures. It’s thus beneficial for civil engineers to be near with commonly used admixtures [10].

2. Design Mixtures and Components

2.1 Raw Materials

2.1.1 Cement

Cement Common which meeting the specification requirements of ASTM C150-15 [11] has been utilized in this paper. The materials test results were shown in Tables (1).

Table 1:Test results of the cement

Physical test results				
Test		Unit	result Test	ASTM C 150 -15 [11] Limits O.P.C- Type I
Initial Setting time		minute	149.00	45 - 375
Compression strength 3.0 days age 7.0 days age		MPa.	 15.70 23.60	 12.00 min. 19.00 min.
Chemical test results				
Composition		outcome		ASTM C 150 -15 Limits O.P.C- Type I
%	SiO_2	18.500		---
	Al_2O_3	04.100		---
	Fe_2O_3	02.700		---
	CaO.	46.900		---
	MgO.	03.660		6 max.
	C_3A	03.300		---
	SO_3	02.250		3.000 max.
L.O.I. %		02.750		3.000 max.
I.R. %		00.520		0.750 max.

2.1.2 Sand

Normal sand has been used in Basra city. The results of sand classification according ASTM C33-13 were shown below [10] limits, Table (2 and 3) shows the properties of the fine aggregate used.

Table 2: Grading of the sand used

Sieve (mm)	Percent Passing		
	Sand	Limits of (ASTM C33-13) [12]	
9.50	100.00	100	100
4.75	98.00	95	100
2.36	85.00	80	100
1.18	66.00	50	85
0.60	40.00	25	60
0.30	13.00	5	30
0.15	2.00	0	10
0.075	1.50	0	3

Table 3: Properties of the sand

Discerption	Result
Fineness Modulus	2.91

Specific gravity	2.65
Sulfate content (SO_3) %	0.33
Absorption %	1.2
Loose bulk density kg/m^3	1645

2.1.3. Gravel

A gravel ranged between 19 to 4.75 mm used from Basrah town. Gravel grading was presented in Table (4) according to ASTM C33-13 [12]. Table (5) shows the chemical properties.

Table 4: Grading of the gravel.

Sieve opening mm	Percent Passing		
	Gravel	ASTM C33-13	
25	100.00	100	100
19	95.00	90	100
9.5	41.00	20	55
4.75	6.00	0	10
2.36	3.00	0	5
0.075	0.60	0	1

Table 5: Physical and Chemical test results of the coarse aggregate.

Discerption	Result
Specific gravity (SG)	2.615
Sulfate content (SO3)	0.083 %
Chloride content (Cl)	0.097 %
Absorption	0.850 %
Loose bulk density(gravel) kg/m^3	1588
Loose bulk density(rubber) kg/m^3	432
Loose bulk density(volcanic) kg/m^3	1010

2.1.4 Partial replacement of coarse aggregate

By usage rubber tire parts and volcanic Aggregate as shown in Figure 1.

