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**Original Research Article**

# Study on Utilization of Waste Tire Rubber Chip as Coarse Aggregate with Mineral Admixture in Concrete

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## Abstract

The research has shown that use of tire rubber as coarse aggregate in Reutilization of waste tire material can help reduce the environmental pollution, generated each year in Oman's landfills, where tire waste is often improperly or illegally disposed of. The number of vehicles over the decade has increased considerably, and the need to identify feasible solutions to minimize tire waste is needed. The aim of this project is to identify the optimal use of waste tire rubber as coarse aggregate by partial replacement of 10%, 15%, and 20% with micro silica in the concrete. The objective of this research study is to determine and evaluate the fresh and hardened properties of the concrete. The micro silica replaced the cement by 10%, 20% in the first experiment to determine if micro silica improved the strength in the concrete. Additionally, in the second experiment, the tire rubber was treated in NaOH solution to determine the bonding improvement between the rubber and cement, while using the same replacement ratio. The mix design was developed for C35 strength for both experiments. Using 150X150X150mm cube moulds a total of 28 cubes were casted and cured for 28 days under normal conditions. The mix proportion used is 1: 1.73: 2.2 with water cement ratio of 0.47. The objective of this research is to determine the fresh and hardened properties of concrete under the influence of rubber and mineral admixtures. The results of the experiments showed a reduction in compressive strength as tire rubber content increased when compared to control mix. However, the tire rubber treated in NaOH solution yielded slightly better compressive strength results overall. Furthermore, as the tire rubber content increased a reduction in the workability and weight of the concrete was observed and recorded. The results revealed that the optimal replacement ratio is 20% silica fume + 10% tire rubber, yielding the highest compressive strength among all specimens tested irrespective of the rubber tire. However, the strength did not exceed the control mix. Therefore, when considering both the economic and environmental perspectives, there is an opportunity to utilize waste tire rubber in concrete for non-structural and non-load bearing applications.

**Keywords:** Rubberized Concrete, Tire Rubber, Workability, Compressive Strength, Sodium Hydroxide, Waste Management.



## PROBLEM STATEMENT

Growing issue of tire waste in Oman, as we look towards finding efficient ways to provide a sensible solution to reduce the waste generated in the landfills. Tire waste amongst other waste is non-decaying waste material that will remain in the landfills for hundreds of years. This waste material has been causing a disposal crisis around the world, thereby impacting the environment further. Figure 1.1 below illustrate tire graveyard located in Kuwait, the stockpile was captured from space.

**Fig-1.1: Stockpile captured from space**

Extensive studies and research have been made to find alternate solutions to better utilize waste materials. In Oman, research to find suitable solutions to reduce the tire waste in the country is lacking. Discarded tires are harmful to the environment and are not bio-degradable; they are also health hazards affecting the ecosystem. The stockpiles of tire can pose a severe fire risk due to negligence.

**Fig-1: Typical Graveyard Stockpile in the GCC**

Figure 1 shows the typical graveyard for discarded tires in the GCC. This can have substantial impact to environment if the issue remains unaddressed, therefore alternate solutions to address the waste management problem to significantly reduce the waste material globally and within the region are needed.

Over the years, Oman has seen a boom in the construction industry, major development expansion in the infrastructure such as wastewater treatment plants, storm water drainage, express highways and airports, to meet the growing population. Concrete plays a very important role in these developments and used by all construction sites globally. Though the use of tire rubber in concrete is been studied for many years, tire rubber contributes to environmental preservation, it is not widely used in concrete due to its poor strength performance.

