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# WASTE-GLASS AS A PARTIAL REPLACEMENT FOR FINE AGGREGATE IN CONCRETE

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## ABSTRACT

Waste glass has raised lots of environmental concerns all around the world. It is very troublesome to manage the produced waste glass. Every year large amounts of waste glass are getting piled up on landfill all around the world. Lots of research and investigation are being performed to manage the produced waste glass but failed to provide a reasonable solution for this emerging problem. We have experimented on concrete cubes of 10 cm size and M20, M25 and M30 grade. Here crushed waste glass is used to replace the fine aggregate up to some proportion as a filler material that may be a better solution. Along with the compressive strength test, slump, dry unit weight and chemical resistance test was performed to evaluate basic concrete properties and present here in this paper.

**Keywords:** Recycled waste glass, M20, M25, M30

## I. INTRODUCTION

After the boom from industrialization, various innovative construction materials are being developed and researched all around the world. Various pieces of the literature suggest the use of concrete since 1300 BC. More than 10 billion tons of concrete produced and used in concrete industries annually all over the world. The basic ingredients of concrete are cement, sand aggregate and water. Among those around 70% occupied by inert aggregates. On the other hand, waste management is a global issue. Even though in Nepal, solid waste management is a great problem due to scarcity of landfill site. Being a developing country, a major part of solid waste includes the construction industry. And in building construction use of glass increased drastically and reasonably waste glass deposited day by day all over the world. Recycling of the waste glass may not be a complete solution therefore alternative use of glass waste may add a solution for solid waste management.

Glass takes about one million years to decompose naturally. Since waste glass occupies a large amount of space on landfill and due to its slow decomposing nature, the life span of the landfill also decreases. Many kinds of research have suggested that waste glass powder produces the pozzolanic effect on the concrete. The use of the waste glass on concrete not only recycles the generated waste but it also decreases the demand on natural resources. It helps to reduce the consumption of the natural aggregate from the river bed as well as preserve the natural river path. Many construction industries have already started the use of the waste glass powder on the construction industry.

Being inert material, waste glass can be easily used in concrete without a change in its chemical properties. Course aggregate occupies a major part of concrete followed by fine aggregate. The use of crushed glass can replace fine aggregate. Fine aggregate fills the small gaps in concrete while additives like pozzolanic materials react with hydroxides produced during hydration of cement. Therefore finer waste glass may act as pozzolanic material and or filler inert materials. To analysis and found out the behaviour of crushed glass the following objectives are targeted in this experimental research.

1. To study the workability, Compressive strength and durability of a concrete mix containing waste glass as a replacement for fine aggregate.
2. To determine the optimal use of finely crushed waste glass in concrete.

## II. LITERATURE REVIEW

The use of recycled waste glass in the concrete industry has been rising lately due to its environment-friendly advantage. Various researches support the use of waste glass as a replacement of fine and coarse aggregate.

**Park and Lee (2004)**[1]used waste glass instead of natural sand (glass size 4.75–0.3 mm) 10%, 20%, 30%, 50% and 100% by weight as a replacement of sand. With the increase in the replacement percentage, the flexural and compressive strength was found to be decreased. When the glass content was more than twenty per cent then the strength was found to be reduced significantly.

**Chen CH (2004)**[2]noticed with the increase in the percentage replacement of sand with glass aggregate the strength parameters of concrete were found to have deteriorated.

**Seung et al. (2004)**[3]noticed the decrement in workability with the increase in glass percentage and concluded it to be due to the angular shape of waste glass. With 30% Replacement of the sand with waste glass maximum mechanical properties of concrete was obtained.

**Shayan and Xu (2004)**[4]studied the twenty-eight-day mechanical properties of the concrete comprising waste glass (size 4.75–0.15 mm) as the fine aggregate replacement at levels of 10%, 20%, 30% and 40%, by weight. Result obtained from the experiment showed positive growth in the mechanical properties of concrete.

**De Castro and de Brito (2013)**[5]studied the twenty-eight-day mechanical properties of the concrete by replacing the fine aggregate with a waste glass of size < 4mm at levels of 5%, 10% and 20%, by volume. Workability of the mixture was studied with the help of the slump. Workability was found to be reduced with an increment of the percentage of the waste glass. The reduction in the workability was found to be 1.97%, 1.57% and 4.33% after the addition of 5%, 10% and 20% of waste glass.

