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Experimental analysis of concrete having partial replacement of fine and coarse aggregate by waste glass with addition of fly ash for alkali silica reaction

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Abstract —*Waste glass is a large element of solid waste stream in many countries. Waste glass can be recycled many times but when different colored glass get mixed then it is impossible to recycle them, therefore it is sent to landfill. Other alternatives must be found instead of sending this waste glass to landfill. One alternative is use in concrete. The main goal is to investigate the possibility to improve the compressive strength over a range of glass percentages. Waste glass is the least expensive of all the concrete constituents and is much less expensive than natural aggregates and sand, thus the idea is to replace as much of the natural aggregates and sand as possible to save money and to reduce the amount of disposable wastes, as well, but care has to be taken in order not to weaken the concrete by adding too much glass. Studies were carried out in two phases. In first phase coarse aggregates are replaced with waste glass aggregates. In phase two fine aggregates are replaced with waste glass aggregates. The investigation was carried out using workability test, compressive strength test, indirect tensile strength test and water absorption test of concrete made of different percentages of waste glass. Total forty four test specimen were casted with increment of waste glass aggregates replacement from 10% to 60%. Moreover fly-ash is also added to suppress alkali silica reaction. The workability of concrete increases as we increase the waste glass content in both phases. This result is evaluated using slump test on fresh concrete. In phase one when coarse aggregates are replaced then both compressive and tensile strength decreases. This is evaluated by testing the specimens in UTM. In phase two similar methodology is applied and it is evaluated that both compressive and tensile strength increases when fine aggregates are replaced. In both phases it is seen that concrete becomes more durable with increase in waste glass content which is evaluated by conducting waster absorption test on hardened concrete.*

Keywords*- Waste glass, mechanical properties, fly ash for alkali silica reaction.*

I. INTRODUCTION

Concrete is an artificial conglomerate stone made essentially by mixing of Portland cement, water, and aggregates to achieve desired properties. Concrete is one of the oldest and most common construction materials in the world, mainly due to its low cost, availability, its long durability, and ability to sustain extreme weather environments. Concrete's versatility, durability, sustainability, and economy have made it the world's most widely used construction material. The worldwide production of concrete is 10 times that of steel by tonnage. About four tons of concrete are produced per person per year worldwide and about 1.7 tons per person in the United States. Concrete is a brittle material that has a high compressive strength, but a low tensile strength. Thus reinforcement of concrete is required to allow it to handle tensile stresses. Such reinforcement is usually done by using steel [1].
A proper concrete is one which has Strength, durability, workability and economy. Since concrete is a structural element and provide compressive strength to the structure, its strength normally ranges from 2000 pounds per square inch (psi) to 5000 pounds per square inch (psi). However concrete with as high as 10,000 pounds per square inch (psi) can also be prepared for special structures. The significance of this project is to compare the strength of conventional concrete with concrete made of waste glass as partial replacement of coarse and fine aggregates [2]. The project consist of two phases. In phase one replacement of coarse aggregates with waste glass and 20 % fly-ash replacement of cement is carried out. In phase two replacement of fine aggregates with waste glass and 15 % cement as replacement of cement is carried out [3].

II. LITERATURE REVIEW

Studies concluded that 20% replacement of fine aggregates by waste glass showed 15% increase in compressive strength at 7 days and 25% increase in compressive strength at 28 days. Fine aggregates can be replaced by waste glass up to 30% by weight showing 9.8% increase in compressive strength at 28 days [4]. With increase in waste glass content, percentage water absorption decreases. With increase in waste glass content, average weight decreases by 5% for mixture with 40% waste glass content thus making waste glass concrete light weight. Workability of concrete mix increases with increase in waste glass content. Use of waste glass in concrete can prove to be economical as it is non useful waste and free of cost. Use of waste glass in concrete will eradicate the disposal problem of waste glass and prove to be environment friendly thus paving way for greener concrete. Studies on waste glass as replacement of aggregates and he found out that with the help of slump test, concrete made of crushed glass aggregates has more workability then control mix. Slump of concrete increases with increase in waste glass content hence workability increases. In case of strength, concrete with using waste glass powder averagely have higher strength at 28 days [5]. Conventional concrete shows at 7 days compressive strength as 14.51 N/mm2 and split tensile strength of 1.55 N/mm2. Conventional concrete shows at 28 days compressive strength as 19.25 N/mm2 and split tensile strength of 1.88 N/mm2. Worked on waste glass as replacement of coarse aggregates in concrete. In his studies he found out that 28 day strength of concrete decreases up to 40 % replace however there is a marginally increase in strength up to 20 % replacement [6]. According to his studies the optimum replacement of waste glass as coarse aggregates is 10 %. Studies on waste glass replacement as fine aggregate in concrete mix. He in his studies found out that Crushed glass sand can be used to partially replace the natural sand to produce concrete with at least equivalent mechanical properties. The optimum replacement percentage is 45%. For a constant slump of 65±5mm, the concrete trial mix with 45% replacement of natural sand achieved higher compressive strength and similar modulus of elasticity at age of 28 days.