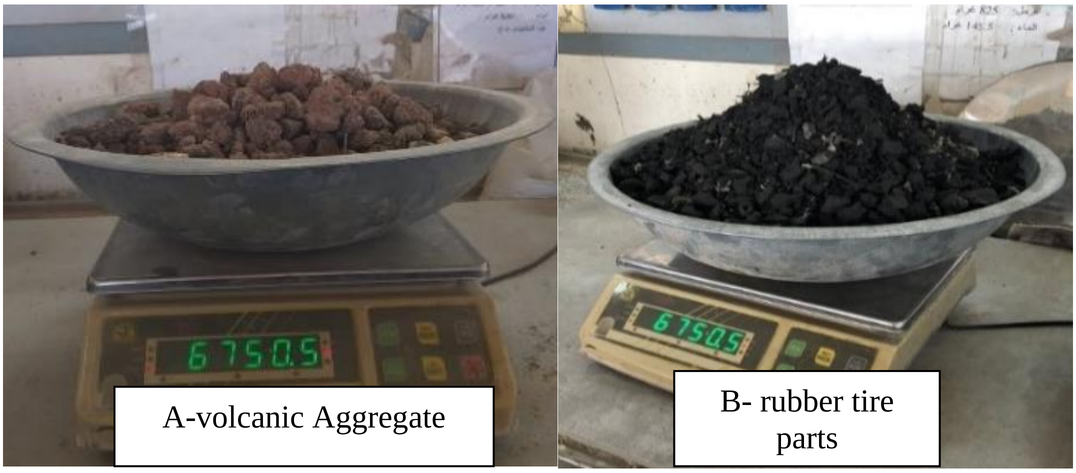

Figure 1: Sample of: A-volcanic aggregate, B- rubber tire part

2.1.5 Kut-plast IWP

Depended as Super plasticizing, high range water reducing admixture with properties as revealed in Table (6).

Table 6: Kut plast IWP admixture

Typical Properties	**Specifications**
Calcium chloride content:	Nil to BS 5075
Specific gravity:	1.22to 1.25 at 20°C
Air entrainment:	Less than 1%
Setting Time	Less than 2 hr
Cement combability	Compatible with sulphate resistance cement and other Portland ordinary cement

*From manufacturer

2.1.6 Styrene Butadiene Rubber SBR

The polymer was utilized styrene butadiene rubber (SBR) with characteristics as illustrated in the Table (7).

Table 7: Styrene butadiene rubber (SBR)

Description	test
Classification	Cementitious material
Color	White
Material Name	(S.B.R.)
Specific Gravity	1.00
Product kind	Admixture
Material Resistance	Abrasion resistant, Chemical & Water

*From manufacturer

2.2 Mixture Design

A mass ratio of 1:1.5:3 for Cement: Sand: Gravel has been used as a reference mix. The mix design adopted for the different types of coarse aggregates and admixtures are presented in Table 8

<table>
<tr><th rowspan="2">Trial W/C %</th><th rowspan="2">Used W/C %</th><th rowspan="2" colspan="2">Type of concrete</th><th rowspan="2">Cement %</th><th rowspan="2">Sand %</th><th rowspan="2">Gravel %</th><th rowspan="2">Replacement Gravel %</th><th colspan="2">Admixture %</th></tr>
<tr><th>SBR</th><th>Kut</th></tr>
<tr><td rowspan="2">35, 40. 45 and 50</td><td>45</td><td colspan="2">Normal concrete (Mix 1)</td><td rowspan="2">100 (424 kg/m3)</td><td rowspan="2">100 (636.36 kg/m3)</td><td>100 (1272 kg/m3)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>40</td><td>Modified concrete</td><td>(Mix 2) Rubber</td><td>85</td><td>15</td><td>4</td><td>1</td></tr>
</table>

						(190 kg/m3)			
			(Mix 3) Volcanic			85 (190 kg/m3)	15	4	1

Table 8: The mixtures designed

3. Experimental Work

Atrial mixes of various percentages of the W/C ratio were 0.35, 0.40, 0.45, and 0.50 to investigate the suitable W/C ratio for mixes designed of this investigation. 36 Cubes mould with dimensions 150×150 ×150 mm was prepared for compressive strength (BS EN 12390-3, 2019) [13]. and examined at age 7 and 28 days. For water penetration test same dimensions of compression have been conducted, and tests were done at age 28 days as shown in Figure 2 according to (BS EN 12390-8, 2019) [14]. Cubes with dimensions 100×100 ×100 mm prepared for water absorption test at 28 days age (BS EN 1881-122, 2011) [15].

Figure 2: Device of the water penetration test

4. Results

4.1 Slump Test

Slump test was performed according to BS EN 12350-2: (20019) [16], as shown in Figure 3. The results showed a clear change in the results of the slump test for different w / c ratios. The results observed the slump increase from 55 mm to 140 mm with an increase in the w/c ratio from 0.35 to 0.50, respectively. A clear effect of adding polymer on the workability. Depending on slump results, for this study, (W/C) ratio of 0.45 was adopted for normal concrete and 0.40 for modified mixtures 2 and 3 because of closed slump results for those mixes, as shown in Figure 4.

