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Partial Replacement of Fine Aggregate with Waste Rubber Tyre and Coarse with Recycled Aggregate in Concrete

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Abstract
The production of rubber tyre increase with rising number of vehicles. The urbanization and industrialization lead to more production and use of rubber tyre. The used rubber tyre from vehicles ultimately the waste rubber tyre as by product. Rubber has high calorific value, so it could be used as fuel by burning. The major side effect has release of greenhouse gases by burning. Also the demolished waste in the Nepal, after Gorkha earthquake has high. The concrete demolished has been causing the major problem's in the waste management. The rubber tyre has breading places for mosquito and has non-biodegradable waste material. The use of both waste material as replacement of coarse with recycled aggregate at rate of 0 percentage, 10 percentages, 20 percentages, 30 percentage and fine aggregate with rubber tyre dust(1.18 mm or less) at rate of 2.5 percentage up to 12.5 percentage could be best solution. The concrete mix design was done for the M20 Mpa as per Indian standard. The workability, compressive strength and split tensile strength were determined. The split tensile strength of concrete was found to increase up to certain percentage replacement of fine aggregate with rubber tyre dust.

Keywords
Partial, Rubber tyre, Recycle aggregate, Porosity, Void

1. Introduction

Concrete has been widely used material in construction, so the depletion of the natural resources could be the future problems. As the demand of the construction materials increased, the cost of construction material rises up. The use of recycled aggregate could be the appropriate solution for environmental friendly construction materials. The use of recycled aggregate has produced green concrete and have positives impacts towards saving the environment. This could lead to some useful management of waste tyre and demolished waste materials.

The rubber tyre demand increased day by day as the urbanization and industrialization increases more rapidly. The peoples of the urban areas need more and more vehicles for daily lifestyle. The use of more vehicles has skyrocketed the scrap rubber tyre. The increased rubber tyre from rapid growing of vehicles (from urbanization) has posed great challenge for disposal. The scraped tyre has threat to environment, health and aesthetic due to its bulky, non-biodegradable and good place for mosquito breading. The various attempts has been adopted for proper utilization and disposal of scrap tyre.

So, by partial replacing the natural resource in the concrete with recycled coarse aggregate and rubber tyre as fine aggregate,could reduce the cost of construction and minimize the load of dumping material into landfill. The use of the waste rubber tyre could be environmental friendly solution for the disposal of the demolished waste and rubber tyre.

2. Statement of problem

The increasing urbanization and use of more vehicles for daily life could lead to produce more waste rubber tyre. The waste tyre has non- biodegradable nature which posed serious environmental, health hazards and land fill problems. The use of huge natural resources in the construction could lead to the scarcity of materials for the construction in the future.

Ultimately, the cost of construction materials got increased as demand of natural resources increased. The use of the waste rubber tyre and recycled aggregate could be the possible solution for this.

3. Objectives

1. To determine the compressive and split tensile strength of concrete by using rubber tyre waste as partial replacement of fine aggregate.
2. To determine the compressive and split tensile strength of concrete by using rubber tyre as partial replacement of fine aggregate and recycled aggregate as partial replacement of coarse aggregate.

4. Scope

The environmental friendly construction materials become the demanding situation to adopt with changing environment. The use of natural aggregate from the river, caused the serious warning in the river bed erosion. The waste rubber tyre and recycled aggregate management could have challenging situation. So, the proper utilization and management migth could lead to best possible solution. The use of these waste in construction industry might minimized environmental and land fill effects. The waste tyre has non-biodegradable material, so its proper utilization without polluting environment and health hazards could be, used these waste in the construction materials. Finally,it reduced the use of the natural construction materials.

5. Literature review

The waste rubber tyre and demolished aggregate could be used in the construction by partially replacing natural resources. The demolished waste of the building has major waste management problems in Nepal after Gorkha earthquake. The use of such building waste in construction could reduce the use of natural resources in construction. Also, it might lead to the successful management of the demolished waste and environmentally friendly construction. Waste rubber tyre has major polluting matter when used as fuel for different purposes and produces carbon dioxide and others toxic gases. Hence, waste tyre could have better use in the construction as partial replacement of fine and coarse aggregate.