The drying shrinkage, apparent volume of permeable voids, and chloride diffusion coefficient decrease with the increment of replacement ratios of glass sand. The alkali silica reaction results show that the glass sand used in this project is acceptable as an aggregate. Data indicates that better durability can be achieved when crushed glass sand is used in concrete mixes. Studies shows that when waste glass is used as replacement of coarse aggregates then mass density was decreased by the increase of water cement ratio. More specifically, for the concrete with water cement ratio of 0.6, the concrete mass density decreased when the portion of coarse waste glass exceeded 0.4 [7]. The output results revealed that using coarse waste glass within the concrete mix lead to a considerable reduction in the mix workability for water cement ratios 0.5 and 0.6. Also, it was noticed that the coarse waste glass content almost did not affect the workability of the concrete mix at water cement ratio of 0.4. For concrete mixed with coarse waste glass as a partial occupant instead of coarse aggregates, some numerical analysis methods were employed to conclude that the optimum value of coarse waste glass to be used within the concrete mix with a water cement ratio of 0.4 was determined as about 0.265, and the corresponding expected 28-days hardened concrete compressive strength was about 385 kg/cm2. [8] For concrete mixes containing the optimal portion of coarse waste glass content, it was concluded that there was negligible effects on the pull-out strength, considerable enhancement of the flexural strength, and slight reduction of the splitting tensile strength of the mix. Moreover in case of fine glass it was concluded that the concrete mass density was inversely affected by the increase of water cement ratio. In more specific manner, for the concrete with water cement ratio of 0.4, the concrete mass density was adversely affected when the portion of coarse waste glass exceeded 0.4. The output results revealed that using fine waste glass within the concrete mix lead to a comparatively slight reduction in the mix workability for water cement ratios 0.5 and 0.6. Also, it was noticed that the coarse waste glass content almost did not affect the workability of the concrete mix at water cement ratio of 0.4. For concrete mixed with fine waste glass as a partial occupant instead of fine aggregates, the same mathematical analytical procedure was followed to conclude that the optimum value of fine waste glass to be used within the concrete mix with a water-cement ratio of 0.4 was estimated as almost 0.195, and the corresponding expected 28-days hardened concrete compressive strength was almost 400 kg/cm2. For concrete mixes containing the optimal portion of fine waste glass, it was concluded that there was negligible effects on the pull-out strength, considerable enhancement of the flexural strength, and slight reduction of the splitting tensile strength of the mix. There is great potential for the utilization of waste glass in concrete in several forms, including fine aggregate, coarse aggregate and glass powder. It is considered that the latter form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as silica fume, fly ash and cement. The use of glass powder in concrete would prevent expansive ASR in the presence of susceptible aggregate. Strength gain of GLP-bearing mortar and concrete is satisfactory. Micro structural examination has also shown that GLP would produce a dense matrix and improve the durability properties of concrete incorporating it. It has been concluded that 30% GLP could be incorporated as cement or aggregate replacement in concrete without any long-term detrimental effects. Up to 50% of both fine and coarse aggregate could also be replaced in concrete of 32 MPa strength grade with acceptable strength development properties. Effective utilization of colored glass aggregates in a range of architectural concretes and their properties tests. The performance test results conducted in this research confirm that the properties of those special mixed concretes are satisfactory. The properties tested include workability, air content, density, compressive strength, tensile strength, and water absorption [9]. Moreover, it is found that water absorption is strongly related to the strength of the concrete. Ultimately, glass is found to be an ideal material as a decorative aggregate in architectural concrete with its satisfactory performances and aesthetic property improvement. Studies shows the necessity of sustainable construction in present world and the possibility of waste glass recycling and using into concrete production. The study focuses on practical use of glass as coarse aggregate in concrete instead of stone chips or brick chips. Stone chips are costly and needed to collect straight from natural resource, brick chips are also expensive and its production causes environmental pollution. In this context, [10] it can be said that waste glass may open a new path of economic and pollution free concrete construction if desired strength can be achieved. During the study, maximum of 3889 psi compressive strength was found from several mixes, which is quite acceptable; though rough textures in glass samples would have provided better bond and better strength. In recent future, the optimum mix will be cast for other W/C ratios and different cement and fine aggregate ratios for achieving better strength. As glass doesn't absorb water, it is expected that same mix will provide better strength in lower W/C ratio. Admixtures like barium salts, lithium nitrate, lithium carbonate, lithium hydroxide will be added further to reduce the ASR (alkali silica reaction). After receiving the optimum combination, it will be required to do the durability test. [11]