However, the scope of the study is to investigate the potential use of tire rubber in concrete as partial replacement for aggregate. The tire rubber for this study was collected from a local car workshop. The research study conducted over period of 10 weeks, to investigate the effects of the tire rubber on the fresh and hardened properties in concrete during which two separate experimentations were developed in the study using two different samples of rubber namely Untreated Tire Rubber (UTR) and Treated tire rubber (TTR). Twenty eight concrete test specimens were cast and then cured for 28 days under normal condition. Afterwards, the cubes tested at college lab facility using the UTM equipment;

## OBJECTIVES

The study was prepared to investigate the following objectives of this research:

- To develop the mix design using the ACI method of mix proportion
- To determine suitable replacement ratio and enhance the waste rubber tire chip strength in the concrete when adding micro silica.
- To investigate the effects of NaOH on treated waste tire rubber chip in enhancing the bonding between the tire rubber and cement to the concrete.
- To evaluate the workability and weight reduction of the tire rubber concrete.

## LITERATURE REVIEW

Disposal of waste tire in the GCC is a major waste management problem, which is adversely impacting the environment. It been reported that some countries around the world have banned the disposal of waste tire in landfills, and those same countries are finding alternate solutions to reduce the waste. Many studies have been conducted on finding feasible solutions which can help reduce and control the waste. A research was done to find potential application of waste tire in civil engineering projects.

Investigating the workability when introducing the tire rubber in concrete, reported that there is an increase in the slump value. However, other researchers have found a decrease in slump with an increase in rubber content Furthermore, it was mentioned that rubber contents above 30% of total aggregate volume, the concrete was not workable manually [1].

In another study it was indicated that when mineral admixture is introduced along with the mixture, it decreased the workability [2]. A research work reported that the shape, size and the surface of the tire aggregates are smoother than the traditional gravels, resulting in slight improvement in workability. However, those studies that found improvement in the workability, where using fine crumb rubber which had better workability than those with larger tire rubber. It was also noted that since the behavior in workability changes as the rubber tire is introduced to the mixture, the W/C must be increased to overcome issues on the workability [3].

An experimental study showed that replacing the fine and coarse aggregate by weight using different percentage gave the concrete ductility and plastic failure as oppose to brittle failure [4].Research work also exhibited similar compression failure, indicating that the mode of failure was a gradual type. Both results were observed during the compressive load test. Reason for this is that rubber tire aggregate has elasticity properties and can absorb energy better than normal aggregate, therefore allowing the specimen to absorb the energy better than the normal controlled specimen [5].

A study carried out on modification of the tire rubber surface has suggested an attempt to address this issue [6]. In study carried out by researcher's treatment on rubber was done using NaOH (sodium hydroxide) to modify the surface of the tire rubber. The tire rubber was soaked in the NaOH solution for 20min and then used in the concrete mix. The results of their study showed the NaOH treatment enhanced the bonding of tire rubber with cement paste, and slightly increased the result of the compressive strength. The weak bonding is the primary cause in the reduction of strength, although the NaOH treatment has shown to improve bond between tire rubber and cement in the concrete [7].

Durability of concrete is determined by performing water permeability test. The permeability of concrete is essential to prevent against environmental conditions, which can cause concrete failure. Water permeability test was conducted on the concrete mixtures containing the rubber aggregate. The result showed the water permeability depth was higher, due to the reduction in the bonding between particles in the concrete mixtures. The results of the water absorption were also very high, but when compared to rubber powder concrete mixture water absorption was reduced. Its reduction in water absorption was due in part, to the fillings of voids with powder, but the depth water penetration was still high [8].

Compressive strength of replacement tire aggregate in concrete has been reported by several researchers. The results of the studies show that the compressive strength of tire rubber mixtures is affected by the size, proportions, and surface texture.. It was reported that the when the percentage of the rubber chip aggregate increased into the concrete, the flexural strength of beam decreased. This indicates weak bonding between the rubber and cement paste, due to concretes low tensile strength as compared to it compressive strength. During the flexural strength test the sample undergoes tensile strength on one side and compressive strengthen on the other [9]. Sodium Hydroxide (NaOH), is a highly caustic substance, when dissolved in water, is very corrosive, making it a suitable substance to modify the surface of the tire rubber aggregate, in the attempt to improve the interfacial transition [10].