Although using of rubber won't play any role in increment in concrete properties, but this may be used to increase the volume of concrete as the actual coarse aggregate materials such as stones and other building material volume can be reduced. Even by utilization of rubber as coarse aggregate the unit weight of concrete reduced. Utilizing the rubber as coarse aggregate makes an opportunity to reuse, recycling of rubber which has been hazardous to dispose or burn in environment [1]

The fine aggregate was replaced with 4.75 mm to 0.075 mm rubber dust. Replacement fine aggregate 5 percentage to 30 percentage reduction in compressive strength was 0.7 percentage to 78.95 percentage. Mohammed, concluded that rubber could be used in producing of members/products that can be used in improving life quality of habitants due to its high sound absorption, high electrical resistivity and lower thermal conductivity [2].

The partial replacement of fine aggregate with rubber tyre at 2.5 percentage, 5 percentages, 7.5 percentage result showed that compressive strength decrease where as tensile strength at 2.5 percentage was appreciable increase. The flexural strength was decreased with rubber tyre. So,result showed replacement of fine with rubber tyre at 2.5 percentage was found to be suitable [3].

They studied for M 25 grade concrete by replacing coarse aggregate with rubber 10 percentages, 20 percentages, 30 percentages by weight. The result showed that workability of concrete decreases as the percentage of rubber increased. The compressive strength for 0 percentage, 10 percentages, 20 percentages, 30 percentages at 28 days was 35, 32, 28, 22 MPa respectively. This showed that compressive strength decreased with increasing the percentage of rubber. The unit weight of concrete was decreased as percentage of rubber increased, so it could be used as light concrete [4].

The fine and coarse aggregate were partial replaced with 25 percentages, 50 percentage, 75 percentage by volume with rubber. This showed that, decreased in the compressive strength more in case of coarse aggregate 47.8 percentage, 54.4 percentage 61.9 percentage and less in case of fine aggregate 24.7 percentage, 28.3 percentage 37.1 percentage respectively. The slump was decreases with increased in the percentage of rubber tyre. The slump for 0 percentage, 20 percentage, 40 percentage, 60

percentage, 80 percentage, 100 percentage was 75, 61, 36, 18, 10, 5 mm respectively [5].

5.1 Rubber tyre

Rubber tyre has solid waste, its disposal poses environmental threat due to its non-biodegradable nature. Disposal of waste rubber tyre caused environmental, aesthetic and health related problems to the surroundings. If it could be dumped in the environment, causing landfill problems with high risk of health hazard such as risk of fire, provide shelter to harmful insects, rodent and animals (such as rats, mosquitoes, snakes, mice etc). [2].

Rubber has lower specific gravity than other solid material in the concrete. The results showed, that unit weight of the rubber concrete decreased 4-5 percentage replacement of aggregates. Addition of rubber decrease the workability of the concrete and air content was increased. Rubber concrete was more resistance to thermal change with 5 percentage shredded rubber tyre and cracking reduce to 0.4-0.6 mm. Rubber reduced the freeze and thaw damage, adding 5-10 percentage rubber, mixture exhibit 50 percentage higher durability factor after 300 cycles of freezing and thaw damage. Rubber has provided sufficient restrain against propagation of micro cracks [6].

Figure 1: Rubber tyre used in concrete

5.2 Recycled aggregate

Recycled aggregates come from demolished buildings, airport runways, bridge support and even concrete roadbeds. The concrete which used this kind of aggregates was referred to as recycle aggregate concrete. There have several factors and strong characteristics of recycle aggregate which will influence the original concrete. For example, the strength, distribution size and water absorption capabilities of concrete will have affected. Recycle aggregate concrete could helps to protect natural resource and reduce environmental pollution [2].

Figure 2: Recycled aggregate after collection

Figure 3: Processed recycled aggregate

Recycled concrete was the main component of the old concrete and recycling add benefit to the landfill disposal. The use of recycled involves breaking, removing and crushing existing concrete to specified size and quality. Recycling concrete could helps to promote sustainable development by protecting natural resources and reducing the disposal. Recycled aggregate normally have higher water absorption and lower specific gravity. The density of recycled aggregate has the lower than the density of the normal aggregate. The porosity of the recycle aggregate has higher than the natural aggregate. The bulk density was 1250 kg/m3 and porosity 5.03 percentage by

volume. The highest water absorption was 10.6 percentage for 37.5 mm size aggregates. The results showed that best valued of compressive and split tensile strength was obtained from 10 mm coarse aggregate [7].