## III. METHODOLOGY

The main role of fine aggregate is to produce workable concrete, fill the void created by the coarse aggregate, help to harden the cement by allowing the passage of water through voids, prevent the possible segregation of concrete. From the previous study, it was found that replacement of the fine aggregate by the waste glass showed a positive effect on the workability up to some level of replacement which would be due to weak cohesion between glass powders and cement paste. Since glass is inert material it does not absorb water and has a smooth (glossy) surface which will result in high workability. In contrary to that, some study showed a decrease in workability due to angular shape, higher aspect ratio, and rough texture. When glass size is less than 1.18mm it should increase the workability of concrete by acting as a ball bearing. So less percentage of replacement is found to be more suitable. Since the glass has low specific gravity as compared to the sand inclusion of it would result in the formation of comparatively lightweight concrete. Glass has more resistance to chemical attack than sand.

The various experiments showed a decrease in compressive strength after inclusion of waste glass above some level and attributed it to weaker bonding due to sharp edge and smooth surface at the interfacial transition zone. In contrary to those results showing the increase in compressive strength attributed it to pozzolanic effect, surface texture and higher strength of the glass as compared to that of sand.

Most researchers are conducted to replace a large amount of sand with glass by compromising the properties of concrete. It results in the formation of concrete which would not be applicable in all structure and utilization of waste glass reduced. So it would be better to ensure that the properties of concrete would not be hindered with the addition of glass aggregate. For this, one has to replace less percentage of waste glass and glass of size less than 1.18mm. It will improve the workability, produce slightly low-density concrete and meaningful increase in strength and durability. It should be crucial to use lower percentage replacement and finer glass size since it only works as filler material and not reacts with cement to produce a hydrated paste. But the refinement of pores and being not reactive and durable material should improve the durability of concrete against chemical attack as well as environmental impact.

## IV. EXPERIMENTAL DETAILS

Waste glasses were collected from different part of Kathmandu city. The major portion of waste glass was comprised of the broken window glass (non-coloured). Before studying the effect of waste glass, physical properties of other ingredients were studied and results are tabulated below in Table-1. The experimental study was conducted in the laboratory of the Department of Civil Engineering, Pulchowk Campus, Institute of engineering, T.U. Lalitpur.

**Table-1:** Physical Test on ingredients of concrete

| TEST ON COARSE AGGREGATE | | | | |
|---|---|---|---|---|
| **S.N** | **DESCRIPTION OF TEST** | **CODE** | **Value Obtained for** | **Result** |
| **1** | Specific gravity test | IS 2386-3-1963 | Specific gravity | 2.61 |
| **2** | Sieve analysis | IS 2386-1-1963 | Fineness modulus | 7.81 |
| **3** | Los Angeles abrasion test | IS 2386-4-1963 | Los Angeles abrasion Resistance | 55% |
| **4** | Water absorption test | IS 2386-3-1963 | Water absorption | 1.40% |
| **5** | Moisture Content test | IS 2386-3-1963 | moisture content | 0% |

| | | | | |
|---|---|---|---|---|
| | | | | |
| **TEST ON FINE AGGREGATE** | | | | |
| **1** | Specific gravity test | IS 2386-3-1963 | Specific gravity | 2.51 |
| **2** | Sieve analysis | IS 2386-1-1963 | Fineness modulus | 3.88 |
| **4** | Water absorption test | IS 2386-3-1963 | Water absorption | 1.40% |
| **5** | Moisture Content test | IS 2386-3-1963 | moisture content | 0 |
| | | | | |
| **TEST ON CEMENT** | | | | |
| **1** | Standard Consistency Test | IS 4031-4-1988 | | 38% |
| **2** | Initial Setting Time | IS 4031-5-1988 | Initial Setting time | 43 |
| **3** | Final Setting Time | IS 4031-5-1988 | Final Setting time | 625 |
| **TEST ON GLASS AGGREGATE** | | | | |
| **1** | Specific gravity test | IS 2386-3-1963 | Specific gravity test | 2.27 |
| **2** | Sieve analysis | IS 2386-1-1963 | Sieve Analysis | 3.43 |
| **4** | Water absorption test | IS 2386-3-1963 | Water absorption test | 0 |
| **5** | Moisture Content test | IS 2386-3-1963 | moisture content test | 0 |

