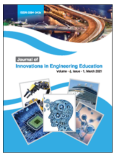

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Controlled substitution of coarse aggregate with waste glass and syringe needle in M20 concrete

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Abstract

Certain types of inorganic waste can be reused by substituting the primary materials of M20 concrete in controlled percentage. Inorganic wastes like waste glass and syringe needle are some of its examples which are currently being sent to landfill sites in a large share. This study considers the waste glass (toughen glass, flat glass) generated from the construction site & glass market and autoclaved syringe needle generated as a hospital waste. Waste glass was used to partially replace up to 20% and syringe needle 2% of coarse aggregate in combined form for all concrete mixes. The workability test, compressive strength test and Flexural strength test was conducted to evaluate the effectiveness of the mix. The use of combination of waste glass and syringe needle resulted in decreasing the slump value due to angular grain shape of glass and reinforcing property of needle, whereas the compressive strength noticeably enhanced. With increasing the waste glass and syringe needle percentage the strength gradually increases up to a given limit beyond which it started to decrease. The maximum compressive strength of concrete was obtained at 10% of waste glass and 1% of syringe needle and the value of the compressive strength of the for 28 days of curing is 32.29 N/mm^2. The Flexural strength for the sample 2 was observed 3.07 N/mm^2.

1. Introduction

Population growth creates development activities such as construction of high-rise buildings, bridges, shopping complexes, institutional buildings, road, hospitals industries and other infrastructure which trigger the production of waste in environment. Solid waste is a consequence of human activities which increase with rapid urbanization, improved living standards and changing consumption patterns [1]. There are major challenges to manage this day by day increasing volume of solid waste. We have many ways to make solid waste into valuable resources but if these are not properly managed, it can result in serious adverse impacts on environment and public health. Solid waste management is therefore a critical component within urban sanitation, and it is also one of the most important and resource intensive services provided by municipalities [2]. Organic waste from different sources is not serious problem for management due to its decomposable character but the inorganic waste is rigorous to manage due to lack of proper recycling provision within our country.

According to report of waste management baseline survey of Nepal 2020 published by Central Bureau of Statistics (CBS), the huge portion of the waste was covered by organic waste that is 54% of total waste whereas inorganic waste covered 33.3% and rest of total waste is 12.7% included as other waste. The combined quantity of inorganic waste was averaged to 743.5mt in 2075/76. The total annual waste glass generation from the Metropolitan city alone is 1551.0 MT in 2075/76 [3]. In current situation, although a small proportion of the post-consumer glass has been recycled and reused, a significant proportion, which is about 84% of the waste glass generated, is sent to landfill [4]. According to S. P Gautam in case of India, most of the waste glasses have been dumped into landfill sites. The land filling of waste glasses is undesirable because they are not biodegradable, which makes them environmentally less friendly

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According to Healthcare waste management guideline of Nepal, 2014 total health care waste from Nepal was estimated as 0.533kg/bed/day. Out of these 0.256kg/bed/day was non-hazardous but non-biodegradable waste,0.147 kg/bed/day was biodegradable waste and 0.120kg/bed/day was infectious including needle or sharp and 0.009kg/be/day was hazardous chemical waste[6]. HCWs are either being dumped by the riverbank or go to the landfill site along with domestic waste. In many cases HCWs are burned in metal drums or just openly. This results in the emissions of by-products and toxic gases and substances like dioxin and furan along with the heavy toxic metals like lead, mercury and cadmium into the environment [7].

The major problem is lack of well managed solid waste management within our country and day by day reducing capacity of the landfill site. The existing situation of solid waste management in the Valley demands techniques to reduce solid waste at the disposal state if not at the production phase. In this situation, the management of solid waste becomes challenging for concerned local government responsible for management and segregation of solid waste at the local level. Using waste glass and combination of other waste seems very advantageous in the concrete construction sector. This adoption decreases the production cost of concrete side by side help to manage waste in proper way. Aggregates occupy about 70% of the volume of concrete, thus a large amount of it can be reused. To avoid consumption of raw materials that are already scarce, this option is crucial, especially for European countries that are facing mineral deficiency [8].