III. RESEARCH METHODOLOGY

This chapter discussed on the methodology for the workability test and hardened concrete specimen test. Workability test included slump test. Hardened concrete specimen test included compression test and indirect tensile test. In our project total of 44 Test specimens are casted consisted of waste glass replacement as 15%, 25%, 40%, 45% and 60% replacement of fine aggregates and coarse aggregates, 22 moulds are casted for compression test and 22 moulds are casted for indirect tensile strength test. Mixture proportion for both fine aggregates replacement and coarse aggregates replacement with waste glass is given.

Table 1: Mixture Proportion for Coarse Aggregates Replacement

Waste Glass (%)	W/C Ratio	Water (Kg)	Cement (Kg)	Fly-ash		Sand (Kg)	Coarse Aggregates (Kg)	Waste Glass (Kg)
				(%)	(Kg)			
0	0.65	1.196	1.84	0	0	3.91	7.94	0
10	0.65	1.196	1.472	20	0.368	3.91	7.146	0.794
30	0.65	1.196	1.472	20	0.368	3.91	5.558	2.382
40	0.65	1.196	1.472	20	0.368	3.91	4.764	3.176
45	0.65	1.196	1.472	20	0.368	3.91	4.367	3.573
60	0.65	1.196	1.472	20	0.368	3.91	3.176	4.764

Table 2 Mixture Proportion for Fine Aggregates Replacement

Waste Glass (%)	W/C Ratio	Water (Kg)	Cement (Kg)	Fly-ash		Sand (Kg)	Waste Glass (Kg)	Coarse Aggregates (Kg)
				(%)	(Kg)			
0	0.65	1.196	1.84	0	0	3.91	0	7.94
10	0.65	1.196	1.564	15	0.276	3.519	0.391	7.94
30	0.65	1.196	1.564	15	0.276	2.737	1.173	7.94
40	0.65	1.196	1.564	15	0.276	2.346	1.564	7.94
45	0.65	1.196	1.564	15	0.276	2.1505	1.7595	7.94
60	0.65	1.196	1.564	15	0.276	1.564	2.346	7.94

III. RESULTS AND DISCUSSION

Series of test was carried out on the concrete cylinders to obtain the strength comparison of waste glass concrete with conventional concrete. This chapter discuss on the results that obtained from the testing. The results are such as slump test, water absorption test, compression strength test and indirect tensile strength test. The curing time period for each cylinder was 28 days. The percentage of fly-ash was 15% for each fine waste glass concrete cylinders, while in case of coarse glass concrete cylinders, fly-ash was 20% for 10% and 25% coarse glass concrete cylinders, 25% fly-ash for 40 and 45% coarse glass concrete cylinders and 30% fly-ash for 60% coarse glass concrete cylinders.

1. Slump Test:

The slump test indicates increasing trend of workability when the percentage of both coarse waste glass and fine waste glass is increased. Table below shows the average value of two slump tests for each proportion of coarse waste glass concrete and fine waste glass concrete respectively. The range of required slump for our project is between (1” - 2”).