**Table-2:** Test on green and hardened concrete

| **S.N** | State of Concrete | Test for | Test Description | Code | Value evaluated in terms of |
|---|---|---|---|---|---|
| **1** | Fresh Concrete | Workability | Slump Test | IS 1199-1959 | slump in mm |
| | | | | | |
| **2** | Hardened Concrete | Strength | Compressive strength test | IS 516-1959 | Compressive Strength |
| | | | | | |
| | | Density | Dry Density Test | ASTM C 642 – 06 | $kg/m^3$ |
| | | | | | |
| **3** | Hardened Concrete | Durability | Chemical resistance test | | Deterioration in weight and strength |

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## V. OUTCOMES AND DISCUSSION

Figure 1 Slump Value for M20 Grade Concrete

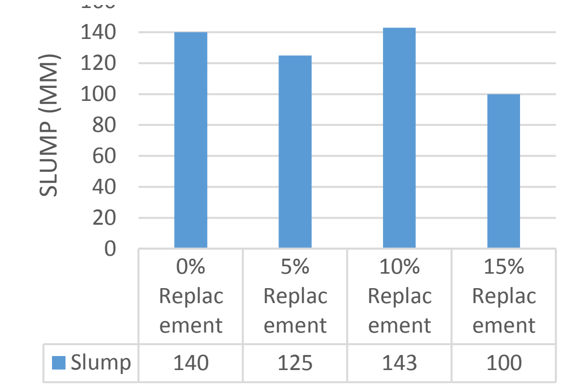


Figure 2 Slump Value for M25 Grade Concrete

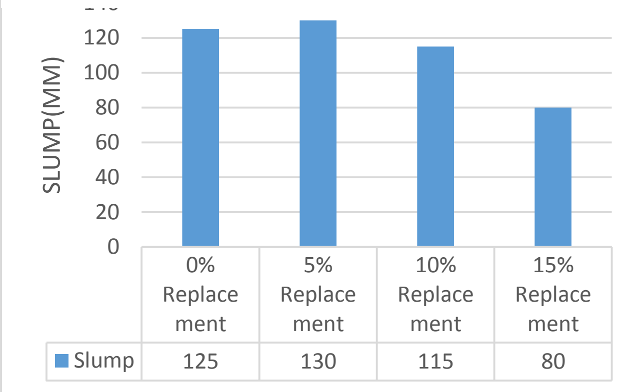


Figure 3 Slump Value for M30 Grade Concrete

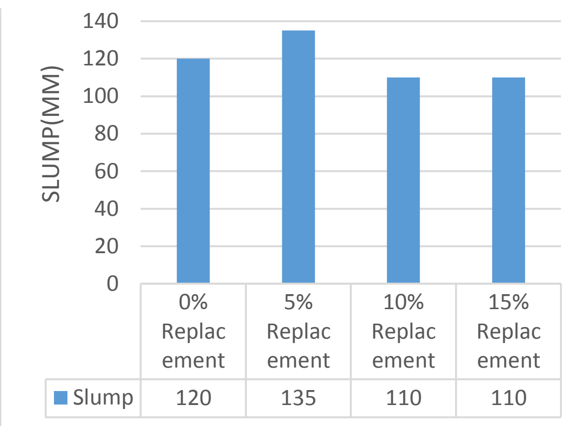


Figure 4 Durability Test on M20 Grade Concrete

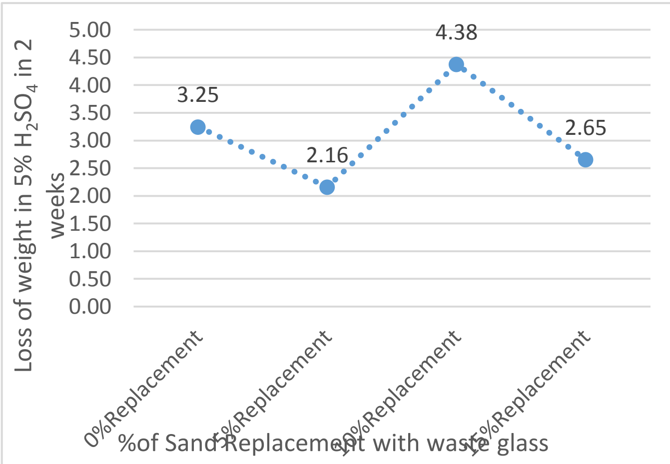


Figure 5 Compressive Strength of M20 Grade Concrete

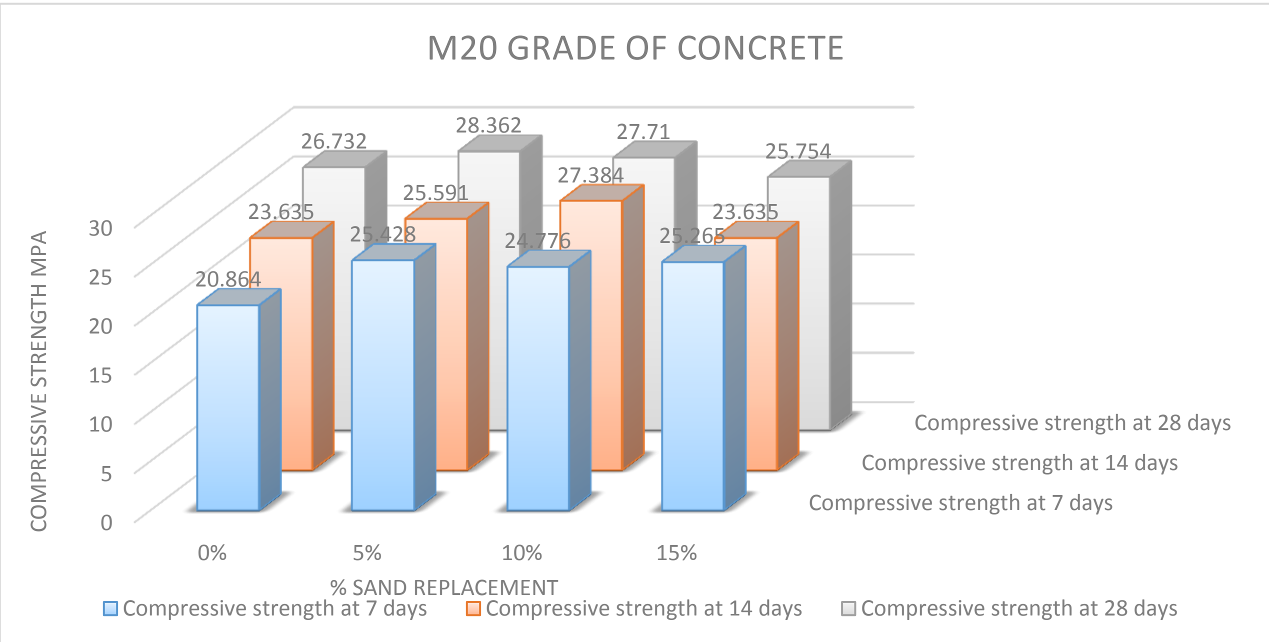

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Figure 6 Compressive Strength for M25 Grade Concrete