2. Methodology

2.1. Preparation of materials

For this research Ordinary Portland Cement with the fineness 6.68% was used. The cement was collected from the near market and stored within laboratory of the Thapathali campus. Fine aggregate used in this research was Quarry sand confirming the grade of IS 383-1970 and collected from nearer supplier. The Coarse aggregate passes through the 20mm IS sieve and confirming the grade of IS 383-1970 was used. The WG (mainly toughen and sheet glass) was collected from different sources especially from glass market and construction site. The WG collected was first washed and then leave it for drying. The dried WG then broken into small pieces by hammering process. The sieve analysis is done to make the waste glass as compatible size of aggregate. Then the received WG was use for the research in different proportion by weight of aggregate. The syringe needle was collected from Kathmandu Model Hospital, Pradarshani Marga, Kathmandu. The collected Needle was sure to be autoclaved. Collected Syringe contained other inflammatory object such as blade and sharp materials within the bucket. Firstly, we separated the Syringe with other elements. Received needle was caped for the safety and a small portion of plastic called needle hub was attached with needle; both needle cap and needle hub were cut down to get the needle portion only. Then the entire needle with different sizes was use for the research in different proportion by weight of aggregate.

2.2. Preparation of samples

After collecting all required materials experimental setup was done within material lab of Thapathali Campus as shown in Figure 1. Total 30 numbers of M20 samples containing different proportions of WG and SN were prepared. Each sample has 6 number of cubes having size of 150mm × 150 mm × 150 mm. Cubes with 0% of WG and SN were considered as the control specimens. Within this experiment, the water-cement ratio was fixed to 0.55. The summary of the materials used description of the mixes and mixed proportion for each mix are shown in Table 1 and 2.

Figure 1: Experimental setup for compression test

Table 1: Description of mixes of control and experimental samples

Samples	Waste-Glass	Syringe needle	Remarks
Controlled	00%	0.0%	-
Sample 1	05%	0.5%	-
Sample 2	10%	1.0%	-
Sample 3	15%	1.5%	-
Sample 4	20%	2.0%	-

2.3. Mixing procedure

The combination of waste glass and syringe needle were used in replacement of coarse aggregate at 0%, 5% &

Table 2: Summary of mix proportion for each mix

Samples	Cement (kg)	F.A (kg)	C.A (kg)	Waste glass	Syringe needle	W/C
Controlled	8.8	13.2	26.4	0	0	0.55
Sample 1	8.8	13.2	24.95	1.32	0.13	0.55
Sample 2	8.8	13.2	23.5	2.64	0.26	0.55
Sample 3	8.8	13.2	22.04	3.96	0.40	0.55
Sample 4	8.8	13.2	20.59	5.28	0.53	0.55

0.5%, 10% & 1%, 15% & 1.5% & 20% & 2% respectively. The mixing method was nominal because of its simplicity in practical use and batching of the materials was done by weight.

A cube mold with dimension 150mm × 150mm × 150mm was cleaned and tighten with the bolt to fix properly. The walls and base of the mold were properly lubricated to avoid the adhesion of concrete. Adopting the 0.55 w/c ratio, 6 numbers of cubes with 0% of WG and 0% of SN by the weight of aggregate were prepared as the controlled mix. The mixing was done on dry, clean, smooth, and hard surfaces by use of a shovel. Firstly, the mixing was dry mixing, and afterward measured water was taken and sprinkled into the mixture, and mixed them well. This process was done rapidly till the proper mixture was not prepared. By using of trowel prepared mixture was poured into the cube mold in three layers. After each layer, at least 25 stokes as per layer was given by the help of tamping bar for the required compaction. After filling the cube placed them into a sheet vibrator for the smoothness then vibrated on the concrete vibrating table. Then composition with 5.0% of WG and 0.5% SN, 10.0% of WG and 1.0% SN, 15.0% of WG and 1.5% SN, 20.0% of WG and 2.0% SN, respectively was prepared. During these mixing and casting of concrete slump test was done for each sample for workability test. A total of thirty numbers of cubes was produced for testing. After the 24 hours of concrete casting, the concrete cubes were detached from the mold and kept in the curing tank which was filled with water for curing. Three numbers of each sample were taken out after the 7 days of casting for 7 days of Compression testing and the rest of them leave for 28 days' test.

