EVALUATING THE EFFECTS OF WASTE GLASS AND WASTE MARBLE ON THE FLEXURAL STRENGTH OF RCC-BEAM AND BOND STRENGTH OF CONCRETE

A Thesis of

Master of Science

By

Jawad Ahmad

(NUST-2017-MS-SE-00000203470)

DEPARTMENT OF STRUCTURAL ENGINEERING

MILITARY COLLEGE OF ENGINEERING RISALPUR

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

ISLAMABAD, PAKISTAN

(2019)

THESIS ACCEPTANCE CERTIFICATE

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EVALUATING THE EFFECTS OF WASTE GLASS AND WASTE MARBLE ON THE FLEXURAL STRENGTH OF RCC-BEAM AND BOND STRENGTH OF CONCRETE

Submitted by

JAWAD AHMAD

has been accepted towards the partial fulfillment
of the requirements for the degree
of
Master of Science in Structural Engineering

SUPERVISOR: ________________________________

ASSISTANT PROFESSOR (Dr. MUHAMMAD SHAHID SIDDIQUE)

MILITARY COLLEGE OF ENGINEERING, RISALPUR

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY, ISLAMABAD

UNDERTAKING

I certify that research work titled ***"Evaluating the effects of waste glass and waste marble on the flexural Strength of RCC-Beam and bond strength of concrete"*** is my own work. Where the material has been used from other sources it has been properly acknowledged / referred.

Signature of Student

Engr. Jawad Ahmad

M.Sc. Structural Engineering

ACKNOWLEDGEMENTS

The completion of this project was only possible due to unlimited blessings of almighty Allah because nothing is possible without his will and collaboration of many people, to whom I wish to express my gratitude.

First and foremost, I would like to express my heartfelt gratitude to our supervisor *Dr Muhammad Shahid siddique* for his never-ending patience, tremendous advice, guidance, support, continuous discussion, suggestions and encouragement throughout the project.

Secondly, my respectful thank you goes to lab staff of concrete laboratory. They have always given their heartfelt cooperation and assistance in this research. Besides that, my respectful thank you goes to lab staff of strength of materials laboratory that have been provided me a help during testing.

Finally, I greatly appreciate all the help from my friends and family members who always been so supportive and motivating throughout the process.

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LIST OF ABRIVATIONS

ASTM	American Society for Testing Material
ACI	American concrete institute
kN	kilo Newton
Li	Liter
MPa	Mega Pascal
Psi	Pound/inch^2
Mm	Millimeter
SSD	Saturated Surface Dry
W/c	Water to cement ratio
%	Percentage
C.A	Coarse Aggregate
F.A	Fine Aggregate
UTM	Universal Testing Machine
WG	Waste Glass
WM	Waste Marble
OPC	Ordinary Portland cement
PCSIR	Pakistan council of scientific and industrial research
RSM	Response Surface Methodology
FN	Fineness
SG	Specific gravity
MC	Moisture content
WA	Water absorption
BD	Bulk density
SA	Sieve analysis

ABSTRACT

The industrial waste has been rapidly increased day by day due to the fast growing population and usage of products, which dumps unscrupulously resulting in environmental pollutions. Therefore, it has been recommended that, the disposal of industrial waste would be greatly reduced if it could be incorporated in concrete production. The basic aim of this study is to investigate the characteristics of concrete by using waste glass as binding material in proportion 10%, 20% and 30% and marble waste as a fine aggregate in proportion 40%, 50% and 60% for 1:1.5:3 concrete with w/c 0.5. Flexure, Split tensile and pull out tests were conducted after 28days curing. From results it has been concluded that, strength was increased up to 20% replacement of glass powder and then decrease gradually while in case of marble, strength was increased up to 50% replacement then decrease gradually. Similarly for both cases slump values were higher than conventional concrete. Statistical approach of Response surface methodology was performed to develop contour and 3D response surface for flexure strength, split tensile strength, and pull out strength. Select three best possible options from statistical analysis and were verified through experimental tests. Based on experimental results, highest strength is obtained at ratio 15% glass and 30% marble respectively.

CHAPTER 1

INTRODUCTION

1.1 General overview

Concrete is most extensively used man made construction materials around all over the world. According to the recent research, more than a ton of concrete is produced each year because concrete is one of the most durable, strong and economical.

Concrete is a heterogeneous mixture of cement, aggregate (coarse and fine aggregate) and water. Aggregate can not only affects the strength of concrete but can also affect workability, permeability as well as durability of concrete. Fine aggregate (sand) is one of the most important components of concrete. Generally natural river sand is mostly used as fine aggregates. The annual global consumption of fine aggregate (sand) is very high due to extensive used of concrete and as a results the requirements of fine aggregate (sand) is very high in many countries owing infrastructure growth. In many parts of the world, construction industries are facing one problem due non availability of good quality sand for making good quality concrete which seriously effects the construction growth.

On the other hand, globally the annual cement production rate has reached 2.8 billion tons and expected to further increase 4 billion tons per year. Cement factories are facing many problems such as rapidly increase cost of energy, arrangements to minimize carbon dioxide evolution and the non availability of raw materials in sufficient quantities.

Keep in mind all the above factors we have need to develop some alternate source instead of cement and sand. For that reasons this study is undertaken to evaluate the effect of partial replacement of cement and sand with industrial waste in concrete.

1.2 Marble waste

Marble waste is produced during the cutting shaping and polishing marble in marble plants. According to the researched, about 20 to 25% of the process marble is turn into waste. Pakistan is one of the topmost exporters of marble, every year million tons of marble wastes are released from marble plants. Such marble waste disposal on soil cause reduction in permeability and also contaminates the over ground water when deposited along catchment area. Thus utilizing of marble waste in concrete not only protect environment from dump sites improve the property of concrete but also decrease the scarcity of natural resources.

1.3 Glass waste

Glass waste is normally produced from the glass industries, during the cutting, shaping and polishing. Thus, the main aim of environmental authorities is to reduce the disposal of waste glass in landfill or recycle to glass products as far as possible. Therefore, it has been supposed that, the disposal of waste glass would be greatly reduced if it could be incorporated in concrete production. Thus the used of waste glass to replaced the cement in concrete improve the fresh and harden property of concrete, directly reduced carbon dioxide emission which is produce from cement plant during the manufacturing process of cement, not only this but the cost of concrete is also reduce because cement is one of the costly ingredient an concrete mix.

Because of these reasons the use of wastes glass and waste marble materials from industries came into the picture to reduce the wastes from manufacturing units, as well as to decrease the scarcity of natural basic aggregate.

1.4 Problem Statement

The industrial waste has been rapidly increased day by day due to the rapidly increased population and usage of products. Only significant quantities have been utilized while the reaming insignificant part has been dumped unscrupulously which results environmental pollutions. Therefore, it has been supposed that, the disposal of industrial waste would be greatly reduced if it could be incorporated in concrete production. The basic aim of this study is to investigate the characteristic of concrete by using waste glass as binding material and marble waste as a fine aggregate and obtain combine ratio of waste glass and waste marble which leads to best performance of concrete.

1.4 Objectives

The main objective of the study is to examine the usability of the waste glass powder and waste marble powder as partial substitute of cement and fine aggregate in concrete respectively. Effect of these waste materials in concrete has been investigated by experimental tests on conventional concrete without any waste with varying quantities of waste glass and waste marble by replacing the cement and sand partially respectively.

- To investigate the effect of waste glass and waste marble on the bond strength of concrete.
- To investigate the effect of waste glass and waste marble on flexural strength of reinforced concrete beam.
- To evaluate the individually optimum replacement of waste glass and waste marble materials.
- To perform statistically analysis to identify best possible option for combined substitution.
- To compare predicted value from statistically analysis and experimental value.