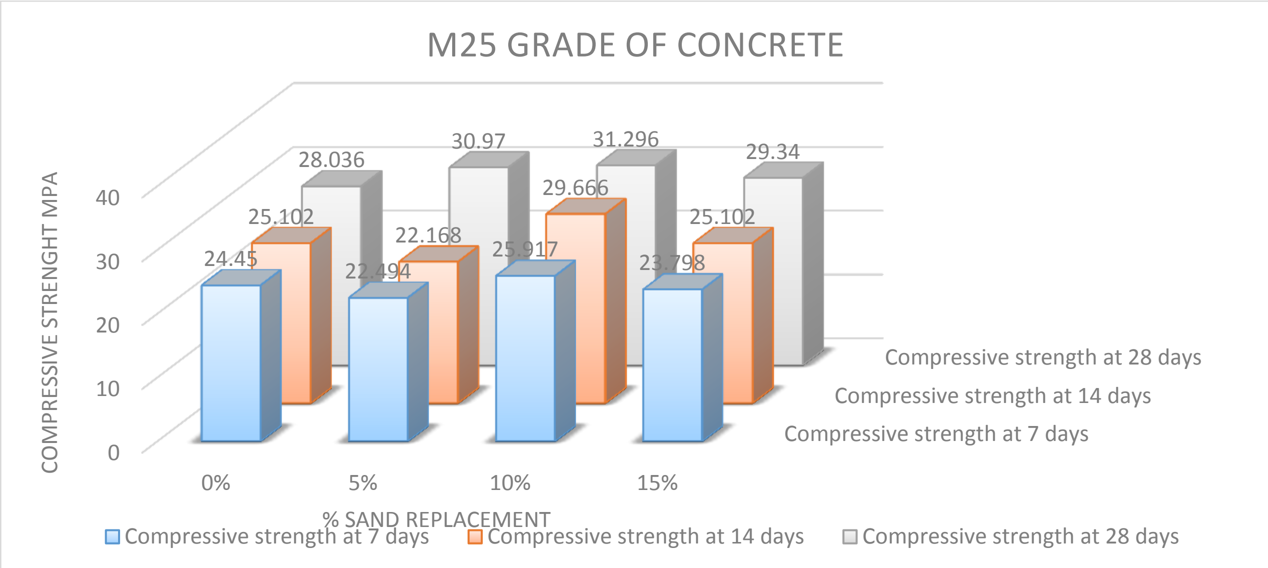


Figure 7 Compressive Strength for M30 grade concrete

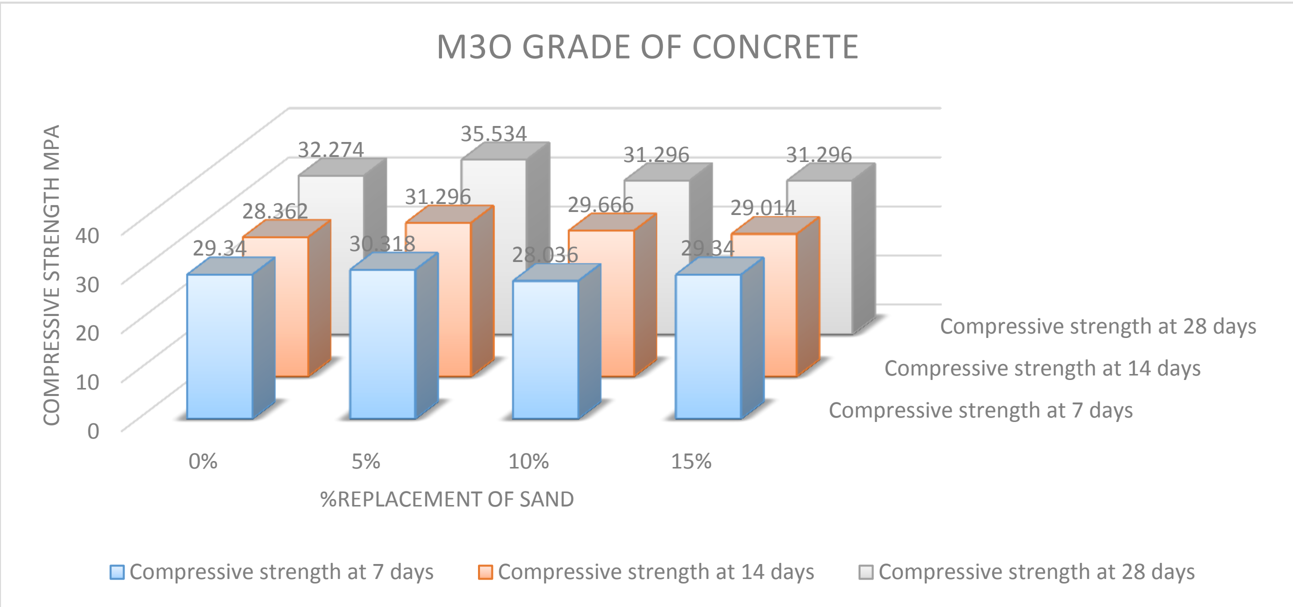


Figure 8 Dry Density for M20 grade Concrete