Table 3: Slump Test Results for Waste Glass as Coarse Aggregates

Waste Glass Proportions	Fly-ash (%)	W / C	Slump Value (Inches)	Slump Value (mm)	Increase in Slump (%)
Control Mix	-	0.65	1.1	27.94	-
10% Coarse Glass concrete	20	0.65	1.3	33.02	18.2
25% Coarse Glass concrete	20	0.65	1.4	35.56	27.3
40% Coarse Glass concrete	25	0.65	1.6	40.64	45.5
45% Coarse Glass concrete	25	0.65	1.7	43.18	54.5
60% Coarse Glass concrete	30	0.65	1.9	48.26	72.7

Table 4: Slump Test Results for Waste Glass as Fine Aggregates

Waste Glass Proportions	Fly-ash (%)	W / C	Slump Value (Inches)	Slump Value (mm)	Increase in Slump (%)
Control Mix	-	0.65	1.1	27.94	-
10% fine Glass concrete	15	0.65	1.3	33.02	18.2
25% fine Glass concrete	15	0.65	1.5	38.1	36.4
40% fine Glass concrete	15	0.65	1.8	45.72	63.6
45% fine Glass concrete	15	0.65	1.8	45.72	63.6
60% fine Glass concrete	15	0.65	2.2	55.88	100

2. Compressive Strength Test (ASTM C 39 - 04a)

2.1 Compressive Strength Test Results and Analysis for Fine Glass Aggregates:

The compression test indicates an increasing trend of compressive strength as the percentage of fine waste glass is increased in concrete. Table below shows the value of compressive strength of fine waste glass concrete specimen. Figure below shows the graphical representation of compressive strength of fine waste glass concrete. The reason for increase in compressive strength is that when the size of waste glass is less than 4.75mm (passing #4 sieve) then its pozzolanic properties activates, and fine waste glass also act as a binder in concrete apart from cement, due to which the strength of concrete increases.

2.2 Compressive Strength Test Results and Analysis for Coarse Glass Aggregates:

The compression test indicates a decreasing trend of compressive strength as the percentage of coarse waste glass is increased in concrete. Table below shows the value of compressive strength of coarse waste glass concrete specimen. Figure below shows the graphical representation of compressive strength of coarse waste glass concrete. The reason for decrease in compressive strength is that the bond between smooth surface coarse glass and gravel is weaker than gravel to gravel bond, due to angular shape of gravel aggregates.

Table 5: Compressive Strength Test Results For Waste Glass As Fine Aggregates

Waste Glass Proportions	Fly-ash (%)	W / C	Load(KN)	Stress(Psi)	Increase in Strength(%)
Control Mix	-	0.65	398	3099.15	-
10% Fine Glass concrete	15	0.65	409	3181.82	2.67 %
25% Fine Glass concrete	15	0.65	417	3244.72	4.69%
40% Fine Glass concrete	15	0.65	445	3464.84	11.8 %
45% Fine Glass concrete	15	0.65	427	3323.33	7.23 %
60% Fine Glass concrete	15	0.65	424	3299.75	6.47 %