1.5 Research Approach

Concrete mix M20, w/c is 0.50 and types of coarse aggregate is keep constant throughout study. Materials will be procured from the local available industries and quarry sites and then tests will be performed on the materials. Cement will be brought from the local purchasers and glass will be procured from "Gunj glass factory Hassanabdal" and will be grinded at "PCSIR laboratory Peshawar". Coarse and fine aggregates will be also procured from locally available quarry sites. Casting of specimens will be performed. A total of 90 samples will be prepared. For pull out and split tensile test, standard cylinders (6x12inches) will be casted and for flexural strength test beams (6x6x20inches) will be casted. After 28 days curing hardened concrete tests will be performed on samples. Pull out test (ASTM-C234) and split tensile strength (ASTM-C496) will be performed on cylindrical samples and flexural strength test (ASTM C78-84) will be performed on beam samples.

1.6 Organization of the report

Chapter 1 is an introductory chapter about concrete, objective of the study and thesis overview.

Chapter 2 describe literature review in details

Chapter 3 represents the procedure and materials of test setup, the testing programs and casting of specimens.

Chapter 4 discusses the tests results, observations and calculation, and graphical representation of results

Chapter 5 describes conclusions based on experimental results of research and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Level of Research Already Carried Out on the Proposed Topic

Sadiq and Atoyebi (2018) carried out his research with fine aggregate partially replaced with waste glass in proportion 10%, 20% and 30%. Reinforced concrete beams of size 150mmx150mmx1000mm were casted and subjected to flexure load after 28 days curing. From results it has been concluded that at 30% replacement, flexure strength is increased about 3.3% higher than reference beam. Therefore 30% replacement is the optimum replacement.

Hashmi and Ali (2014) partially replaced cement with marble waste in cement concrete and studied their effect on flexure strength of Reinforced concrete beam. The fine aggregate is replaced by waste marble at 0, 5, 10, 15 and 20% for M30 concrete. After 28 days curing the beam (150mmx150mmx700mm) elements were subjected to flexural load. From results it has been concluded that at 10% replacement, flexure strength is increase about 12% higher than reference beam. Therefore 10% replacement is the optimum replacement.

Latha and Nishanthi (2017) used waste ceramic tiles as partial replacement of coarse aggregate in concrete. The coarse aggregate is replaced by waste ceramic tiles 0%, 10%, 15%, 20%, 25%, and 30% for M30 concrete. After 28 days curing the unreinforced concrete beam (100mm x 100 mm x 500mm) subjected to flexural load. From results it has been concluded that at 30% replacement flexure load is increase about 44.75% higher than reference beam.

Raju and kumar (2014) carried out his research with cement as a partially replacement of waste glass in concrete. The waste glass were replaced at the interval of 5% from 0% to 40% by weight of cement for M20 concrete with w/c 0.5 and study their effect on the performance of concrete. From results it has been concluded that the slump is decrease with the addition of marble waste while in case of strength, compressive and flexure strength is increased up to 20% replacement and then decrease gradually. At 20% replacement, compressive strength is increased about 29%,23% and 24% while flexure strength increases about 27%,19 and 16% at 7,28 and 90 days curing respectively. Therefore 20% replacement is the optimum replacement.

Somber and berwal (2017) used 0, 5, 10, 15 and 20% of glass powder an concrete as partial replacement of cement for M20 concrete with a w/c 0.5 and find their compressive strength at the age of 7&28 days curing. From results it has been concluded the compressive strength is increased up to 15% replacement of cement with waste glass and then decrease. Compressive strength at 7 and 28 days curing is about 3 to 4% higher than convention concrete at 15% replacement of waste glass with cement and therefore 15% replacement is the optimum replacement.

Vandhiyan et al (2013) carried out his research on partially replacement of cement with waste glass in concrete by proportion 0%, 5%, 10% and 15%. Flexure strength and split tensile strength were conducted at 28 days curing and compressive strength were conducted after 7, 14, 28 days curing. At 10% replacements, the compressive strength is increasing about 31%, 16% and 9%at the age of 7, 14 and 28 days curing from reference concrete respectively. In case of split tensile strength, a little improvement was observed at 10% replacement while the flexural strength at 10% replacement is 37% higher than control specimen. Hence overall 10% replacement is the optimum replacement.

Vijayakuma et al (2013) substitute waste glass as partially replacement of cement an proportion 0%,10%,20%,30%and 40% by weight of cement for M20 concrete with a w/c 0.53. After 28 days curing flexure strength compressive strength and split tensile strength were performed.

From results it has been concluded that at 40% replacement compressive, split tensile and flexure strength is about 33.7%, 4.4 %and 18.6% higher than from conventional concrete and therefore 40% replacement is the optimum replacement.

Kumar et al (2014) studies the effect of partially replacement of cement with waste glass in proportion from 0 to 40% by volume at 5% interval for M20 concrete with a w/c 0.45. Split tensile and compressive tests were conducted after 7, 28, 60 days curing. From results it has been concluded that the workability is continuously decrease as the addition of waste glass increase and compressive strength is about 25%, 36%and 35% higher than the convention concrete at the age 7, 28, 60 days curing receptively while split tensile strength is about 33%, 19%and 18% higher than the convention concrete at the age 7, 28, 60 days curing receptively and thus 20% replacement is the optimum replacement.

Subramani and Ram (2015) carried out his research on partial replacement of cement with waste glass powder in concrete as proportion 0%, 10%, 20% and 40%. After 7,14 and 28 days curing, split tensile and compressive test were conducted for the above replacement. Results showed that at 10% replacements, the compressive strength is increasing about 12%, 2.5% and 1.5%at the age of 7, 14 and 28 days curing from reference concrete respectively. Similar at 10% replacement, split tensile strength is increase about 14 % ,13% and 8% at the age of 7, 14 and 28 days curing from reference concrete respectively. Hence overall 10% replacement is the optimum replacement.

Alyamac and Aydin (2015) used marble waste as a partial replacement of fine aggregate in a proportion of 10 %, 20%, 30%, 40%, 50% and 90% by volume. The compressive are performed at the age 7, 28, 90 days curing while split are performed at the age 28 days curing. From the results it has been concluded the slump is continuously decrease with the addition of marble waste and compressive strength is increase up to 40% replacement of fine aggregate with marble waste and then gradually decrease. Therefore, using up to 40% marble powder in concrete is suitable in accordance with the requirements.

2.1 Conclusion

According to past researches and mentioned literature, substitution of waste glass and marble waste in concrete had a positive response to the strength of concrete due to which these can be good alternatives for cement and sand in concrete. Higher strength along with workable can be achieved by partially replacing fine aggregate with waste marble and cement with waste glass powder but it should be noted that these research were done only separately replacement of waste glass as a cement and marble waste as a fine aggregate. We are trying to identify combine ratio of waste glass and waste marble which lead to best performance of concrete.

CHAPTER 3

EXPERIMENTAL SETUPS

3.1 Introduction

Based on literature survey and the objective of the proposed work, the testing program has been decided. The experiment work contains testing of each material that can be used in the experiments. Standard test procedure with reference to ASTM code would be performed on materials like cement, sand, aggregates, waste marble and waste glass, detail study about mix proportion, sample preparation and different test technique and also Effect of these waste materials in concrete has been investigated by experimental tests on conventional concrete without any waste with varying quantities of waste glass and marble dust powder by replacing the cement and sand partially respectively.

3.2 Methodology

Concrete mix 1:1.5:3, w/c ratio 0.50 and types of coarse aggregate were kept constant throughout study. Then methodology was divided into the following phases.

Phase 1

Materials were procured from the local available industries and quarry sites and then tests were performed on the materials. Cement was brought from the local purchasers and glass was procured from "Gunj glass factory Hassanabdal" and grinded at "PCSIR laboratory Peshawar". Coarse and fine aggregates were procured from locally available quarry sites.

Phase 2

Mix design was performed after the characterization of materials and trial samples were casted for 28 days after mix design to reconfirm the performed mix design and strength criteria.

Phase 3

Castings of specimens were performed. A total of 90 samples were prepared. For pull out test 6inch cubes were casted while standard cylinders (6x12inches) were casted for split tensile test and for flexural strength test beams (6x6x20inches) were casted.