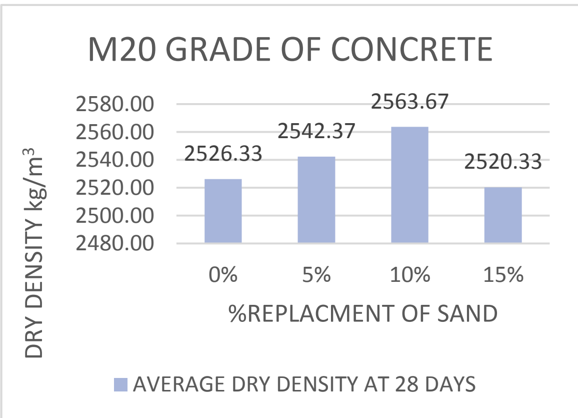


Figure 9 Dry Density for M25 grade Concrete

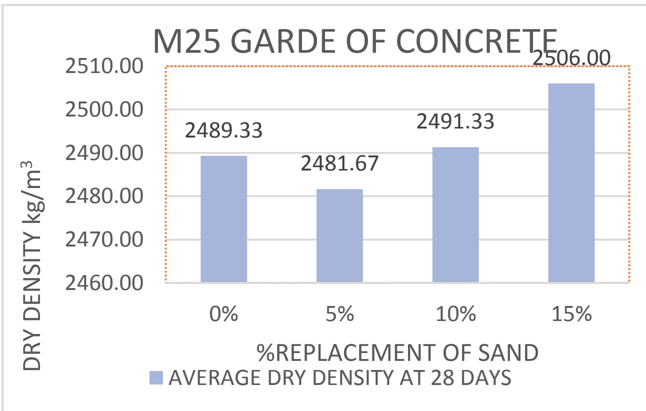