6. Study design

The sample of grinned rubber tyre collected from Shank Tyre Resoling Center Chauthe, Pokhara Nepal. The collected rubber tyre was sieved to the required size (passing 2.36 mm sieve) . Coarse aggregate was partially replaced by waste recycled aggregate. The mix design was done for M20 grade concrete as per Indian standard code(IS 10262 2009). The mix design with replacing coarse aggregate with recycled aggregate from 0 percentage to 30 percentages at interval of 10 percentage whereas fine aggregate was replaced at rate of 2.5 percentage up to 12.5 percentage. The sample was prepared in laboratory and workability, compressive strength and split tensile test was conducted. The optimum percentage of partial replacement of fine and coarse aggregate were determined for the feasibility of the replacement of the fine and coarse aggregate simultaneously. The total twelve samples six cubes to conduct compressive strength test and six cylindrical to analyzed the split tensile strength of concrete.The RCA and R represents recycled coarse aggregate and Rubber.

7. Results and discussions

7.1 Water absorption

The water absorption of natural coarse aggregate was recorded 0.06 percentage whereas for recycled aggregate it was observed 6.18 percentage. The higher water absorption of the recycle aggregate was due the loose mortar and porous material attached with the recycled aggregate.

7.2 Workability

The workability of the concrete were decreases as the percentage of the rubber tyre and recycled aggregate percentage increases. The workability of concrete was shown in Figure 4 and Figure 5 below. The decrease in the workability of concrete was due to the porous and mortar particles attached with the recycled aggregate.The existence of many micro cracks in the recycled aggregate could have significantly higher water absorption than that of natural aggregate. This factors decreased the workability as percentage of recycled aggregate increased [8].

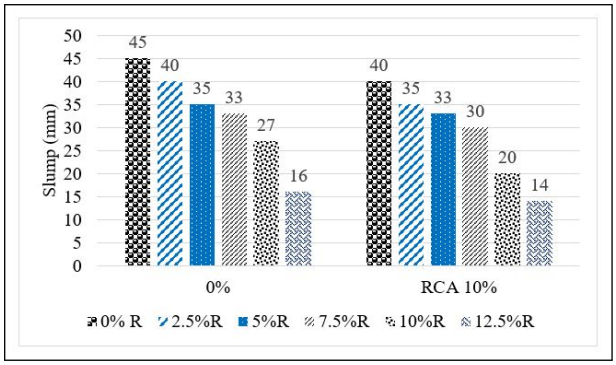

Figure 4: Slump test of concrete with NCA and RCA 10 percentage

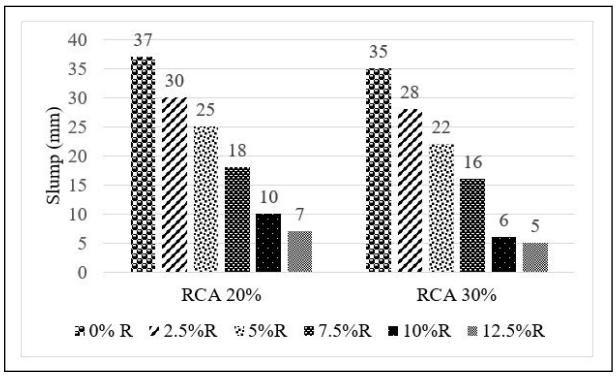

Figure 5: Slump test of concrete with RCA 20 and RCA 30 percentage

7.3 Compressive strength

The compressive strength of the concrete was test with 150 mm x 150 mm x 150 mm cube in compression testing machine. The result of the compression showed that strength was decrease as the percentage of the rubber increased 0 percentage to 12.5 percentage and the RCA increased from 0 percentage to 10 percentages. The compressive strength of the NCA 28 days of 0 percentage rubber was 23.22 Mpa whereas the RCA 10 percentage of 0 percentage rubber was 21.56 Mpa. The strength decreased in RCA from 0 percentage rubber to 12.5 percentage rubber was 23.22 to 15.11 Mpa shown in Figure 6 below. In case of RCA 10 percentage was 21.56 to 10.64 Mpa from Figure 7 below. The strength was gradually decreasing towards in increasing percentage of the recycled aggregate shown in Figure 7 below.