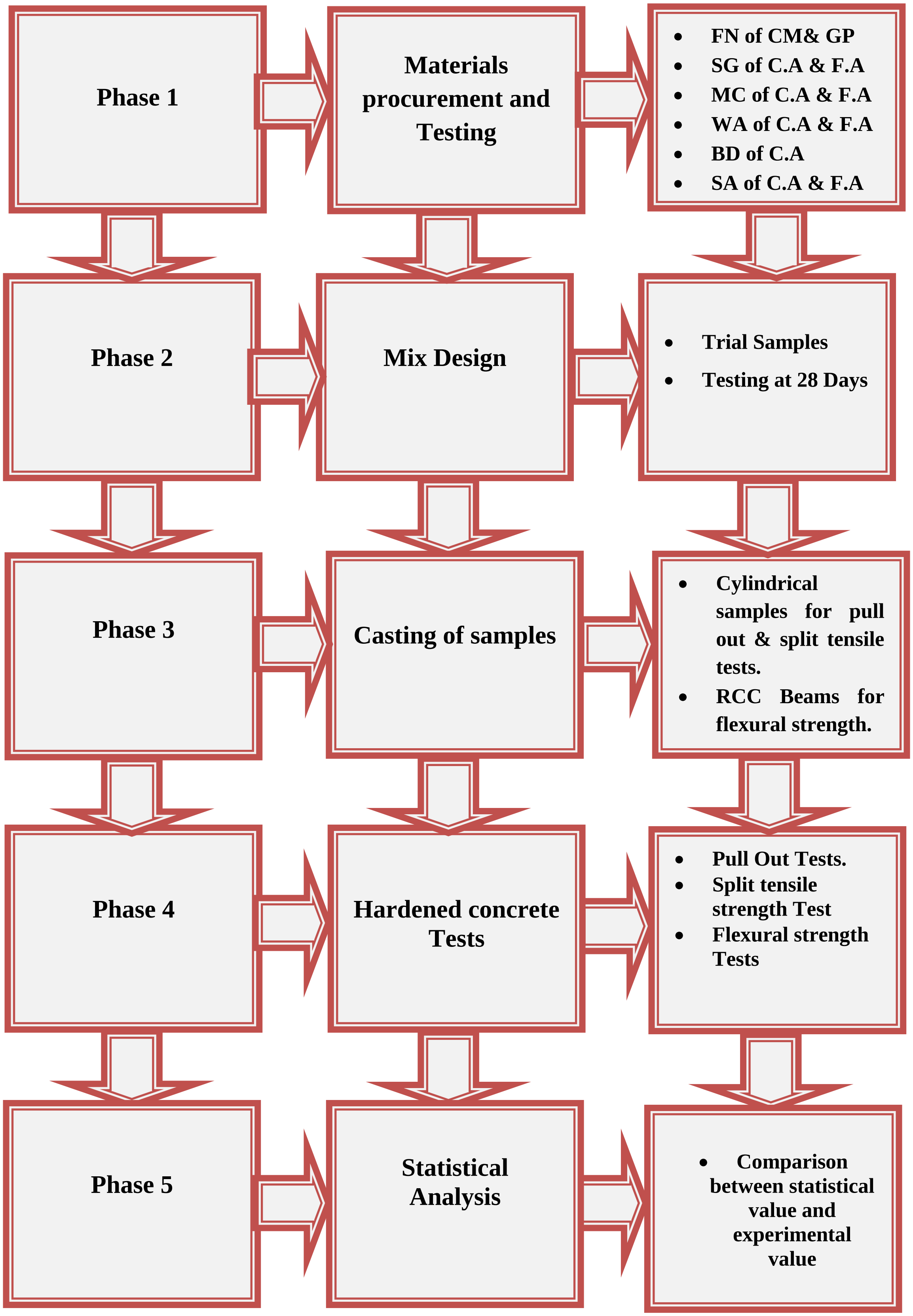
Phase 4

After 28 days curing hardened concrete tests were performed on samples. Pull out test (ASTM-C234) were performed on cube and split tensile strength (ASTM-C496) were performed on cylindrical samples and flexural strength test (ASTM C78-84) were performed on beam samples.

Phase 5

Statistical analysis were performed to develop counter and 3d response surface for flexure strength, split tensile strength an pull out strength . Comparing value obtain from counter map and experimental value.

3.3 Flow chart of methodology



3.4 Materials Properties

3.4.1 Cement

Best way cement (Pakistan) was used as a binding material in this study having characteristics shown in table 1.

Table 1 Physical Properties of Cement

Property	Particle Size	Fineness	Normal Consistency	Initial Stetting Time	Final Stetting Time
Value	≤ 75μ	91.2%	31%	48 min	341 min

3.4.2 Fine Aggregate

Natural sand in saturated dry condition (SSD) was used as a fine which was obtained from local market risalpur Pakistan. Different test were performed on sand to evaluate its physical property and gradation (sieve analysis). Standard (ASTM33/C33M-13) was used for gradation (sieve analysis) of fine aggregate. Results of its sieve analysis and physical property are shown in table 2 and table 3 respectively while gradation curve for material under study and standard curve (upper and lower limits) are shown in Figure 1.

Table 2 Physical Properties of Fine Aggregate

Property	Particle Size	Fineness Modulus	Absorption Capacity	Moisture Content
Value	4.75mm to 0.075mm	2.73	6.28%	4.8%

Table 3 Sieve Analysis of Fine Aggregate

Sieve No	Mass Retain	%Mass Retain	Cumulative % Mass Retain	Cumulative %Passing	Grading Limits (ASTM C33)
4	0	0	0	100	95 to 100
8	41	4.1	4.1	95.9	80 to 100
16	118.7	11.87	15.97	84.03	50 to 85
30	566.1	56.61	72.58	27.42	25 to 60
50	113	11.3	83.88	16.12	5 to 30
100	130	13	96.88	3.12	0 to 10
Pan	14.3	1.43	98.31	1.69	----