Figure 3: slump test

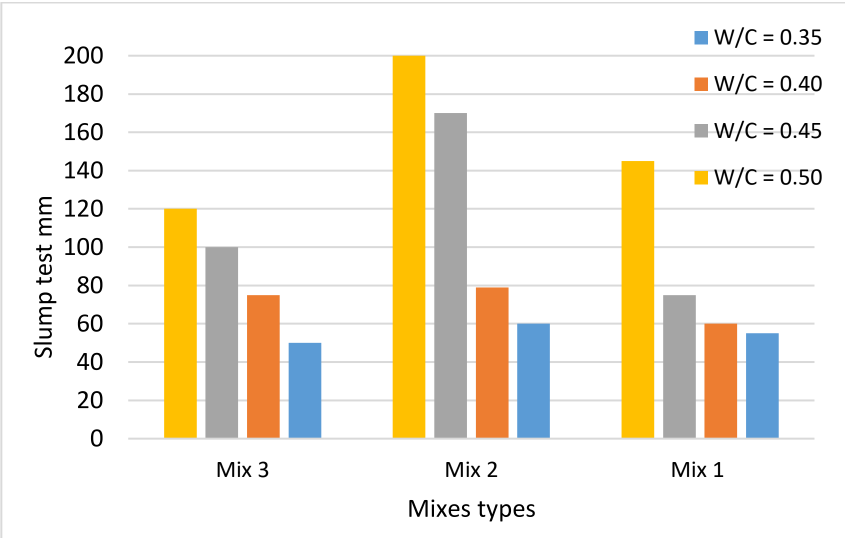

Figure 4: Slump values for the 3 concrete mixes

4.2 Compressive Strength

The results showed a clear improvement in the compressive strength of modified concrete by partial replacement of volcanic aggregate (Mix 3) compared with ordinary concrete. The increase in compressive strength was 10% and 20% for ages 7 and 28 days, respectively. Whereas for Mix (2), there was a decrease about 13% and 21% of the compressive of the modified mix by partial replacement with tires, compared to the conventional mix for ages 7 and 28 days, respectively, as shown in Figures 5 and 6.

Figure 5: compressive test

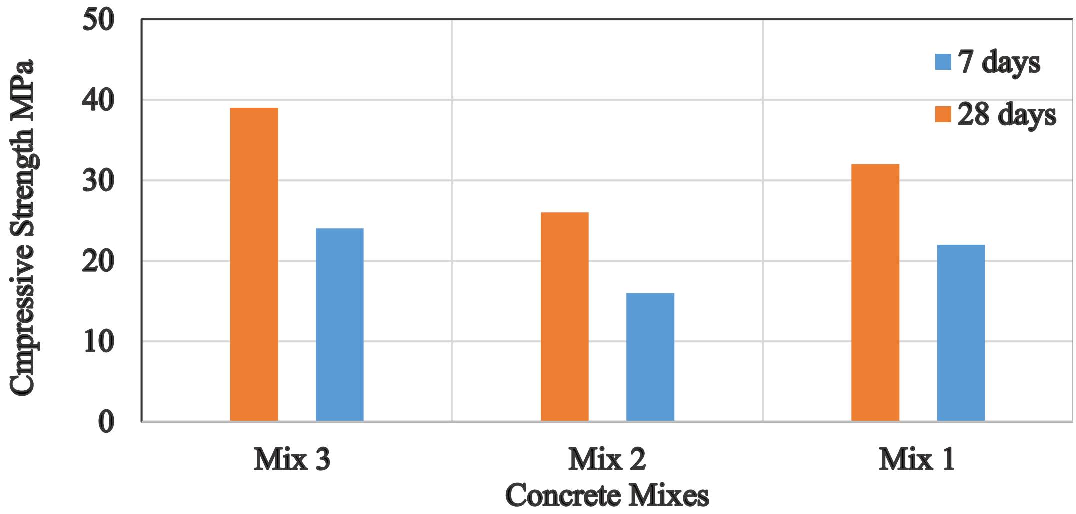

Figure 6: Compressive strength at ages 7 & 28 days

4.3 Water Absorption of Concrete

The results showed a clear advantage in the durability of concrete, as the presence of polymer and superplasticizer reduced the permeability of concrete by 2.9%, 1.4% for Mix2 and Mix 3 compared with the conventional mixture at age 28 days, respectively. Figure 7 and 8 illustrated water absorption for the three types of mixtures.