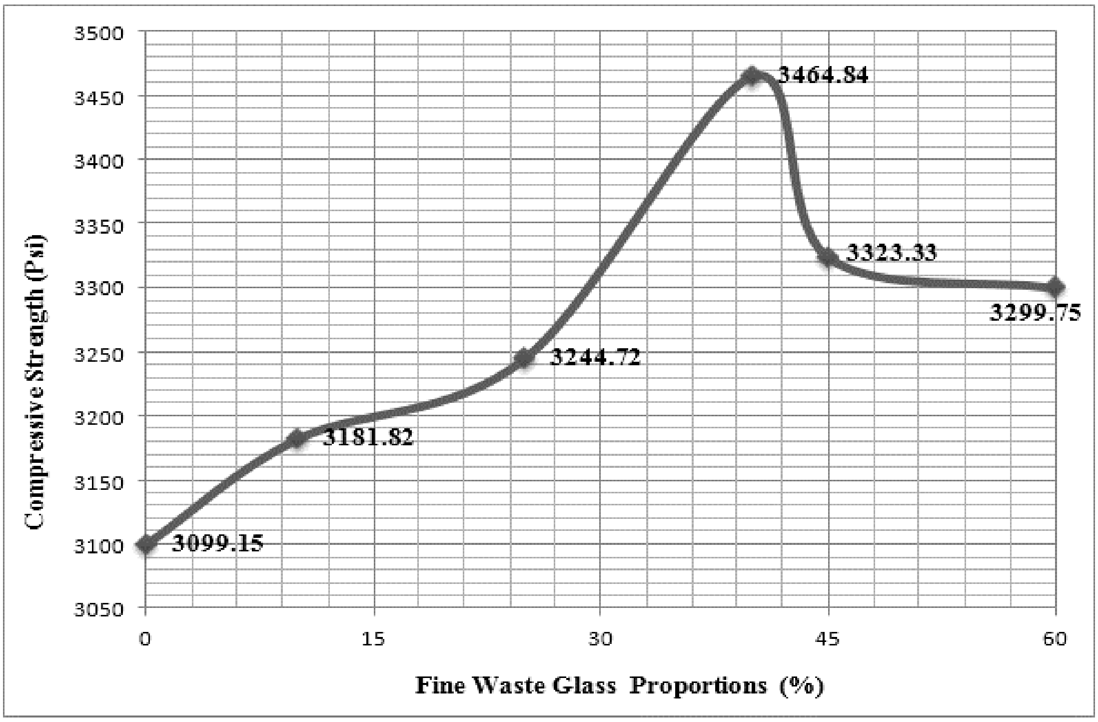

Figure 1: Compressive Strength Test Results For Waste Glass As Fine Aggregates

Table 6:Compressive Strength Test Results for Waste Glass as Coarse Aggregates

Waste Glass Proportions	Fly-ash (%)	W / C	Load (KN)	Stress (Psi)	Decrease in Strength (%)
Control Mix	-	0.65	398	3099.15	-
10% coarse Glass concrete	20	0.65	391	3040.32	1.9
25% coarse Glass concrete	20	0.65	384	2985.29	3.67
40% coarse Glass concrete	25	0.65	377	2930.26	5.45
45% coarse Glass concrete	25	0.65	368	2859.51	7.73
60% coarse Glass concrete	30	0.65	317	2458.57	20.67