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Figure 10 Dry Density for M30 Grade Concrete

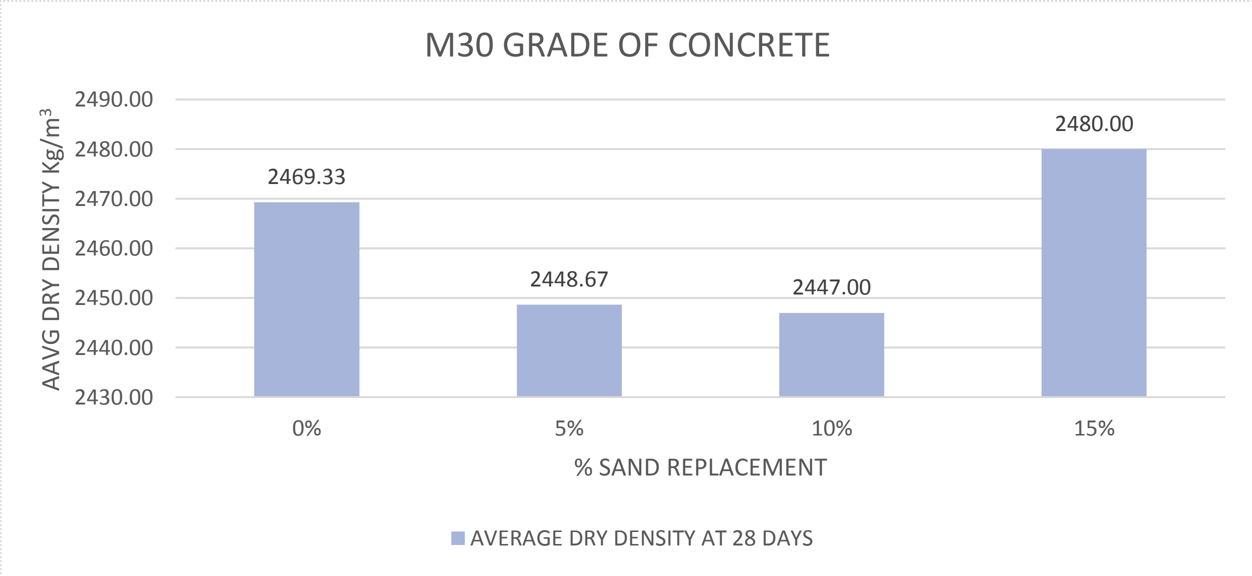
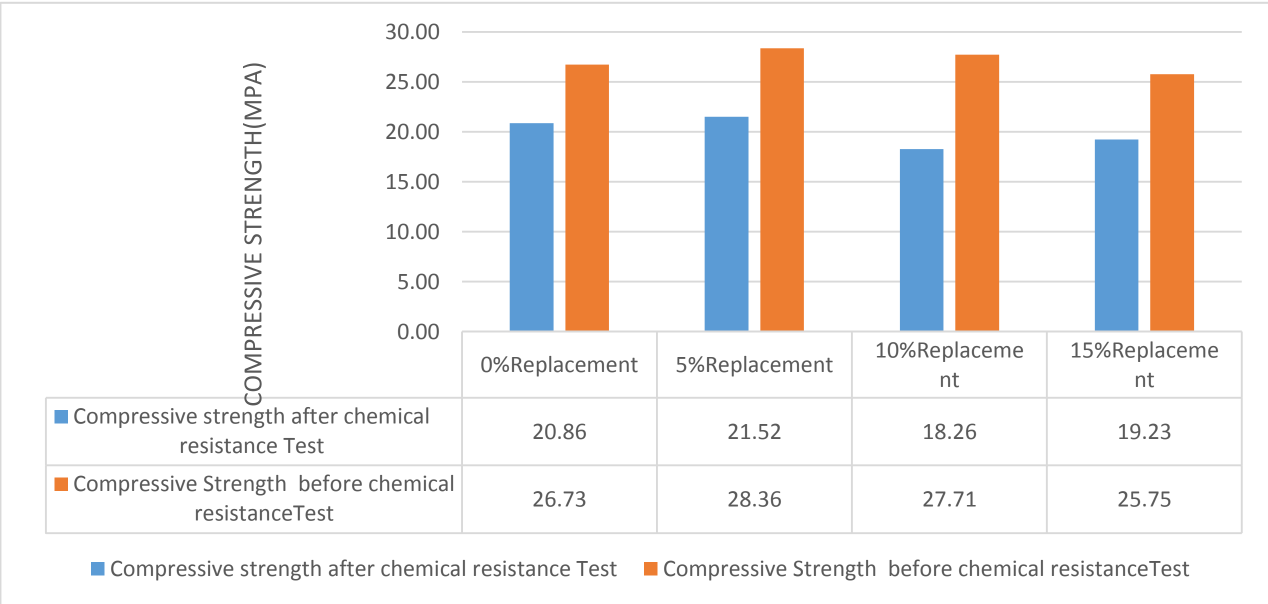