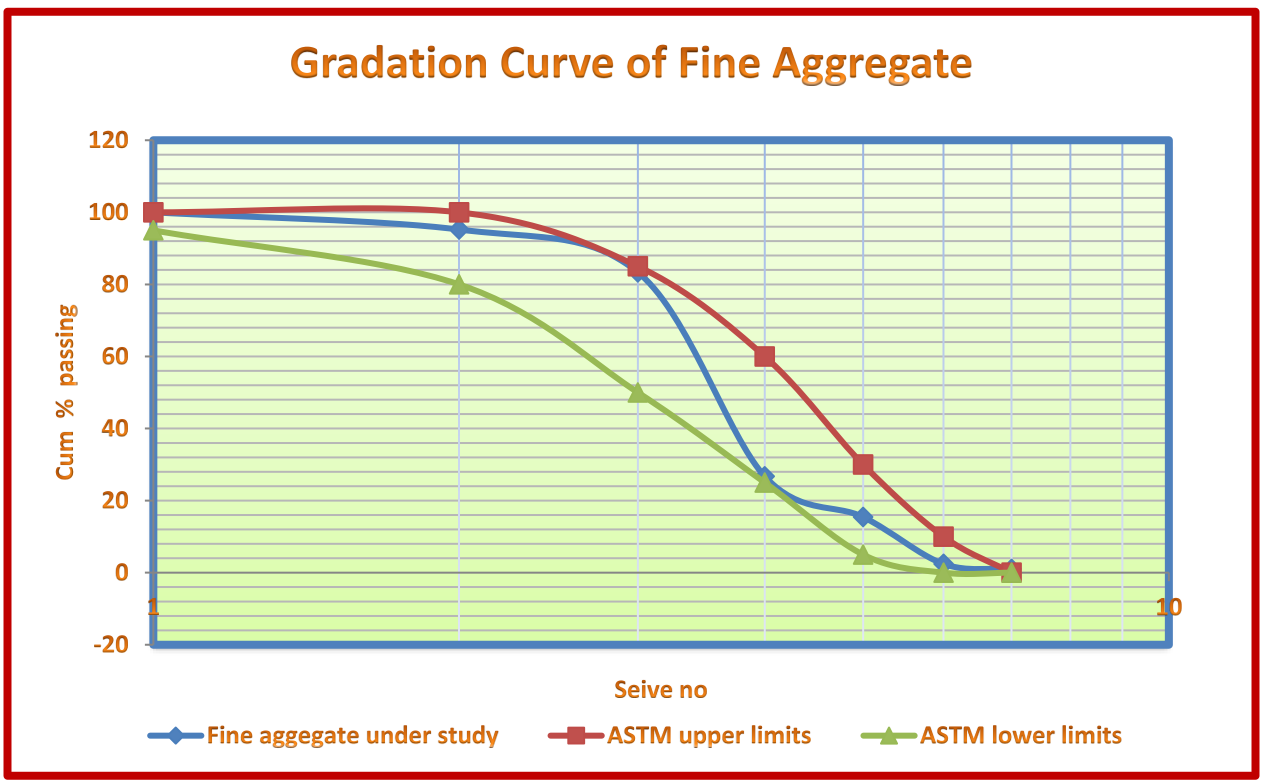


Figure 1 Gradation Curve of Fine Aggregate

3.4.3 Coarse Aggregate

Normal weight coarse aggregate (crush stone) in saturated dry condition (SSD) was obtained from local market risalpur Pakistan shown in Figure 2. Different test were performed on coarse aggregate to evaluate its physical property and gradation (sieve analysis). Standard (ASTM33/C33M-13) was used for gradation (sieve analysis) of coarse aggregate. Results of its sieve analysis and physical property are shown in table 4 and table 5 respectively while gradation curve shown in Figure 3.

Figure 2 Coarse Aggregate (source: Local stacks in Risalpur KPK)

Table 4 Physical Property of Coarse Aggregate

Property	Max. Aggregate Size	Specific Gravity	Particle Size	Density (Compacted)	Absorption Capacity	Moisture Content
Value	25mm	2.50	25mm to 4.75mm	1658 kg/m^3	2.48%	0.45%

Table 5 Sieve Analysis of Coarse Aggregate

Sieve No	Mass Retain	Percentage Mass Retain	Cumulative Mass %Retain	Cumulative %Passing	Grading Limits (ASTMC33)
1	0	0	0	100	100
0.75	130.5	6.525	6.525	93.475	100-90
0.5	1029	51.45	57.975	42.025	……
0.375	566	28.3	86.275	13.725	20-55
4.75mm	259	12.95	99.225	0.775	0-10
Pan	14.3	1.43	100	0	…...

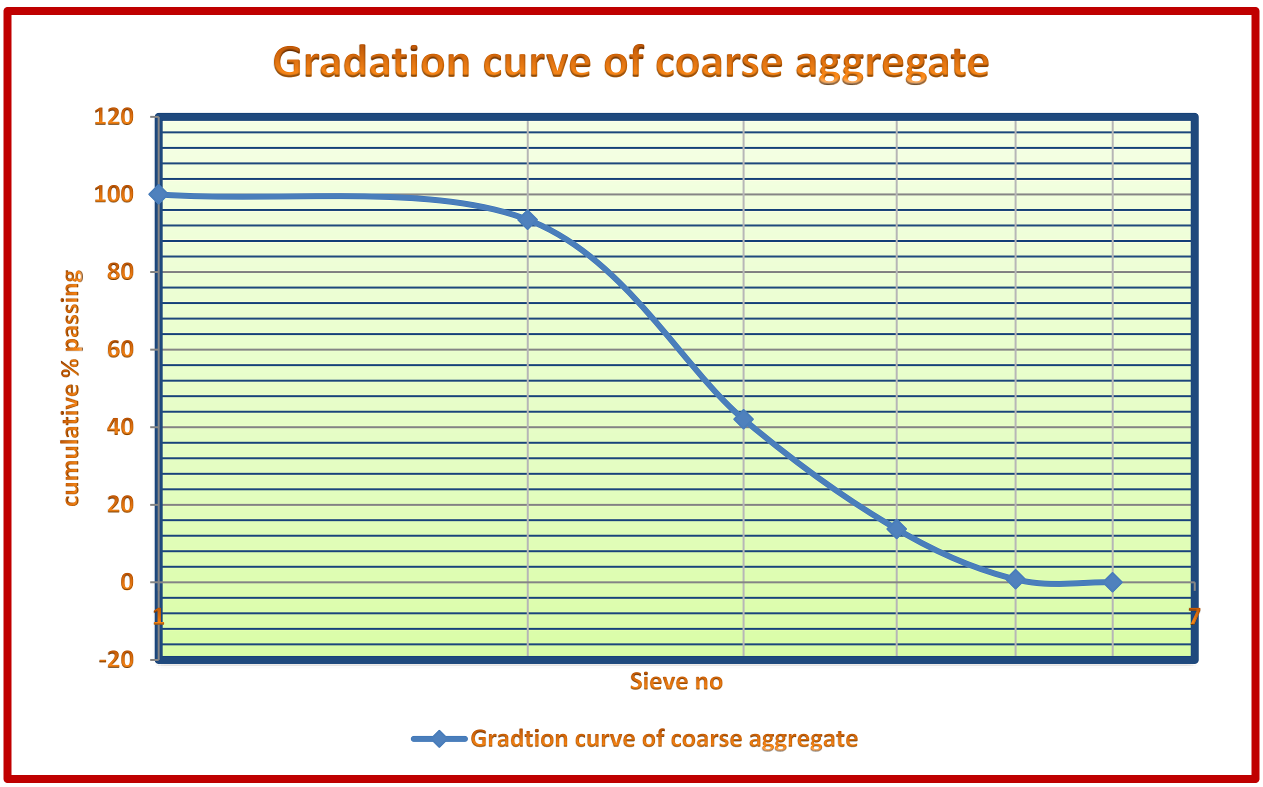


Figure 3 Gradation Curve of Coarse Aggregate

3.4.4 Water

water was used for preparation of concrete mix and curing of specimens was taken from concrete laboratory (Military College of engineering and technology risalpur, Pakistan). The water was ensured to be clean and free from reactive agents or organic impurities.

3.4.5 Waste Glass

Waste glass was procured from “Gunj glass factory Hassanabdal (Pakistan)” and grinded at “Pakistan council of scientific and industrial research (PCSIR)” laboratory Peshawar show in Figure 4 and results of its physical property shown in table 6.

Figure 4 Waste Glass (Source Gunj Glass Factory Hassanabdal Pakistan)

Table 6 Physical Property of Waste Glass Aggregate

Property	Particle Size	Fineness	Color	Water Absorption
Value	≤ 75µ	95.4%	Gray	Nill

3.4.6 Waste Marble

Waste marble was procured from “Pak marble factory industrial zone Peshawar (Pakistan)” and grinded at “Pakistan council of scientific and industrial research (PCSIR)” laboratory Peshawar show in Figure 5. Tests were conducted on waste marble to finds its characteristics and gradation (sieve analysis). Standard (ASTM33/C33M-13) was used for gradation (sieve analysis) of waste marble. Results of its sieve analysis and characteristics were shown in table 3 and table 4 respectively while gradation curve for material under study and standard curve (upper and lower limits) are shown in Figure 6.