## METHODOLOGY

As early mentioned the quantitative approach method was adopted for this study, to collect data and analyze the results by performing an experiment. Therefore, the flow chart in Figure 2 below in was constructed to illustrate and describe the research methodology path developed for the recent study.

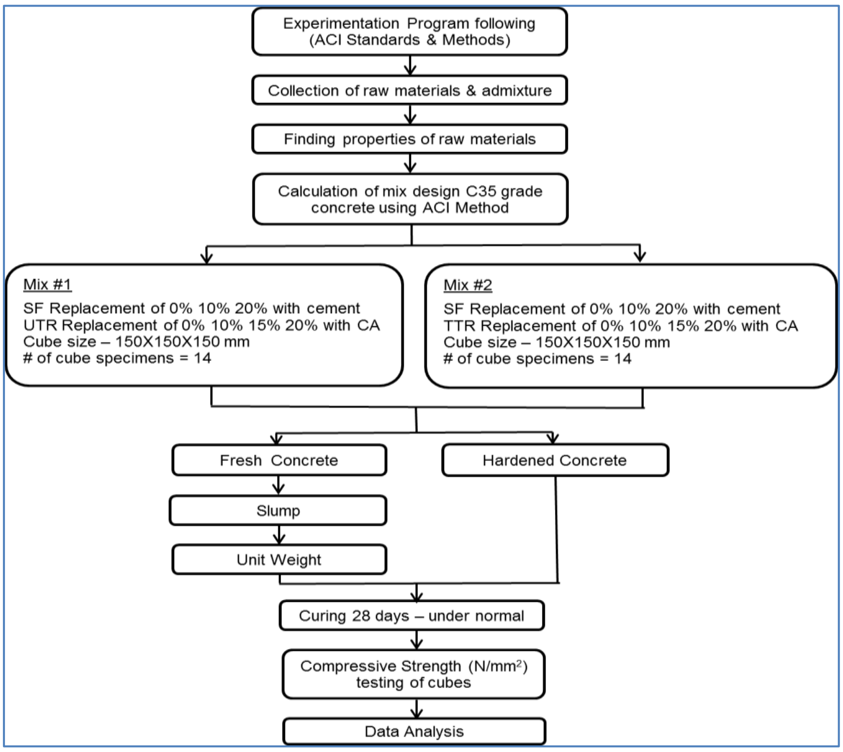

**Fig-2: Methodology Flow Chart**

The basic raw material used in this experiment were Ordinary Portland cement (Cement Type I), Coarse Aggregate (provided by the Caledonian College Lab), Fine aggregate (provided by the Caledonian College Lab), fresh potable water, tire rubber (obtained from local car workshop) and

 

Sodium Hydroxide (NaOH) (obtained from Chemistry for Life LLC). All equipment used for this experiment was supplied by the Caledonian College of Engineering.

**Cement**

Cement is the most important building material in the world and does a soft bonding material that hardens, thus possess the joints and cohesion of the presence of water, which makes it able to connect the components of concrete to each other.

**Fine Aggregates**

In general, it consists of powdered rocks or natural sand, so that the granules of this total can pass through the sieve with openings under 5 mm diameter

**Coarse Aggregates**

It is the residual on a 5mm sieve, according to the approved standard, and contains the percentages allowed in this standard of course materials

**Waste Tire Aggregates**

Waste tire aggregate chip were obtained from a local car workshop. The discarded tires were selected and chopped into pieces manually at the workshop, size of 20mm to replace the coarse aggregate in the current study (Figure 3).

**Fig-3: Tire Rubber Aggregate 20mm**

**Fresh Water**

Water will be obtained from municipality governed by the Ministry of Water & Resources in Oman. The ministry ensures that quality tested water is suitable for construction purpose, free from pollutants and other contaminates.