Figure 11 Chemical Resistance Test of M20 Grade Concrete




| | 0%Replacement | 5%Replacement | 10%Replacement | 15%Replacement |
|---|---|---|---|---|
| Compressive strength after chemical resistance Test | 20.86 | 21.52 | 18.26 | 19.23 |
| Compressive Strength before chemical resistanceTest | 26.73 | 28.36 | 27.71 | 25.75 |

## Workability:

For the lower grade (M20) concrete 5% replacement slightly decreases the workability and then further increment up to 10% reinstate as normal concrete. Further increment in replacement of sand by 15% of crushed glass marginally decreases the workability. While in the case of M25 and M30 grade of concrete at first workability slightly increases and then decreases with increase in replacement percentage. In general, we can say there are not marginal increases and decrease in workability up to 10% replacement of sand. One more thing can be observed that as the cement content is increasing (M20 to M25) workability is decreases. The test result of cement showed that most of the cement found in Nepal has around 60% strength in the first three days. Therefore besides the quantity of paste, early hydration of cement should be the reason for the decrease in workability of concrete from a lower grade to the higher grade.

## Strength:

From the compressive strength test on the cube, it can be seen that for all the grade of the concrete within 5-10% of the replacement of fine aggregate, better result of the compressive strength was achieved. While with

15% replacement have to compromise slightly in the strength of concrete but can reduce cost as well as consumes waste glass.

### Durability:

The test result showed that there is not marginal impact on the durability of concrete up to 15% replacement of sand with crushed waste glass. But for M20 grade of concrete that is only tested found more durable for 5% replacement of sand with crushed waste glass.

### Density:

Since the glass has a lower density and specific gravity than sand. The test result shows the relative decrement of the dry density with the addition of waste glass.

## VI. CONCLUSION

Above experiment represents the effect of the addition of waste glass as a replacement of fine aggregate on the workability, compressive strength, dry density and durability of the concrete. It was found that with 5-10% replacement of fine aggregate with waste glass more durable, lighter, workable and strong concrete can be formed while with 15 % replacement may have to compromise in strength and durability slightly.

## ACKNOWLEDGEMENTS

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## VII. REFERENCES

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