Figure 5 Waste Marble (Source: Pak Marble Industrial Zone Peshawar “Pakistan”)

Table 7 Physical Property of Waste Marble

Property	Particle Size	Fineness Modulus	Absorption Capacity	Moisture Content
Value	4.75mm to 0.075mm	2.41	2.1%	1.3%

Table 8 Sieve Analysis of Marble Waste

Sieve No	Mass Retain	%Mass Retain	Cumulative% Mass Retain	Cumulative % Passing	Grading Limits (ASTM C33)
4	1.5	0	0	100	95 to 100
8	25.2	2.52	2.52	97.48	80 to 100
16	136.2	13.62	16.14	83.86	50 to 85
30	279	27.9	44.04	55.96	25 to 60
50	358	35.8	79.84	20.16	5 to 30
100	185	18.5	98.34	1.66	0 to 10
Pan	12	1.2	99.54	0.46	----

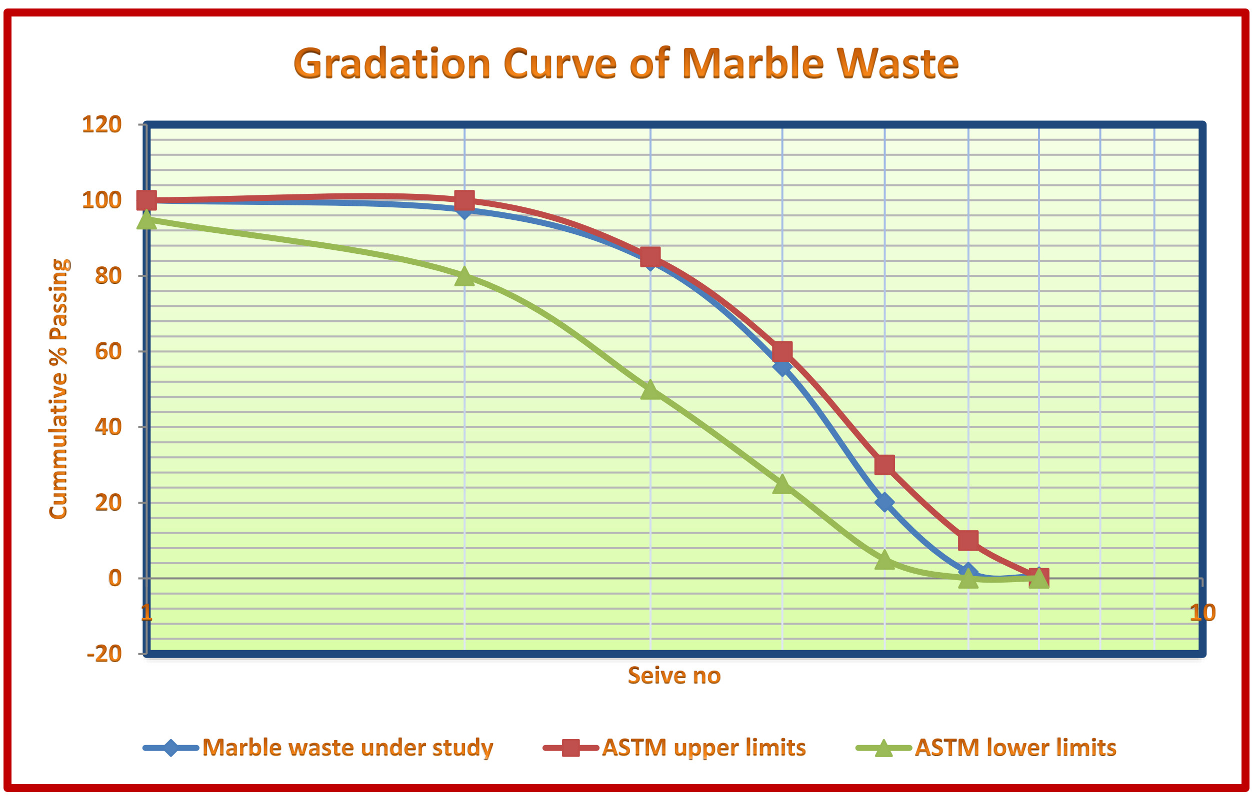


Figure 6 Gradation Curve for Marble Waste

3.5 Mix Proportion

Concrete mix ratio 1:1.5:3 and w/c (water to cement ratio) was used in this study. Four different sets were prepared. One set was control which consists ordinary Portland cement, natural fine and coarse aggregate. Second set consist partially replacement of cement with glass and third set consist partially replacement of sand with waste marble while final sets consists combined partially replacements of cement with waste glass and sand with waste marble.Furthermore quantification of materials shown in table-9.

Table 9 Quantification of Materials

MIX	Cement	F.A	C.A	WG / WM	Split Tensile Strength	Pull out Test	Flexure Strength
Control Mix	100	100	100	0/0	3	3	3
10G0M	90	100	100	10/0	3	3	3
20G0M	80	100	100	20/0	3	3	3
30G0M	70	100	100	30/0	3	3	3
0G40M	100	60	100	0/40	3	3	3
0G50M	100	50	100	0/50	3	3	3
0G60M	100	40	100	0/60	3	3	3
Mix1 (GW&MW)	15	30	100	15/30	3	3	3
Mix1 (GW&MW)	17	35	100	17/35	3	3	3
Mix1 (GW&MW)	20	40	100	20/40	3	3	3
				No of Samples	**30**	**30**	**30**
				Total No of Sample		**90**	

3.6 Mixing Process

Before mixing process was started, required quantity of material was weighed by method of weighing. Mixer which is used for mixing of materials was in shown in Figure 7. For mixing process coarse and fine aggregate were added to mixer, both ingredients were dry mixed then required quantity of cement and water were added with time and mixing was done about 5-6 minute.

Figure 7 Mixing of Concrete Ingredients

3.7 Casting of sample

All samples were casted according to mix proportion shown in Table 9. Before casting, all moulds surface were properly oiled for easily removal of sample. Fresh concrete were put into the moulds and top surface were level with the help of trowel as show in Figure 8.Leave moulds undisturbed for 24 hours at room temperature as shown in Figure 8. Now carefully samples were removed from moulds and put into curing tank as shown in Figure 8 for period as per standard test requirement.

Figure 8 Casting of Concrete Sample

3.8 Testing procedure

3.8.1 Slump test

Vertical settlement of freshly prepared concrete, sinking in height and flowing to the sides without any supported as known is slump. Slump indicates workability of concrete. A concrete is said to be workable if it can be easily placed, compacted and finished.

ASTM C-143 was followed for slump test, slump cone should be filled in three layers and compacted each layer with tamping rod of 25 blows and then mould is left vertically from concrete. Figure 9 show setup for slump cone test.

Figure 9 Slump Test

3.8.2 Split Tensile Strength

This property of concrete describes strength of concrete in tension. Longitudinally Cylindrical sample were subjected to compressive testing machine after 28 days curing show in Fig-25. It is indirect method to determine tensile strength of concrete in which compressive load is applied until specimen fail due to development of tensile force in concrete. In this method cylindrical sample split across vertical diameter as shown in Figure 10. Direct method cannot be used because it is impossible to apply pure axial load as there will be possibility that load is being applied some eccentricity on the specimen of concrete. Following equation were used for calculating split tensile strength.

$$\boldsymbol{\delta = 2P/\pi LD}$$

Where

δ = Compressive Strength D = diameter of cylindrical sample

P = Maximum Load L = length of cylindrical sample

Figure 10 Split Tensile Strength Test

3.8.2 Flexure Strength

Flexure strength of reinforced concrete beams was determined according to ASTM. In order to find flexure capacity of reinforced concrete beam, reinforced concrete beam of size 6in x 6in x 20in were casted. Size and reinforcement details of beam were shown in Figure 11. After 28 days curing, beam was subjected to universal testing machine (UTM). Figure 12 represents arrangement of flexure strength. Equation used to find flexure strength is given below.