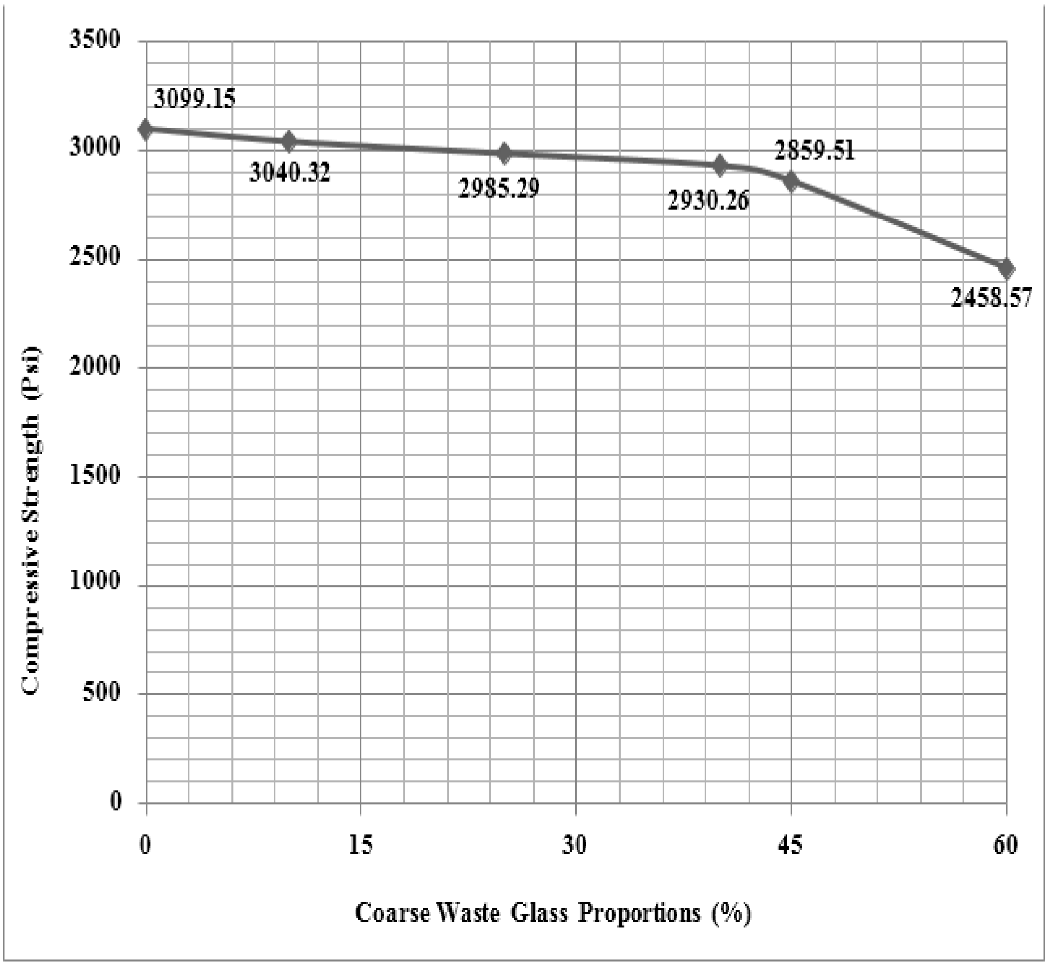

Figure 2: Compressive Strength Test Results For Waste Glass As Coarse Aggregates

3. Tensile Strength Test (C 496 / C 496M – 04)

3.1 Tensile Strength Test Results and Analysis for Fine Glass Aggregates:

The tensile strength test indicates an increasing trend of tensile strength as the percentage of fine waste glass is increased in concrete. Table belowshows the value of tensile strength of fine waste glass concrete specimen. Figure below shows the graphical representation of tensile strength of fine waste glass concrete. The reason for increase in tensile strength is that when the size of waste glass is less than 4.75mm (passing #4 sieve) then its pozzolanic properties activates, and fine waste glass also act as a binder in concrete apart from cement, due to which the strength of concrete increases.

3.2 Tensile Strength Test Results and Analysis for Coarse Glass Aggregates:

The tensile test indicates a decreasing trend of tensile strength as the percentage of coarse waste glass is increased in concrete. Table below shows the value of tensile strength of coarse waste glass concrete specimen. Figure below shows the graphical representation of tensile strength of coarse waste glass concrete. The reason for decrease in tensile strength is that the bond between smooth surface coarse glass and gravel is weaker than gravel to gravel bond, due to angular shape of gravel aggregates.

Table 7: Tensile Strength Test Results for Waste Glass as Fine Aggregates

Waste Glass Proportions	Fly-ash (%)	W / C	Load (KN)	Stress (Psi)	Increase in Strength(%)
Control Mix	-	0.65	213	409.7	-
10% Fine Glass concrete	15	0.65	219	421.56	2.89
25% Fine Glass concrete	15	0.65	223	429.48	4.83
40% Fine Glass concrete	15	0.65	239	461.17	12.56
45% Fine Glass concrete	15	0.65	234	451.26	10.15
60% Fine Glass concrete	15	0.65	231	445.33	8.69