**Admixtures – Micro Silica or Silica Fume (SF)**

The micro silica (silica fume) was obtained from Oriental Concrete Ready-mix LLC (Figure 4). The weight of the bag is 25kg. Micro Silica is used as pozzolanic admixture to strengthen the concrete, and achieve desirable results.

**Fig-4: Micro Silica (Source: Oriental Ready Mix - LLC)**

**Fig-5: Sodium Hydroxide (NaOH)**

The sodium hydroxide was obtained from Chemistry for Life LLC (Figure 5). In the experiment, 1 molar of NaOH = 0.040 grams – diluted in one litre of water, the tire rubber was soaked in the solution for 20 minutes.

**Mix Design Calculations for C30 Concrete Grade According to the (ACI)**

In this study OPC concrete was formulated to the strength grade C-35. The ACI Method of Mix Proportion was used to prepare the concrete mix design in this study.

The mix proportions for 1m$^3$ of concrete mix is shown in Table and the mix design ratio of 1: 1.73: 2.2 with W/C of 0.47 for concrete grade strength of C-35 as shown in Table 1. The mix design ratio is shown in Table 2 and quantities for each specimen are seen in Table 3 which was calculated based on the derived mix design used in the study.

**Table-1: Mix Proportions for 1m³ of Concrete Mix**

| Materials | Concrete Grade C-35 |
|---|---|
| Cement (OPC) | 436.1 kg / $m^3$ |
| Fine Aggregate (Sand) | 755.7 kg / $m^3$ |
| Coarse Aggregate | 960 kg / $m^3$ |
| Water | 205 kg / $m^3$ |
| W/C | 0.47 |

The concrete mix design for this study was developed in accordance to the ACI Method of Mix Proportion:

- Characteristic compressive strength required @ 28 days - C 35
- Maximum size of aggregate — 20 mm
- Fine Aggregate - Uncrushed
- Course Aggregate — Angular - Uncrushed
- Tire Rubber Chip – 10mm to 20 mm max.
- Degree of workability – Slump 75 – 100mm
- Type of cement: Ordinary Portland Cement – 42.5

**Table-2: Mix Design Ratio**

| Ingredients | Cement | FA | CA | Water |
|---|---|---|---|---|
| Quantity (kg/$m^3$) | 436.1 | 755.7 | 960 | 205 |
| Ratio | 1 | 1.73 | 2.2 | 0.47 |

**Table-3: Mix proportion of quantities used in the experiment**

| SI | Cement (kg) | % of replacement SF | SF (kg) | FA (kg) | CA (kg) | % of replacement TTR | TTR (kg) | Water (ltr) |
|---|---|---|---|---|---|---|---|---|
| 1 | 3.1 | 0% | 0 | 5.30 | 6.77 | 0% | 0 | 1.45 |
| 2 | 2.79 | 10% | 0.31 | 5.30 | 6.09 | 10% | 0.68 | 1.45 |
| 3 | 2.79 | 10% | 0.31 | 5.30 | 5.75 | 15% | 1.02 | 1.45 |
| 4 | 2.79 | 10% | 0.31 | 5.30 | 5.42 | 20% | 1.35 | 1.45 |
| 5 | 2.48 | 20% | 0.62 | 5.30 | 6.09 | 10% | 0.68 | 1.45 |
| 6 | 2.48 | 20% | 0.62 | 5.30 | 5.75 | 15% | 1.02 | 1.45 |
| 7 | 2.48 | 20% | 0.62 | 5.30 | 5.42 | 20% | 1.35 | 1.45 |

**Preparation of concrete mix and casting of cube**

In accordance to relevant studies conducted the decision to carry out the experimentation was based on the collective ideas and extensive research, therefore the preparation of the specimen was developed in the following manner:

Strength C35 – OPC cement

Number of cubes per batch =2
SF replacement with cement - 0%, 10% and 20% TR replacement with CA - 0%, 10%, 15% and 20%

**Experiment Procedure**

The experiment was initiated by setting up the cubes and shuttering oil was applied to all cube molds before casting and cleaned properly as shown in Figure 6.