Figure 7: A- Water absorption test

Figure 7: B- Water absorption specimen test

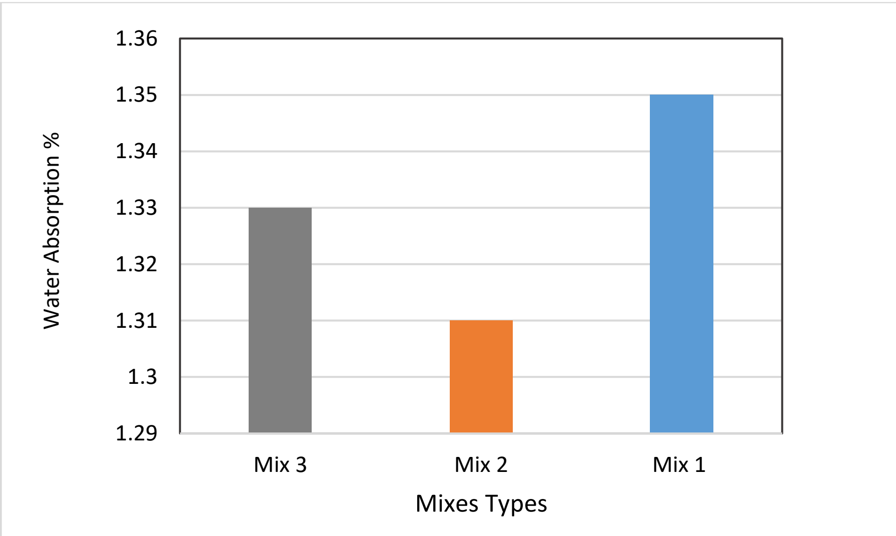

Figure 8: water absorption percentage at age 28 days

4.4 Water Penetration Test

The results observed an enhancement in the durability properties of modified concrete compared to ordinary concrete. Where the water penetration rate of the modified concrete mixes decreased by 40 and 30% for Mix 2 and 3 compared with the normal concrete mixture, respectively, as shown in Figure 9.

This may be attributed to use of styrene butadiene rubber and superplasticizer which modified complex of concrete.