3. Result and discussion

Experimental samples are tested for the workability, compressive strength test and flexural strength test was done for the controlled sample and for that sample at which we found the maximum compressive strength. Compressive strength of concrete is determined by testing the cubes under compression testing machine, workability test is done by use of sump cone test and flexural strength test was done by the Universal Testing Machine (UTM). 7 days and 28 days' compressive strength test was carried for each samples whereas flexural strength test of the sample was carried out at 28 days of casting.

3.1. Slump test results for workability

Workability of fresh concrete indicates the ease of placement and compaction without any segregation. Due to easiness, low cost and fast results slump cone test is done for the workability test for concrete. Workability was determined by the use of slump value; workability specifies water-cement ratio in the concrete. There are different determining factors including properties of materials, mixing methods, dosage, admixtures, etc.

The mold used in this test purpose is in the form of the frustum of a cone having a height of 30 cm, bottom diameter of 20 cm, and top diameter of 10 cm including its base plate. The tamping rod is of steel 16 mm diameter and 60cm long and rounded at one end. The result of the slump test is given in Table 3. The result suggests decreasing rate of the slump with the increased ratio of WG and SN.

Table 3: Slump test results for different experimental samples

Samples	% by volume		Slump values
	Waste glass	Syringe needle	
Control sample	0	0	56
Experimental sample 1	5	0.50	49
Experimental sample 2	10	1.00	43
Experimental sample 3	15	1.50	38
Experimental sample 4	20	2	34

From Figure 2, we can conclude that the workability of concrete decreases with the increasing rate of WG and SN as partial replacement of CA. The workability was minimum at 20% of WG and 2% of SN. This drop in the slump values can be related to the bad geometry (sharper and irregular) of WG and the reinforcing property of SN which may give rise to high friction, and such resulted in less fluidity.

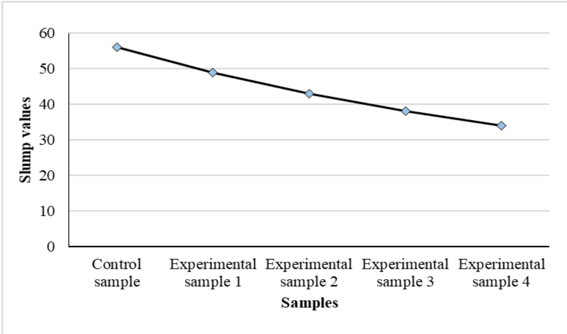

Figure 2: Slump values for different samples

3.2. Test of Compressive strength

It is the mechanical test used to find the maximum amount of compressive load a material can before its failure. The compressive strength of concrete can be determined by the breaking of the cube with dimension 150mm × 150mm × 150mm by applying load at the uniform rate of 340 KN per minute. This test for concrete is done for 7 days and 28 days of cube casting. All the sample needs to be tested were first taken out from the curing tank. They then should be left outside in the sun's presence for its skin to dry of cubes. Skin dried cubes were then placed in UTM centrally between the upper and lower plates. The load was applied uniformly at 340 KN/minute for a while. The ultimate crushing strength was noted and the average strength of three cubes was calculated. The process was repeated for all the cubes of each sample.

$$CS = \frac{MAL\ (KN)}{CAC\ (mm^2)} \qquad (1)$$

Where

CS : Compressive Strength

MAL : Maximum Applied Load

CAC : Contact Area of the Cube

The compressive strength of concrete when applying different percentages of waste glass and syringe needle at the age of curing increased, whereby the highest compressive strength was observed at the age of 28 days of curing. The compressive strength for the M20 concrete in 7 days is expected to be 65% and 28 days is expected to be 99.0% of the specified characteristic compressive strength. Table 4 shows the result of Compressive strength obtained at 7 days and 28 days.