**Fig-6: Application of shuttering oil to cube samples**

Mixing of the ingredients of concrete was done by mixer machine for 2-3 minutes to ensure proper mixing as shown in Figure 7.

**Fig-7: Process of mixing ingredients of concrete**

**Slump**
**Cone Test**

Concrete was transferred from the mixer to tray and the mixed manually by hand to avoid segregation; 4-5 passes with trowel for each batch was conducted. The slump cone was filled in three equal layers, tamped down 25 times for each layer with tamping rod and measured as shown in Figure 8 & 9 respectively.

**Fig-8: Concrete compaction in slump cone**

**Fig-9: Measurement of slump**

**Cube Casting Process**

The concrete was then transferred to the cube mould by filling the concrete in 3 equal layers, compacting each layer 25 times using a tamping rod and smoothening the top surface with a trowel, for each cube specimen as shown in Figure 10, 11 and 12. Labels applied to each cube batch with paper note – (student name, number, and date, type) to avoid misplaced sample.

**Fig-10: Transfer of concrete to cube molds**

**Fig-11: Cubes casted and smoothened**

**Fig-12: Cube Samples labeled**

After 24 hr the cube were removed from their moulds and placed in water tub for 28 days under normal conditions, refer to section 3.4.6 - Curing Method. The study involved two experiments and a total of 28 cube specimens were casted for this experiment following the procedures and guidelines outline in the above section.

 

**Pretreatment of Tire chips using NaOH Solution**

In Mix #2, the tire rubber was treated in the NaOH solution; therefore preparation of the tire rubber was conducted. Health and safety procedures were followed during the application of NaOH on the tire rubber. NaOH becomes an acidic solution when diluted in water and precaution was taken to avoid injury. Preparation of 1 Molar – 40 grams of NAOH pellets were placed in a plastic container, then 1 ltr of water was added into the container. The pellets were then diluted by mixing the solution with a hand trowel, until all pellets were dissolved as shown in Figure 13. Once dissolved the 1 kg of tire rubber was placed in the container and soaked in solution for 20 min. As suggested in the literature review, research suggests that treating the tire rubber in the NaOH solution will enhance the bonding between the tire rubber and cement. This bonding will provide better strength results in concrete, when using tire rubber.

**Fig-13: Dissolving NaOH pellets in water**

**Curing Method**

Curing of the cube specimen took place in the lab testing facility at the Caledonian College. After 24hr of casting the concrete, all test cube specimens were removed from the moulds and immersed into the water tub as shown in Figure 14. All samples were marked and labeled; after 28 days of curing completed the samples were brought to the UTM lab testing facility to carry out the compressive strength testing.

**Fig-14: Specimen curing process**

**Compressive Strength Testing**

The compressive strength of the specimens was conducted using the UTM testing machine in the College. This method of testing is in accordance to the standard method of compressive strength and is used by the industry. The compressive strength tests can be seen in Figure 15 & 16.

**Fig-15: UTM Testing Machine**

**Fig-16: Load applied on the cube**

## RESULTS AND DISCUSSION

Properties of fresh concrete were determined by analyzing the slump test and weight results which were obtained from the experimentation in accordance to ACI standards for concrete testing. The recorded measured values of the slump for Mix #1 – UTR and Mix #2 - TTR corresponding to their respective mix designation and replacement of SF and TR are shown in Table 4 below.