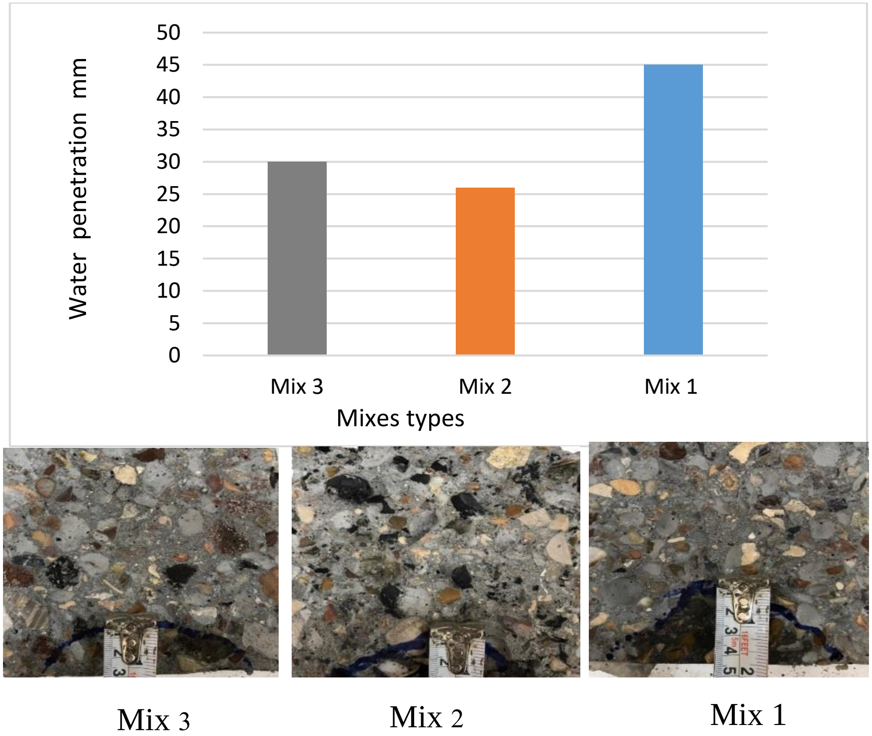

Figure 9: water penetration (mm) at age 28 days

4.5 Density Of Concrete

The results showed that the replacement of rubber tires and volcanic aggregates by 15% by the normal coarse aggregate reduces the weight of concrete by 12% and 9% compared to the normal concrete respectively, because of substituting partially of coarse aggregate by light wight materials. Figure 10 showed density of hardened concrete samples.

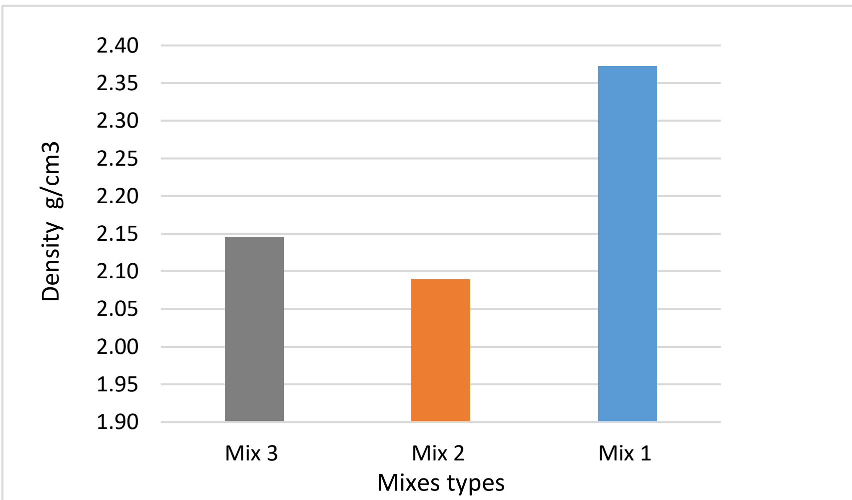

Figure 10: Density of hardened concrete

5. Discussion

By referring to Figure (4) a significant improvement in the workability as a result of adding the polymer and the superplasticizer. This improvement due to increase the cement setting time by delaying hydration process during first periods the mixing process, after that the polymer begins to crystallize forming connecting cement matrix which fill the bores of complex gel of cement paste and act as an adhesive to increase the bonding between the components of the concrete mix. This leads to an increase in the strength of concrete and a decrease in permeability to a certain extent is considered an improvement in the properties of concrete. whereas, the decrease in the compressive resistance of the concrete mixture modified with rubber pieces is attributed to the fact that the tire pieces are a compressible rubber material and have a high degree of flexibility compared to the components of the other mixture, which contribute to increase the internal strain of the concrete, causing internal stresses that lead to faster failure than in the modified concrete with volcanic aggregates and ordinary concrete, this performance is clear in Figures (6, 8 and 9). The used rubber pieces and volcanic rock as coarse aggregate take action as a low adsorption material, decreasing the amount of normal aggregate utilized in the mixture, this crucial role to improve the concrete performance. Nevertheless, making less pores thus prone cracking concrete with significant durability.

As indicated by Figure 10, the results demonstrated that replacing of the rubber tires and volcanic aggregates with gravel reduced the weight of the concrete compared to normal concrete especially for rubber tire using because of density decreasing for partially replacing of gravel by smallest amount of aggregate unit weight.

6. Conclusions

By studying the results, it can be summarized the conclusions as follows:

1- The slump test results of three mixes are reasonable and in close of the specifications range for construction.