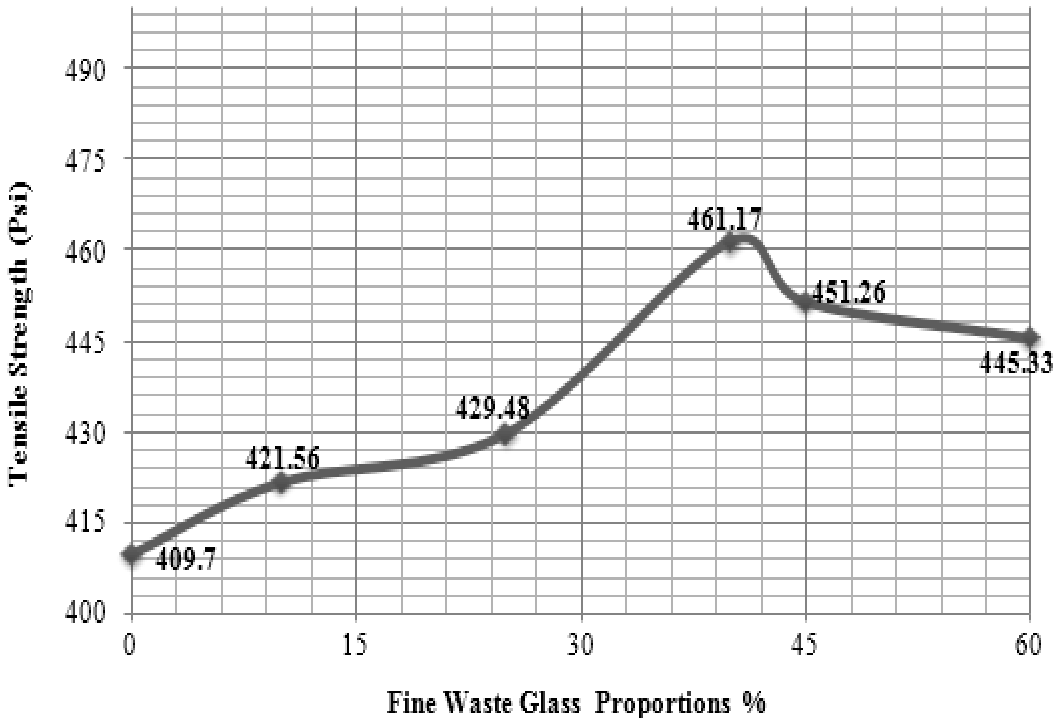

Figure 3: Tensile Strength Test Results for Waste Glass as Fine Aggregates

Table 8: Tensile Strength Test Results for Waste Glass asCourse Aggregates

Waste Glass Proportions	Fly-ash (%)	W / C	Load (KN)	Stress (Psi)	Decrease in Strength (%)
Control Mix	-	0.65	213	409.68	-
10% Fine Glass concrete	20	0.65	203	391.2	4.51
25% Fine Glass concrete	20	0.65	198	381.16	6.96
40% Fine Glass concrete	25	0.65	193	370.36	9.6
45% Fine Glass concrete	25	0.65	186	357.11	12.83
60% Fine Glass concrete	30	0.65	178	341.88	16.55

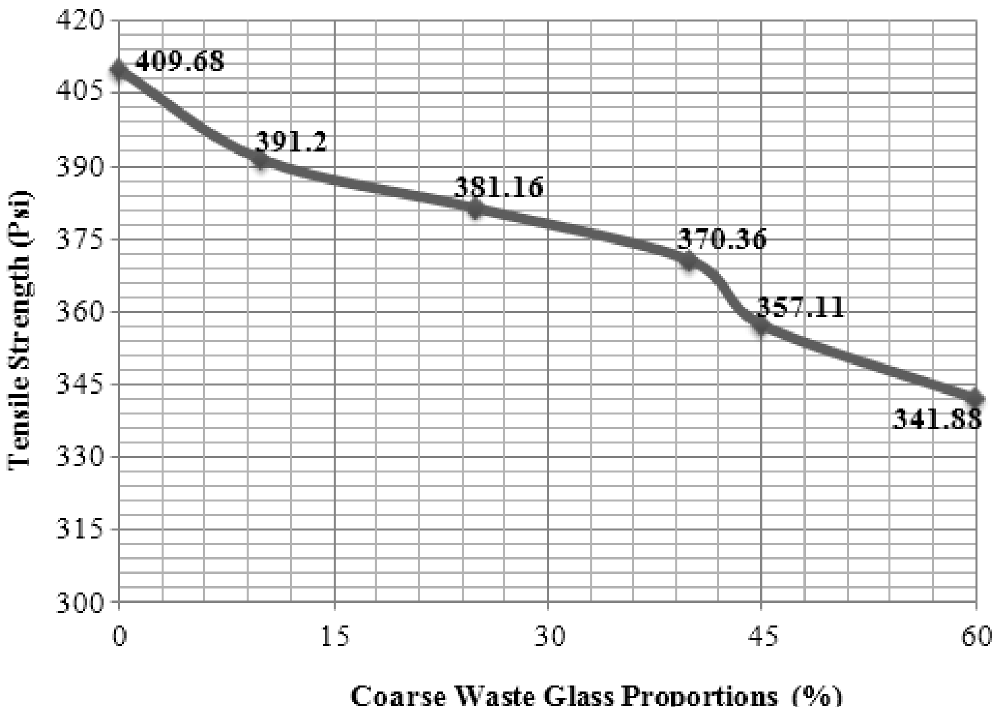

Figure 4: Tensile Strength Test Results For Waste Glass As Coarse Aggregates

IV CONCLUSION

Waste glass as fine aggregates in concrete:

Workability of concrete increases as the partial replacement of natural fine aggregates with fine waste glass is increased. Durability of concrete increases as the partial replacement of natural fine aggregates with fine waste glass is increased. When Glass is used as fine aggregates then compressive and tensile strength both increases. At 40% replacement of natural fine aggregates with waste glass, maximum increase in compressive strength is 11.8%. At 40% replacement of natural fine aggregates with waste glass, maximum increase in tensile strength is 12.56%. Replacing natural fine aggregates with fine waste glass in concrete in uneconomical.