$$\delta = PL/bd^2$$

Where

δ = Flexure Strength　　L = length of beam

D = effective depth　　P = Maximum Load

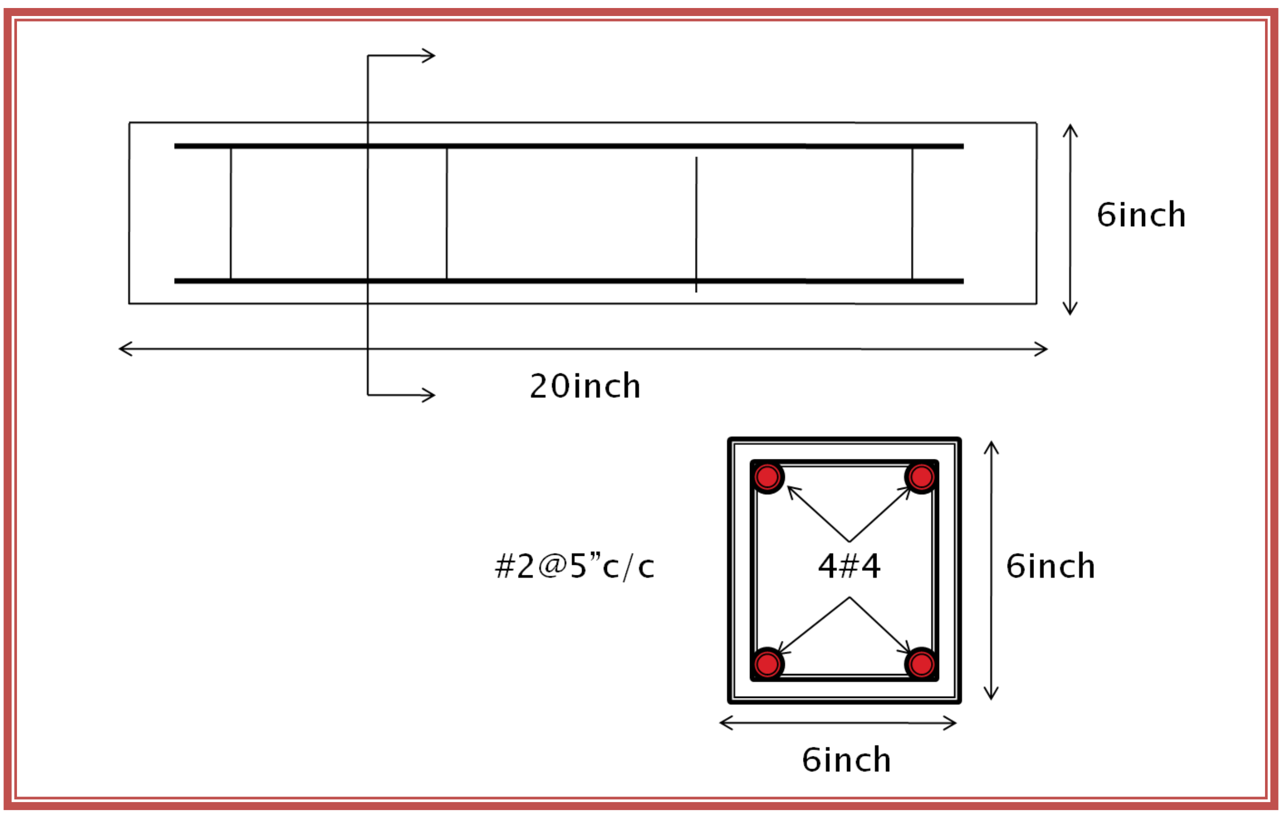


Figure 11 RCC Beam Details for Flexure Strength

Figure 12 Flexure Strength of RCC Beam in UTM

3.8.3 Pull out test

Cube of size 150mm were used for Pull out test which showed determined bond strength between concrete with reinforcing bar and could be performed according to ASTM C-234. For this test, #4 bar is kept 100mm from top of mould before filling the concrete in the mould. Cube left undisturbed for 24 hours at room temperature after filling concrete into the mould. After 24 carefully de moulds the sample and put into the curing tank along with the bar as shown in Figure 8. Then bond strength is calculated by applying pull out force with the help of universal testing machine (UTM), on reinforcing bar against concrete up to failure as shown in Figure 14. Average values of three specimens were considered as bond strength. Bond strength was calculated by using the following formula.

$$\delta = P/\pi DL$$

Where

δ = Bond Strength D = Diameter of the reinforcement bar

P = Maximum Load L = Embedded length of reinforcement bar

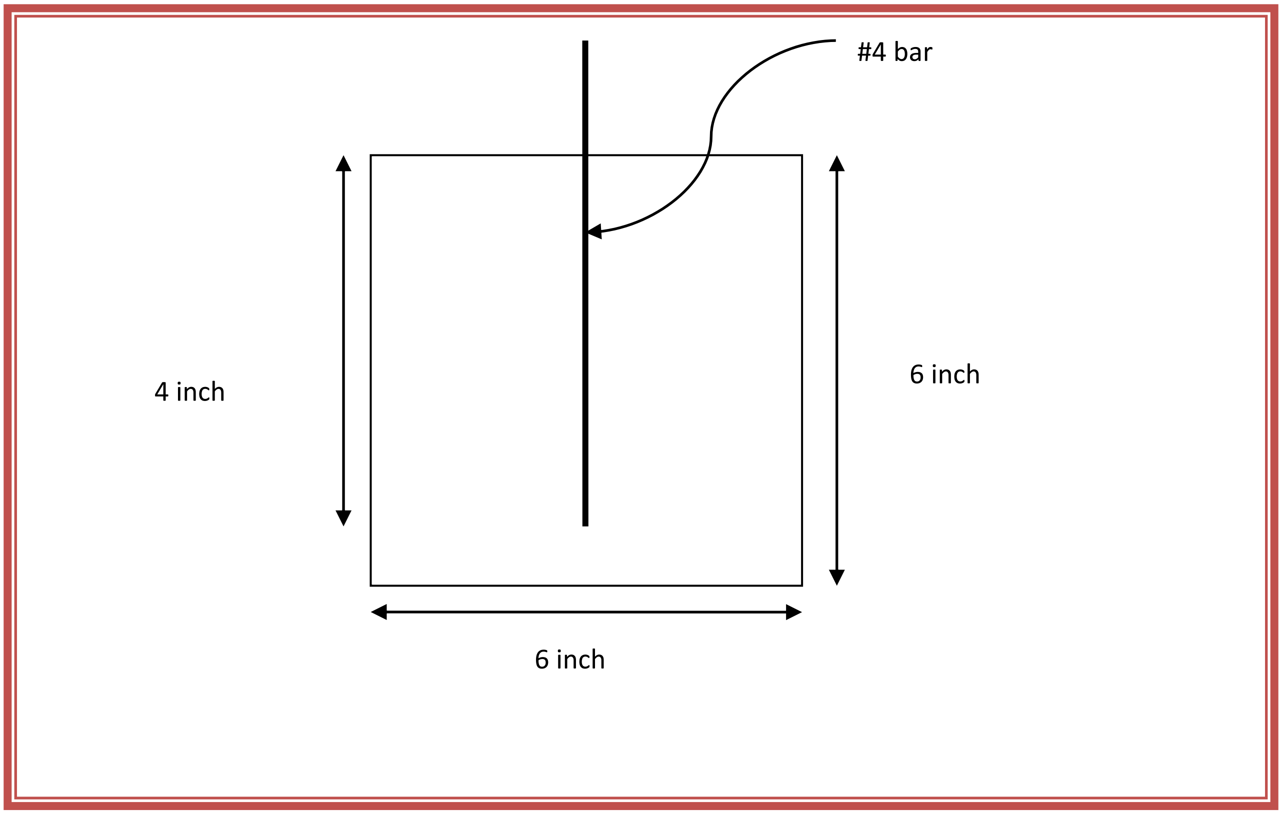


Figure 13 Details for Pull out Test Samples

Figure 14 Pull Out Test in UTM

CHPTER 4

RESUTS AND DISSCUSION

4.1 Slump test

Results of slump test were summaries in table 10. From table it has been concluded that slump value increase as percentage of waste glass and waste marble increase as compared to control mix.

Slump value were 3.9inch, 5.1inch and 5.9inch for concrete containing waste glass in proportions 10%,20% and 30% respectively while slump value were 3.1inch, 4.8inch and 5.3inch for concrete containing marble waste in proportions 40%,50% and 60% respectively.

Although surface area of concrete ingredients (cement and sand) and replacements materials (glass and marble) were same but positive response against workability is due to their comparatively less absorption capacity.