2- The polymer SBR and the superplasticizer delay the setting time, which leads to improving the workability of the concrete mixture.

3- Referring to the mix with replacement ratio of volcanic gravel the use of polymer and superplasticizer improves the compressive strength of modified concrete compared to ordinary mixture by 20 % at age 28 day.

4- As expressed of the mix with replacement ratio of cutting rubber tire the utilizing of rubber tires as partial replacement from gravel reduces the compressive strength of modified concrete compared to ordinary mixture by 21 % at age 28 day.

5- The polymer reduces the permeability of modified concrete by partially replacing of the normal aggregate with volcanic aggregate and cutting car rubber tires compared to ordinary concrete by 40% and 30% respectively.

6- Partial replacement of coarse aggregate with volcanic aggregate or cut tires reduces the weight of hardened concrete, making it suitable for many applications in the field of moderate-weight concrete industry. However, the concrete produced with these aggregates can be used for the civil industry mainly to decrease the dead load of the concrete in the multi-story buildings.

7- The property of the mix modified by rubber pieces of tires is lower than of the conventional concrete despite the improvement of the properties of concrete for absorption and water penetration, which makes it suitable in applications exposed to wet and non-loaded weather conditions.

8- The consumption of spare tires used in the concrete industry contributes to reducing the negative environmental impact as a result of disposal by burning methods or the consumption of large areas for the purpose of storing their waste. Furthermore, the utilizing of rubber tires benefit in sustainability.

References

[1] Vineeta Nirmal, M. S. S., 2021. Experimental Study on Effect of Partially Replacing Coarse Aggregate. International Research Journal of Engineering and Technology (IRJET), 08(03), p. 1119.

[2] Neville, M. A., and Brooks, J. (1987). *Concrete technology* (2 ed.). England: Pearson education limited.

[3] M. RAMYA, S., 2020. EXPERIMENTAL STUDY ON LIGHT WEIGHT CONCRETE USING LECA. International Research Journal of Engineering and Technology (IRJET), 07(05), p. 391.

[4] Hesham A. Numan, M. H. Y. H. A. A.-J., 2019. Comparison Mechanical Properties of Two Types of Light. Civil Engineering Journal, 05(05), pp. 1105-1118.

[5] Ram Prasad A, S. S. V. M. N., S. T., S. M., 2019. Experimental Study on Light Weight Aggregate. Ramco Institute of Technology, Rajapalayam , International Journal of Engineering Research & Technology www.ijert.org.

[6] Safiuddin, Md, et al. "Use of recycled concrete aggregate in concrete: a review." Journal of civil engineering and management 19.6 (2013): 796-810.

[7] Jasmin M, H. H., 2020. Partial Replacement of Fine Aggregate in. International Journal of Engineering Research & Technology (IJERT), 09(03), pp. 620-625.

[8] KEMBHAVI, S. H. S. A. S. S., 2014. Light Weight Aggregate Concrete Replacing Conventional. International Journal of Earth Sciences and Engineering, 07(04), pp. 614-618.

[9] Menhosh, A. A., 2018. Long term durability properties of concrete modified with metakaolin. Construction and Building Materials, Volume 172, p. 41–51.

[10] LI, Zongjin, et al. Advanced concrete technology. John Wiley & Sons, 2022.

[11] ASTM C150-15 May, 2015. Standard Specification for Portland Cement. In: ASTM Test Designation. USA: ASTM International, p. 6.

[12] ASTM, S. C.-1., 2013. C33/C33M-13 (2013). Standard Specification for Concrete Aggregates.

[13] BS EN 12390-3: (2019): Compressive strength of test specimens. BSI: London, Testing Hardened Concrete.

[14] BS EN 12390 – 8: (2019): Depth of penetration of water under pressure. BSI: London

[15] BS 1881 -122: (2011): Testing concrete. Method for determination of water absorption,

BSI: London

[16] BS EN 12350-2: (20019): Testing fresh concrete. Slump-test, BSI: London