**Table-4: Measured slump values for UTR & TTR**

| Mix designation | % of replacement | k #1 - UTR (mm) | k #2 – TTR (mm) |
|---|---|---|---|
| A1 | Control Mix | 95 | 95 |
| A2 | 10% SF + 10% TR | 87 | 90 |
| A3 | 10% SF + 15% TR | 81 | 86 |
| A4 | 10% SF + 20% TR | 74 | 80 |
| A5 | 20% SF + 10% TR | 71 | 77 |
| A6 | 20% SF + 15% TR | 65 | 72 |
| A7 | 20% SF + 20% TR | 60 | 66 |

Figure 17 below show that as the TTR content increased in the concrete the slump and workability reduced. The concrete mixes were designed to have a slump value between 75-100mm; however mixes with 20% SF had a slump less than 75mm. The mix with the UTR replacement showed slightly lower values in slump in comparison to TTR as shown. Previous research indicates similar results and the reduction of workability is determined by the shape and size of the TTR rubber.

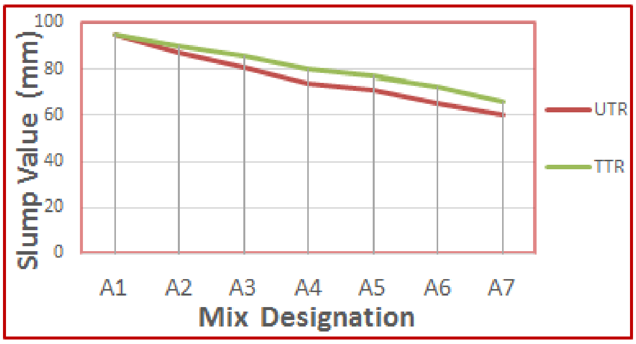


**Fig-17: Slump Values of various mixes**

In Table 5, the UTR compressive strength results for 28 days have been recorded for each mix designation and their respective replacement ratios. The average compressive strength for each cube specimen has been recorded, the unit in ($N/mm^2$).

**Table-5: UTR Compressive strength results for 28 days**

| Mix designation | Partial Replacement of Cement with SF and CA with UTR | Average Compressive Strength of Cubes ($N/mm^2$) |
|---|---|---|
| A1 | Control mix | 38.6 |
| A2 | 10%SF + 10% UTR | 31.55 |
| A3 | 10%SF + 15% UTR | 26.64 |
| A4 | 10%SF + 20% UTR | 20.3 |
| A5 | 20%SF + 10% UTR | 33.4 |
| A6 | 20%SF + 15% UTR | 29.2 |
| A7 | 20%SF + 20% UTR | 24.54 |

The compressive strength results of the tire rubber concrete at 28 days when compared with the normal controlled mix show a gradual reduction in strength for both experiments. When compared to the control mix the replacement of (10%SF + 20% UTR) incurred a loss of compressive strength by nearly 42%, the result can be seen in Figure 18. This confirms that loss of strength in the concrete is imminent.

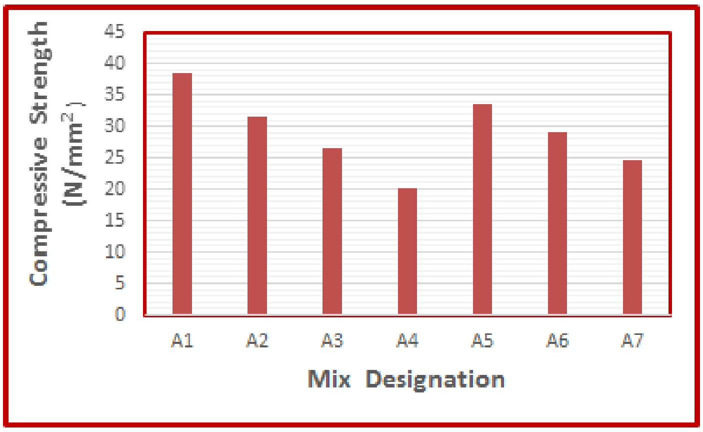


**Fig-18: UTR Compressive strength for 28 days**

In Table 6, the TTR compressive strength results for 28 days have been recorded for each mix designation and their respective replacement ratios. The average compressive strength for each cube specimen has been recorded, the unit in (N/mm$^2$).