Table 10 Results of Slump Test

Sr.NO	WG/WM	Slump Value (Inch)
1	0/0	2.6
2	10/0	3.9
3	20/0	5.1
4	30/0	5.9
5	0/40	3.1
6	0/50	4.8
7	0/60	5.3

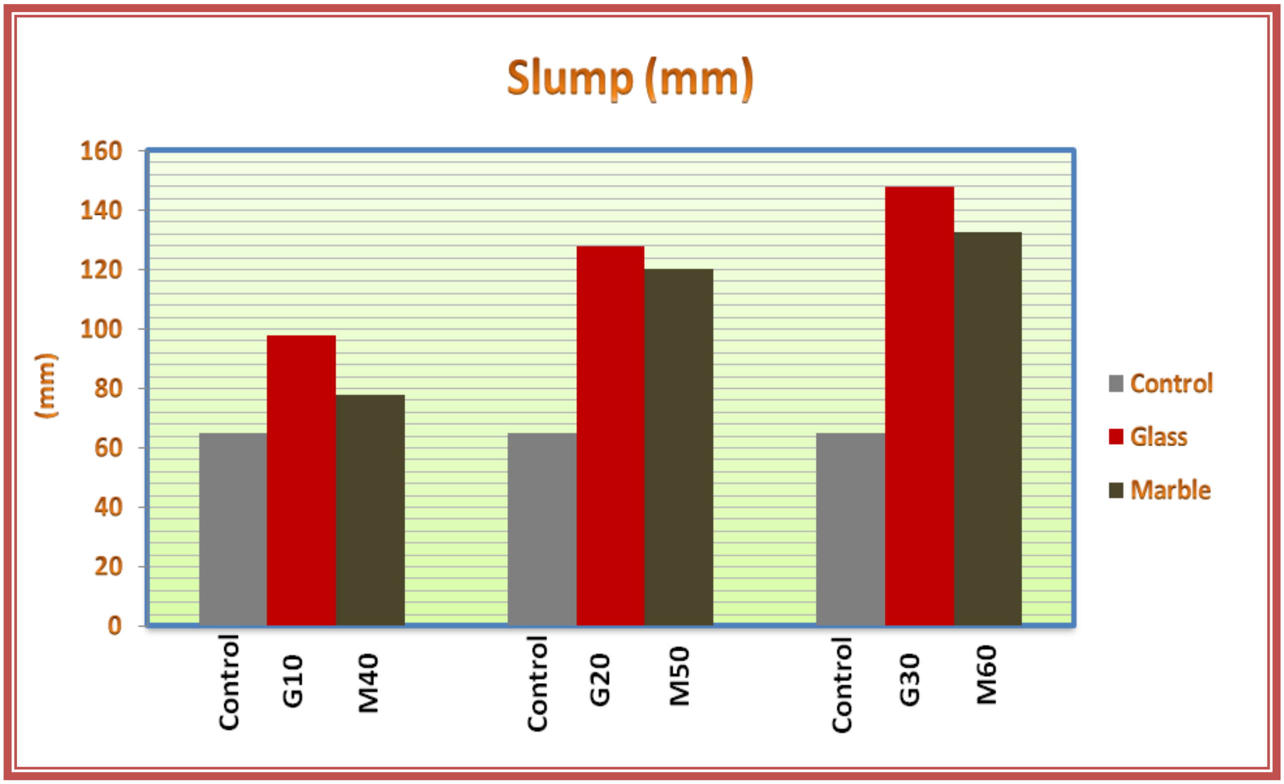


Figure 15 Slump Test Results

4.2 Split tensile strength

Results of split tensile strength test were summaries in table 11 which show that split tensile strength increased as percentage of waste glass increased up to 20% replacement and then decrease while in case waste marble, split tensile strength increase up to 50% replacement and then decrease as compare to control mix.

Split tensile strength were 3.53% and 13.39% higher than from control mix for concrete containing waste glass in proportions 10% and 20% respectively while at 30% replacement of waste glass, Split tensile strength was reduced 19.46% from control mix.

Split tensile strength were 1.76% and 2.35% higher than control mix for concrete containing marble waste in proportions 40% and 50% while at 60% replacement of waste marble, split tensile strength was reduced 21.88% from control mix.

Table 11 Results of Split Tensile Strength

Sr.No	Batch	Load(KN)	Split Tensile strength(Mpa)
1	Control	240	3.397
2	G10	248	3.510
3	G20	271.6	3.844
4	G30	193.3	2.73
5	M40	244.33	3.45
6	M50	245.6	3.476
7	M60	187	2.648

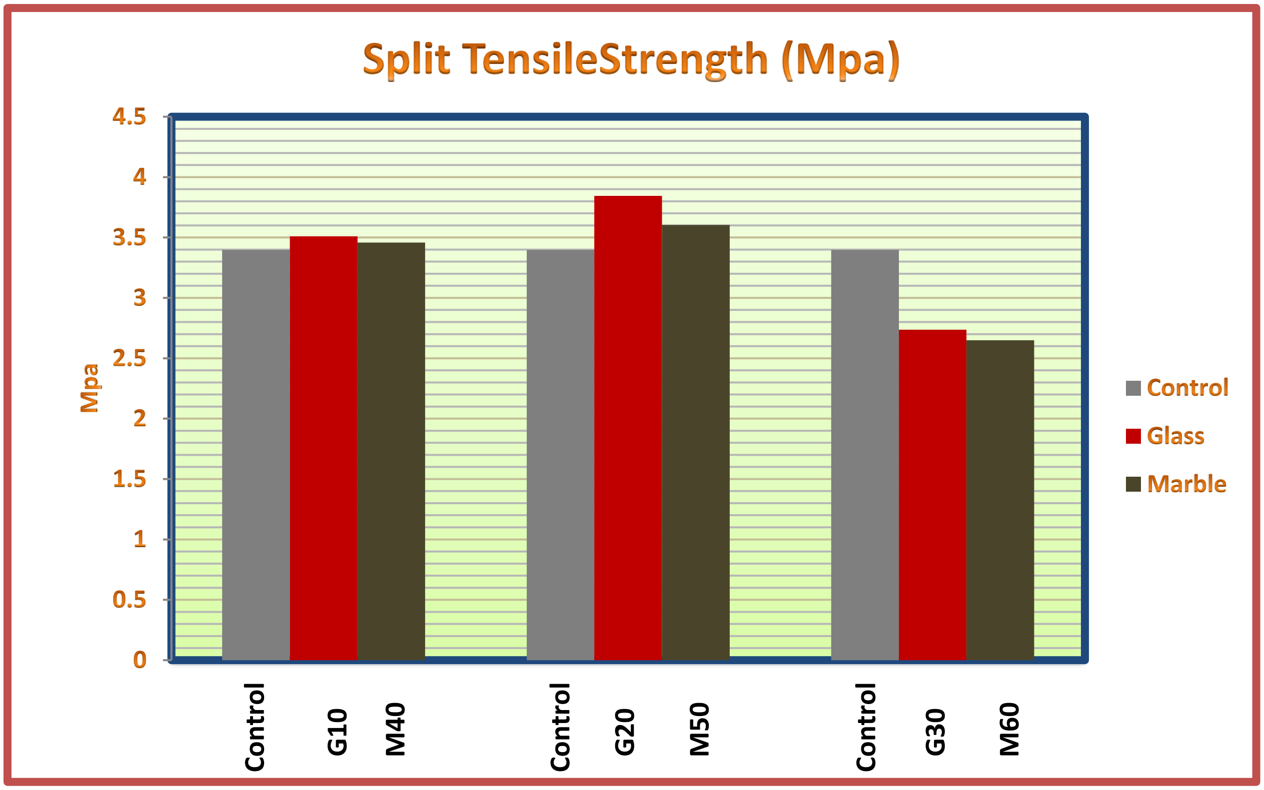


Figure 16 Results of Split Tensile Strength

4.3 Flexure Strength of RCC Beam

Results of flexure strength test were summaries in table 12 which show that flexure strength increase as percentage of waste glass up to 20% replacement and then decrease while in case waste marble, flexure strength increase up to 50% replacement and then decrease as compare to control mix.

Flexure strength were 15.56% and 28.89% higher than from control mix for concrete containing waste glass in proportions 10% and 20% respectively while at 30% replacement of waste glass, flexure strength was reduced 4.43% from control mix.