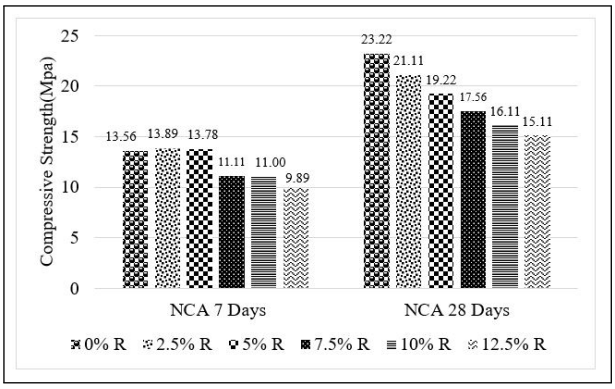

Figure 6: Compressive strength with NCA

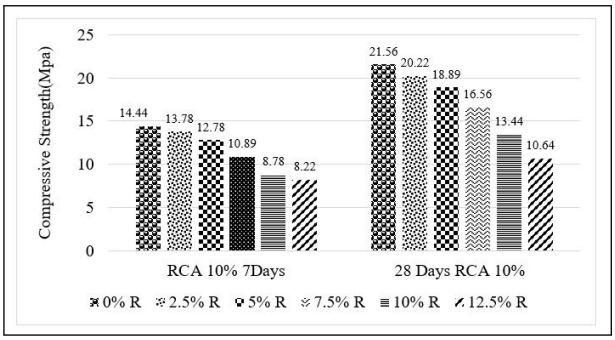

Figure 7: Compressive strength with RCA 10 percentage

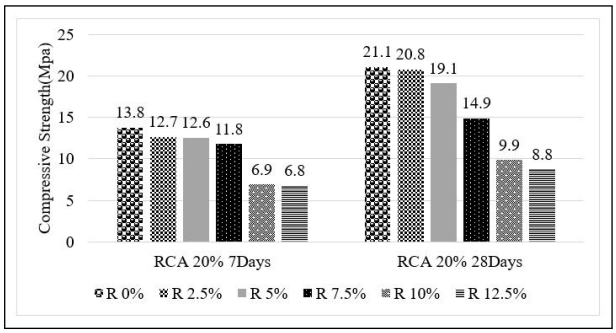

Figure 8: Compressive strength with RCA 20 percentage

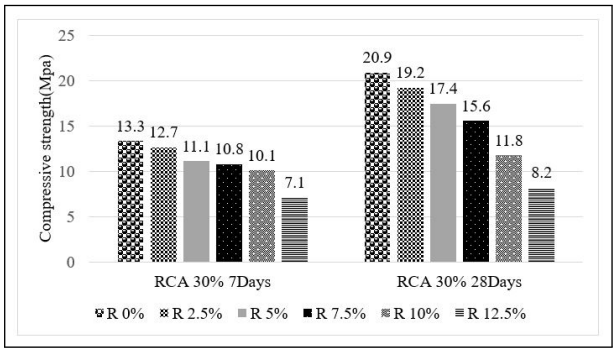

Figure 9: Compressive strength with RCA 30 percentage

Similar trend of the compressive strength was also observed in the case of 20 percentage recycled aggregate. And the results showed decreasing as the percentage of the rubber tyre increased from 0 percentage to the 12.5 percentage. There was decreased in strength from 21.1 Mpa to 8.8 Mpa from Figure 8 below which was 60 percentage reduction in the strength from the 0-12.5 percentage rubber and 20 percentage recycled aggregate. The compressive strength of the concrete, in case of recycled aggregate of 20 percentages and up to 2.5 percentage rubber the strength was above 20 Mpa for which concrete was mix designed.