**Table-6: TTR Compressive strength results for 28 days**

| Mix designation | Partial Replacement of Cement with SF and CA with TTR | Average Compressive Strength of Cubes(N/mm$^2$) |
|---|---|---|
| A1 | Control mix | 38.6 |
| A2 | 10%SF + 10% TTR | 35.3 |
| A3 | 10%SF + 15% TTR | 29.5 |
| A4 | 10%SF + 20% TTR | 25.2 |
| A5 | 20%SF + 10% TTR | 37.15 |
| A6 | 20%SF + 15% TTR | 32.22 |
| A7 | 20%SF + 20% TTR | 27.85 |

In, Figure 1 9 the concrete specimen with (20%SF + 10% TTR), had the highest compressive strength of 37.15 N/mm$^2$ overall amongst the other specimens, but nonetheless it remained lower than the control mix. It was noted that specimens containing 20% SF admixture showed increase in compressive strength, when compared with specimens of only 10% SF. Furthermore, the mixes containing (10% SF + 10 % TTR) & (20%SF + 10% TTR) had compressive strength above strength grade C35. This result demonstrates that the TTR improved the bonding between the treated rubber and cement within the mix.

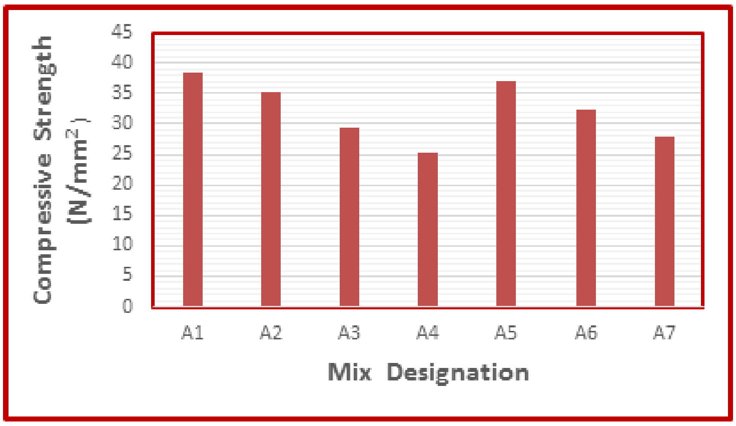


**Fig-19: TTR Compressive strength for 28 days**

In Table 7, the comparisons of UTR & TTR compressive strength results for 28 days have been recorded for each mix designation and their respective replacement ratios. The average compressive strength for each cube specimen has been recorded, the unit in (N/mm$^2$).

**Table-7: Comparison of UTR &TTR compressive strength results for 28 days**

| Mix designation | Partial Replacement of Cement with SF and CA with TR | Mix #1 Average UTR Compressive Strength (N/mm$^2$) | Mix #2 Average TTR Compressive Strength (N/mm$^2$) |
|---|---|---|---|
| A1 | Control mix | 38.6 | 38.6 |
| A2 | 10% SF + 10% TR | 31.55 | 35.3 |
| A3 | 10% SF + 15% TR | 26.64 | 29.5 |
| A4 | 10% SF + 20% TR | 20.3 | 25.2 |
| A5 | 20% SF + 10% TR | 33.4 | 37.15 |
| A6 | 20% SF + 15% TR | 29.2 | 32.22 |
| A7 | 20% SF + 20% TR | 24.54 | 27.85 |

Figure 20 shows an overall increase of the compressive strength in concrete containing TR treated with the NaOH solution as compared to untreated tire rubber concrete specimens. As suggested in previous research that TR treated with NaOH will experience better bonding with cement paste in the concrete mix, therefore the results in this study indicate similar outcome has taken place.