Waste glass as coarse aggregates in concrete:

Workability of concrete increases as the partial replacement of natural coarse aggregates with coarse waste glass is increased. Durability of concrete increases as the partial replacement of natural coarse aggregates with coarse waste glass is increased. When Glass is used as coarse aggregates then compressive and tensile strength both decreases. At 10% replacement of natural coarse aggregates with waste glass, decrease in compressive strength is 1.9%. At 60% replacement of natural coarse aggregates with waste glass, decrease in compressive strength is 20.67%. At 10% replacement of natural coarse aggregates with waste glass, decrease in tensile strength is 4.51%. At 60% replacement of natural coarse aggregates with waste glass, decrease in tensile strength is 16.55%. Replacing natural coarse aggregates with coarse waste glass in concrete in economical. 10% coarse glass replacement with natural coarse aggregates is 6.58% economical and 60% coarse glass replacement with natural aggregates is 46.22% economical as compared to conventional concrete without adding the crushing cost of waste glass.

V. RECOMMENDATIONS

Further testing and studies on waste glass as partial replacement of natural aggregates in concrete is highly recommended to indicate the strength characteristics of waste glass concrete. Below are some recommendations for further studies.

1. Study can be carried out with different plasticizers.
2. Study is required on replacing coarse waste glass with gravel and fine waste glass with sand at the same time.
3. Replacing waste glass powder (passing sieve # 200) with cement in concrete should be studied.
4. More investigation and laboratory tests should be done on waste glass concrete for strength characteristics. It is recommended that testing can be done on concrete slabs, beams and walls.
5. More trials with different percentage of replacement of natural aggregates of concrete with waste glass aggregates are recommended to get different outcomes and higher strength characteristics.
6. Studies on cost analysis for preparation of glass aggregates should carried out.

REFERENCES

[1] I.B. Topcu and M. Canbaz, "Properties of Concrete containing waste glass", Cement and Concrete Research, vol. 34, pp. 267-274, Feb. 2004.

[2] A. Shayan and A. Xu, "Value added utilization of waste glass in concrete", Cement and Concrete Research, vol-34, pp.81-89, Jan.2004.

[3] M. Iqbal Malik, Muzafar Bashir, Sajad Ahmad, Tabish Tariq, Umar Chowdhary " Study of Concrete Involving Use of Waste Glass as Partial Replacement of Fine Aggregates" Vol. 3, PP 08-13, 7 (July. 2013)

[4] Vikas Srivastava , S. P. Gautam, V. C. Agarwa , P. K. Mehta "Glass Wastes as Coarse Aggregate in Concrete" Volume 3, No.1 pp. 67-71

[5] Johnson, C. D., Waste glass as coarse aggregate for concrete, J. Test.Eval., 2, 344–350 (1998).

[6] Topcu, I. B. and Canbaz, M., Properties of concrete containing waste glass, Cement Concrete Res., 34, 267–2 7 4(2 0 0 4) .

[7] Vikas Srivastava, Rakesh Kumar, and Mehta, P. K., "Concrete Made With Waste Materials" J. Environ. Nanotechnol., 2(2), 102-106 (2013).

[8] Ion Dumitru, Tony Song, Vasile Caprar, Phillip Brooks2 and Justin Moss3 "Incorporation of Recycled Glass for Durable Concrete" ISBN 978-1-4507-1490-7

[9] Meyer, C. and Baxter, S. (1998). "Use of Recycling Glass and Fly ash for Precast Concrete", Columbia University, Final Report to New York State Energy Research and Development Authority, Rep. No. 98-18

[10] Meyer, C. (1999). "Development of Glass Concrete Products", Columbia University, Final Report to New York Empire State Development. Nordtest Method NT Build, ISSN0283-7153.

[11] Shao Y, Lefort T, Moras S and Rodriguez D. Studies on Concrete Containing Ground Waste Glass. Cement and Concrete Research, Vol. 30, pp 91-100, 2000.