Figure 3 indicates that the compressive strength of concrete for any curing period increased with an increase of waste glass and syringe needle content up to 10% of Waste glass and 1% of syringe needle as having the highest compressive strength value of 26.65N/mm^2 and 32.29N/mm^2 for 7 and 28 days respectively and reduced appreciably from 10% waste glass and 1% syringe needle content. The 20% of waste glass and 2% of syringe needle had the lowest compressive strength value of 17.75 and 23.08 N/mm2 for 7 days and 28 days respectively compared to other replacement percentages. In accordance with previous findings, the increased percentage of glass waste results in the reduction of compressive strength after having a limit of increased value.

Table 4: Observed compressive strength at 7 days and 28 days

Samples	**Compressive strength (N/mm^2) at 7 days**	**at 28 days**
Control sample	22.00	25.55
Experimental sample 1	24.23	27.33
Experimental sample 2	26.65	32.29
Experimental sample 4	22.83	26.99
Experimental sample 4	17.75	23.08

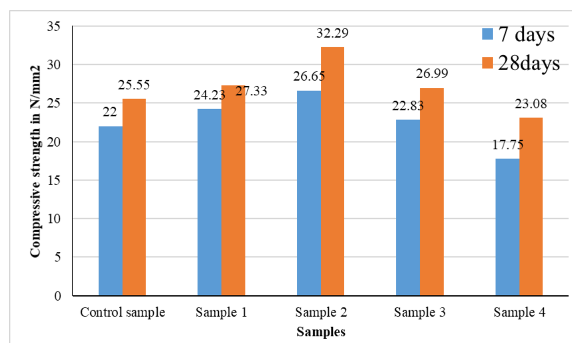

Figure 3: Observed compressive strength at 7 days and 28 days

This finding indicates that the best effect on compressive strength of the concrete was observed at the 10% of waste glass and 1% of syringe needle as coarse aggregate replacement. While the mixing rate of waste increased by % above 10% and 1% of WG and SN fall in the strength takes place. This result can explain that the use of partial replacement of CA with 10% of WG and 1% of SN was the optimal replacement ratio for the better strength.

In Figure 4, a comparison of 7 days compressive strength test of experimental samples with the control mix can be seen. The increment occurs at a point and is then gradually reduced. For the first sample where 5% and 0.5% WG and SN were added, there was about to 10% increment occurs. But for the second sample the increment doubled. The increment of strength was limited

Table 5: Observed Tensile strength test of 28 days

S.N.	Sample description	Flexure load (KN)	Flexure load after correction factor (KN)	Flexural strength (N/mm^2)	Average flexural strength (N/mm^2)	Remarks
	Controlled mix	25	14.13	2.51		
1	(0% waste glass,	24	13.49	2.40	2.47	
	0% syringe needle)	25	14.13	2.51		L = 600 mm
	Sample 2	28	16.03	2.85		B = 150 mm
2	(10% waste glass,	30	17.29	3.07	3.07	H = 150mm
	1% syringe needle)	32	18.56	3.30		

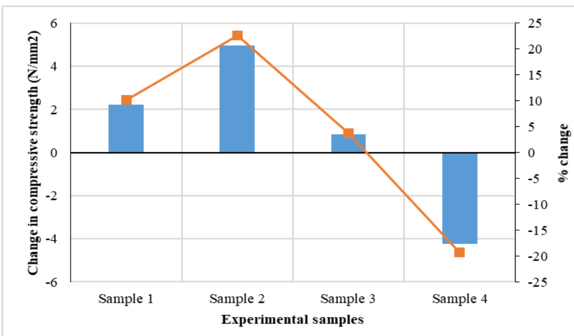

Figure 4: Comparison of experimental samples with control sample mix for 7 days

to 3.78% for sample 3 (15 & 1.5% of WG & SN). Then fall in strength occur afterward for sample 4 at a rate of 19.31%.