In 30 percentage recycled aggregate case, the strength of the concrete for 0 percentage rubber was only above the 20 Mpa which was 20.9 Mpa from Figure 9 below. All others results fall below the 20 Mpa for which the mix designed was done. Up to 7.5 percentage replacement of the fine aggregate the strength decreased from 20.9 Mpa to 15.6 Mpa which was 25.35 percentage. When goes to 12.5 percentage of rubber tyre the decreased in the strength was 60.76 percentage.

The compressive strength of the concrete decreases as the percentage of the recycled aggregate and rubber tyre increase. The replacement of coarse aggregate with recycled aggregate without rubber showed that strength of concrete was not fall down below 20 Mpa. But as the rubber percentage increase it was observed that after 2.5 percentage replacement the strength decreased below 20 Mpa. The poor bonding of scrap tyre dust with the other particles of the concrete materials which creates voids resulting decreased in strength [9]. The decreased in strength was also related to the micro cracks occurred in the recycled aggregate during crushing of the aggregate. Also the more original damaged was accumulated inside the aggregate. Due to the quality deterioration of the recycled aggregate, the compressive strength of RCA was found to decreased [8]. The reduction in compressive strength of concrete compared to conventional concrete was caused by weak bonding of rubber dust and cement matrix due to the presence of interfacial transition zone. The rubber tyre has hydrophobic (non-polar molecule that repels water). The hydrophobic nature has due to the zinc stearate application on tyres during production. These non-polar molecules which repelled water trap air

surrounding the rubber particles which increase the general thickness of the interfacial transition zone. This increased interfacial transition zone weakens the compressive strength of concrete [10]. The rubber dust decreased compressive strength as adhesion between rubber dust and surrounding cement paste decreased [11].

7.4 Split tensile strength

The split tensile strength was determined with cylindrical specimen of 100 mm diameter and 150 mm length. The result shows that the tensile strength at seven days NCA with 0 percentage rubber 1.8 Mpa and 2.5 percentage rubber 1.91 Mpa and at 5 percentage is 1.8 Mpa, decreasing continuously to 1.59 at 12.5 percentage rubber from Figure 10. The split tensile strength at 2.5 percentage rubber was better than the 0 percentage rubber in both NCA and RCA 10 percentage case. So the 2.5 percentage replacement of fine aggregate was the optimum replacement of fine aggregate by weight to optimize the tensile strength of the concrete. The twenty-eight days' strength of the NCA with 0 percentage rubber was 2.65Mpa and 2.5 percentage rubber was 2.76 Mpa. Similarly, for RCA 10 percentage seven days' tensile strength at 0 percentage rubber was 1.7Mpa and 2.5 percentage rubber was 2.02. The twenty-eight days' strength for 0 percentage rubber was 2.48Mpa and 2.5 percentage rubber was 2.76Mpa in Figure 10 below.

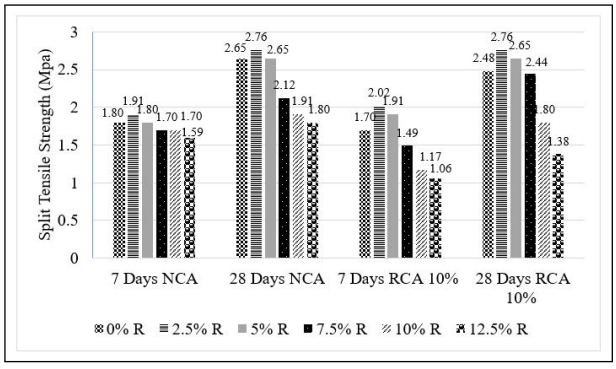

Figure 10: Split tensile strength with NCA and RCA 10 percentage

The tensile strength of concrete at 0 percentage rubber and 20 percentage recycled was 2.02 Mpa whereas at 2.5 percentage rubber it was found 2.76 Mpa. And after further increases of rubber percentage the tensile strength was gradually decreased 2.65, 2.12, 1.91 and 1.8 Mpa. The split tensile strength was found that replacement of the fine aggregate with rubber up to 2.5 percentage increased the tensile strength by 13.67 percentage in case of 20 percentage recycled aggregate from Figure 11. In case of 30 percentage recycled aggregate the increased strength at 2.5 percentage was 18.8 percentage which was larger than that of the 20 percentage recycled aggregate. This shows split tensile strength was decreased more as the recycled aggregate percentage was increased but replacement of fine aggregate with 2.5 percentage rubber increased the split tensile strength up to some limit.