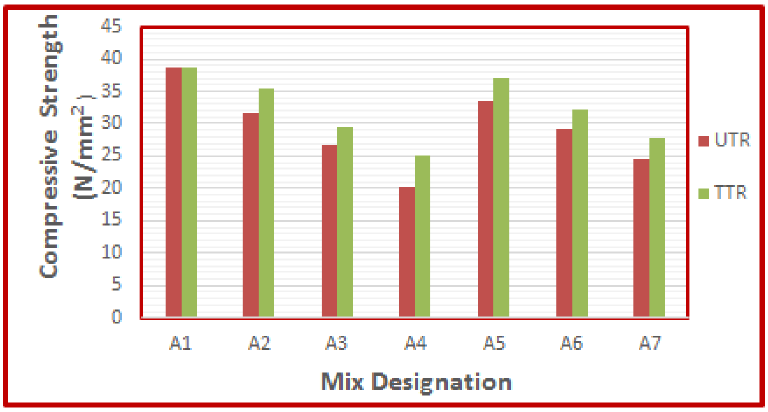


**Fig-20: Comparison of UTR &TTR compressive strength at 28 days**

## CONCLUSION

This study investigated the utilization of waste tire rubber as coarse aggregate with mineral admixture in concrete.

- Results show that slump value decreased when replacement ratio of SF and TTR increased in the concrete affecting the workability of concrete.
- The compressive strength of the tire rubber concrete compared with the normal controlled mix shows reduction in strength.
- Positive effect on the compressive strength of concrete treated with the NaOH solution when compared to untreated tire rubber concrete cube specimens.
- The TTR specimens showed higher compressive strength results when compared to UTR specimens.
- The optimal replacement percentage in concrete is observed (20% SF+10%TTR), strength of 37.15 N/mm$^2$ when compared with other replacement ratio.
- Results indicate that concrete mixes containing (UTR and TTR) are suitable for Non-structural applications.

## REFERENCES

1. Kotresh, K.M., & Belachew, M.G. (2014). Study on Waste Tire Rubber as Concrete Aggregates. *International Journal of Scientific Engineering and Technology*, *3*(4), 433 – 436.
2. Porwal, V., & Dwivedi, R. (2016). Studies on Tire Aggregate Concrete with Fly Ash. *International Journal of Science and Research*, *5*(8): 708-711
3. Boudaoud, Z., & Beddar, M. (2012). Effects of Recycled Tires Rubber Aggregates on the Characteristics of Cement Concrete.*Open Journal of Civil Engineering*,193-197
4. El- Gammal, A., Abdel –Gawad, A. K., El - Sherbini, Y., & Shalaby A. (2010).Compressive Compressive Strength of Concrete Utilizing Waste Tire Rubber. *Journal of Emerging Trends in Engineering and Applied Sciences*, *1*(1): 96-99
5. Ali, A. M., & Sarvanan, A. (2015). Experimental Study on Concrete by Partial Replacement of Fine Aggregate with Crumb Rubber. *International Conference on Engineering Trends and Science & Humanities*, 60-65
6. Albano, C., Nelson, Jacobo., & Feliu, J.L. (2005). Influence of scrap rubber addition to Portland I

concrete composites: Destructive and non-destructive testing. *Composite Structures*, 71:439-446.
7. Deshpande, N., Kulkarni, S.S., Pawar, T., & Gunde, V. (2014). Experimental investigation on strength characteristics of concrete using tire rubber as aggregates in concrete. *International Journal of Applied Engineering*, *4*(2), 97-108.
8. Ganjian, E., Khorami, M., & Maghsoudi, A.A., (2008). Scrap-tire-rubber replacement for aggregate and filler in concrete. *Construction and Building Materials*, 1828-1836
9. Shah, S.N., Jadhao, P.D. & Dumne, S.M. (2014). Effect of chipped rubber aggregates on Performance of Concrete. *American Journal of Engineering Research*, *3*(12), 93-101.
10. PubChem. (2017). National Center for Biotechnology Information. https://pubchem.ncbi.nlm.nih.gov/compound/14798. [Accessed: 15 th May, 2017].