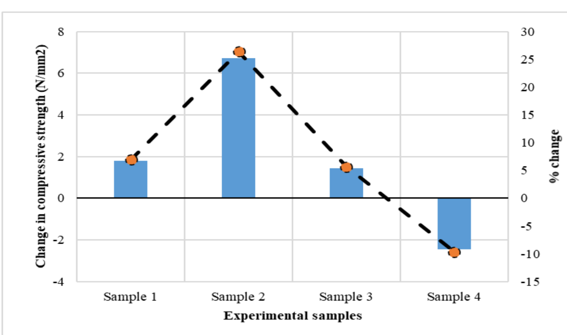

Figure 5: Comparison of experimental samples with control sample mix for 28 days

In Figure 5, a comparison of 28 days' compressive strength test of experimental samples with control mix is shown. The increment occurs at a point and is then gradually reduced, similar as the 7 days' result but in different values. For the first sample where 5% and 0.5% WG and SN were added, the increment was limited at 6.96%. But for the second sample, the increment was at the peak point and the value of increment was 26.38%. The increment of strength was limited to 5.6% for sample 3 (15 & 1.5% of WG & SN). Then fall in strength occur afterward for sample 4 at the rate of 9.67%. like the 7 days result, maximum compressive strength was noted at 10% of waste glass and 1% of syringe needle and the value of compressive strength of cube for 28 days of curing is 32.29N/mm^2.

3.3. Flexure strength test

A flexural strength test was done in order to find out the tensile strength of concrete. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The compressive strength test gives a conclusion that the best effect on mechanical properties of the concrete was observed at the 10% of waste glass and 1% of syringe needle as coarse aggregate replacement. A flexural strength test was carried out for the same sample approved by the previous compressive strength test, and a comparison was made with the normal M20 concrete. The 3 samples for each mix with beam size 150mm × 150mm × 700mm were prepared and an average value was found out. The Test results of flexural strength are shown in Table 5.

From Figure 6, it can be observed that the average flexural strength of concrete with 10% waste glass and 1% syringe needle as controlled replacement of coarse aggregate is greater than that of the controlled mix. This increased value of flexural strength might be due to the angular shape of waste glass which play role in the bonding effect and mainly due to the reinforcing property of the syringe needle.

4. Conclusions

Waste glass and syringe needle were used as the partial replacement of coarse aggregate, and from this experimental works following conclusion were drawn.

- The slump of the wet concrete decreased with increasing percentages of the waste glass and syringe needle as the partial replacement of coarse aggregate. The drop in the slump values can be related to the bad geometry (sharper and irregular) of WG and the reinforcing property of SN

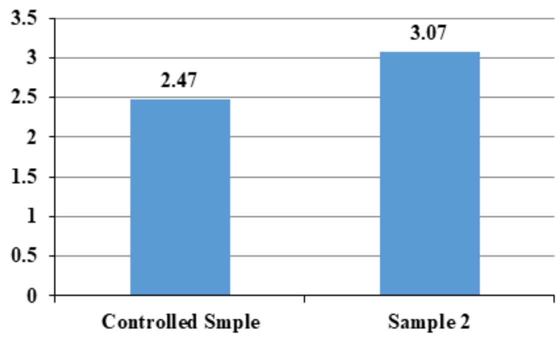

Figure 6: Comparison of flexural strength test of controlled sample and sample 2

which may give rise to high friction, and such resulted in less fluidity.

- Maximum compressive strength of M20 concrete was observed at 10% of waste glass and 1% of syringe needle and the value of compressive strength of the concrete cube at 28 days of curing was 32.29 N/mm^2.
- Flexural strength of concrete with 10% waste glass and 1% syringe needle as partial replacement of coarse aggregate is greater than that of the controlled mix. The increment of flexural strength was at 19.011%. And the obtained value is 3.07 N/mm^2.
- The result obtained from this study help to draw the conclusion that, combine use of waste glass and syringe needle as a controlled replacement of the coarse aggregate in M20 concrete gives dual effect to eliminate inorganic hazardous waste in the environment and at the same time enhance the mechanical properties of concrete.

5. Acknowledgement

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