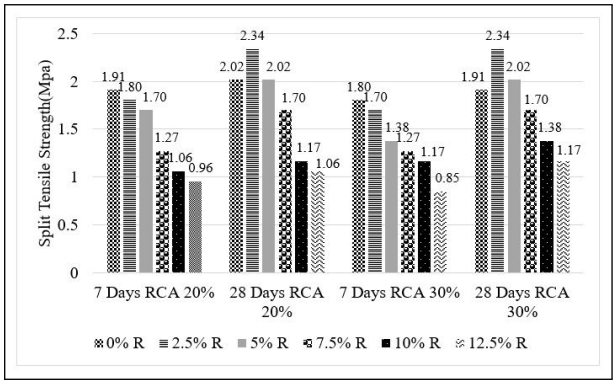

Figure 11: Split tensile strength with RCA 20 and RCA 30 percentage

The decreased in the tensile strength of the concrete was mainly affected by poor bonding of recycled aggregate with the other material of the concrete'[12]. Without rubber tyre brittle failure in compression and tension was observed but in case of rubberized brittle failure was not seen, at the same time gradual decrease in strength of concrete was observed [13].The porosity of recycled aggregate was higher than that of natural aggregate, results in poor aggregate and decrease in strength [14].

7.5 Unit weight

The unit weight of the concrete was gradually decreasing from natural aggregate to recycled aggregate. The unit weight of the concrete with 0 percentage recycled and 0 percentage rubber was 2393.09 Kg/m3 shown Figure 12 below. The replacement of fine aggregate from 0 percentage to 12.5 percentage was reduced the unit weight by 4.87 percentage. Similar in case of 10 percentages, 20 percentages, 30 percentage recycled aggregate the unit weight reduction was 6.21 percentage, 6.32 percentage and 7.11 percentage respectively.

The decreased in the unit was found due to the low value of specific gravity, porous cement mortar adhered to the recycled aggregate and rubber tyre in comparison of the natural coarse aggregate and fine aggregate used in the concrete [15] [16].

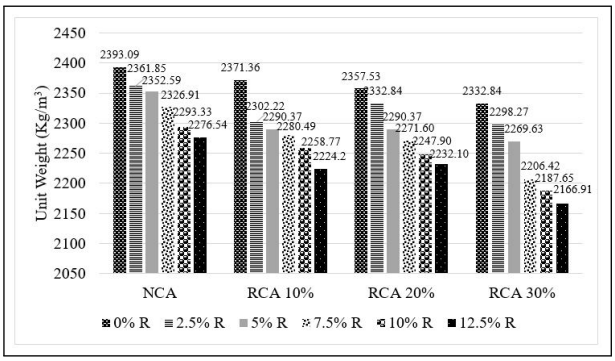

Figure 12: Unit weight of harden concrete

8. Conclusions

From the research work following results were concluded.

1. The recycled aggregate could be used replacement up to 30 percentages without combination with rubber.
2. The water absorption of recycled aggregate was higher than natural aggregate.
3. The workability of concrete was found decreased with increase in the percentage of recycled aggregate.
4. The compressive strength and tensile strength was observe decreased with increase in percentage of recycled aggregate and rubber tyre.
5. The rubber tyre combination with recycled used up to 2.5 percentage found increase in tensile strength and compressive strength above 20 Mpa.
6. Recycled aggregate and rubber tyre combination could produced light weight concrete.

9. Recommendations

1. The concrete with higher rubber content and recycled aggregate could be useful in light weight concrete.
2. The sound absorption of rubberized concrete was good so it can be used sound proof room from the previous study.
3. Heat insulation of rubberized concrete was good so it could be healthy aesthetic purpose.
4. Light weight concrete was obtained with recycled as coarse and rubber as fine, so it could be used in light hollow concrete block.
5. The strength of concrete was decreased with increasing rubber percentage so it could be useful for the purpose of nonstructural concrete.

Future Enhancements

Further research might could have executed with using admixtures in the concrete to increase the strength and workability of the concrete. The natural coarse aggregate used could be replaced with crushed aggregate. The different mix designs with different w/c ration could be checked for variation in the strength.

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