Flexure strength were 3.34% and 21.1% higher than control mix for concrete containing marble waste in proportions 40% and 50% while at 60% replacement of waste marble, flexure strength was reduced 5.78% from control mix.

Table 12 Results of Flexure Strength of RCC Beam

Sr.NO	Batch	Load(KN)	Flexure Strength of RCC Beam (Mpa)
1	Control	90	23.703
2	G10	104	27.390
3	G20	116	30.551
4	G30	86	22.650
5	M40	93	24.493
6	M50	109	28.707
7	M60	85	22.386

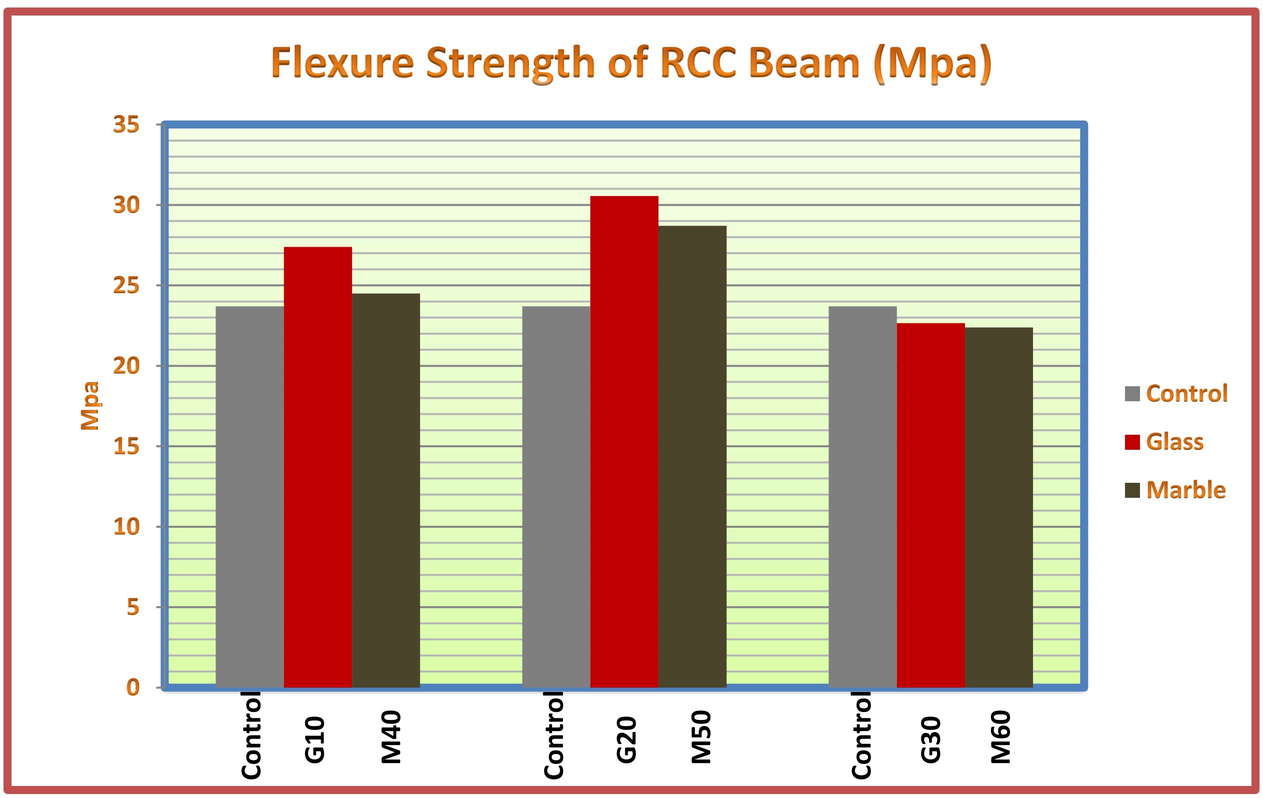


Figure 17 Results of Flexure Strength of RCC Beam

4.4 Pull out strength (Bond strength)

Results of pull strength test were summaries in table 13 which show that pull out strength increase as percentage of waste glass up to 20% replacement and then decrease while in case waste marble, flexure strength increase up to 50% replacement and then decrease as compare to control mix.

Bond strength were 5.82% and 16.32% higher than from control mix for concrete containing waste glass in proportions 10% and 20% respectively while at 30% replacement of waste glass, bond strength was reduced 17.45% from control mix.

Bond strength were 4.1% and 10.6% higher than control mix for concrete containing marble waste in proportions 40% and 50% while at 60% replacement of waste marble, bond strength was reduced 25.9% from control mix.

Table 13 Results of Pull out Strength

Sr.No	Batch	Load(KN)	Pull out Strength(Mpa)
1	Control	45	11.464
2	G10	47.6	12.127
3	G20	52.33	13.332
4	G30	37	9.426
5	M40	46.8	11.932
6	M50	49.8	12.687
7	M60	33.33	8.491

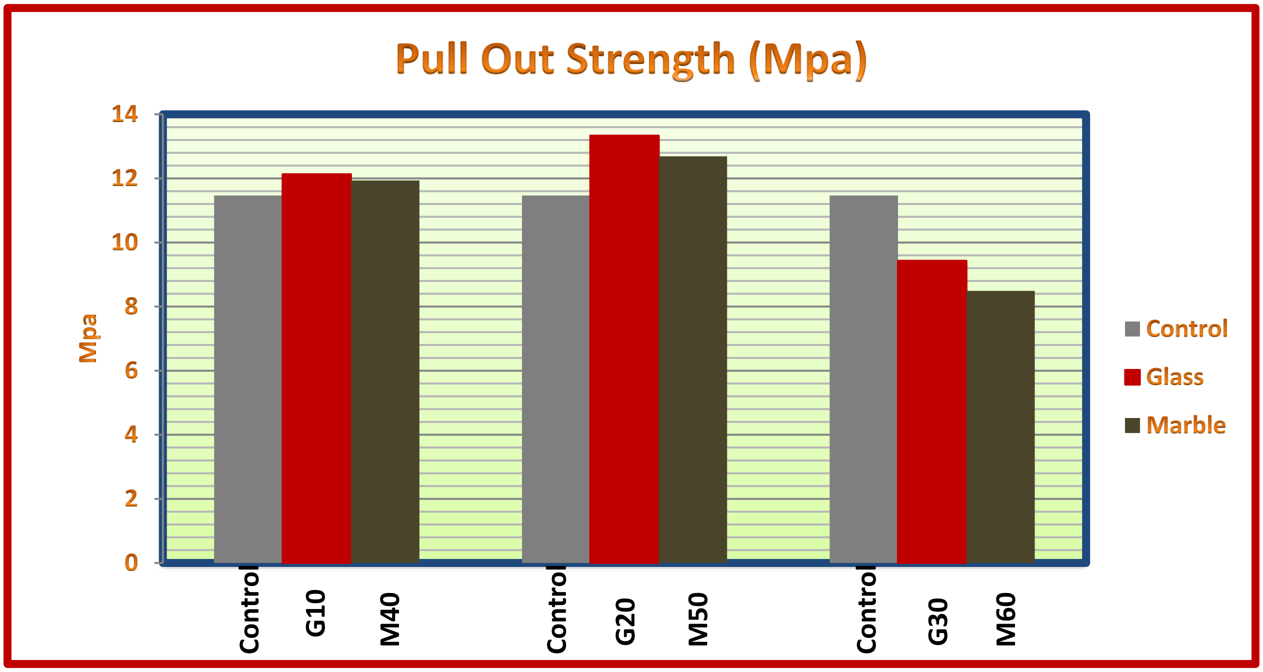


Figure 18 Results of Pull out Test

4.5 Response surface methodology

Response surface methodology (RSM) is a statistical tool and its main objective is to optimize a response or output which can be influenced by several factors or input variables. The response or output can be represented graphically in a three dimensional space or with contours plot. Following flow chart represent steps to develop response surface methodology.

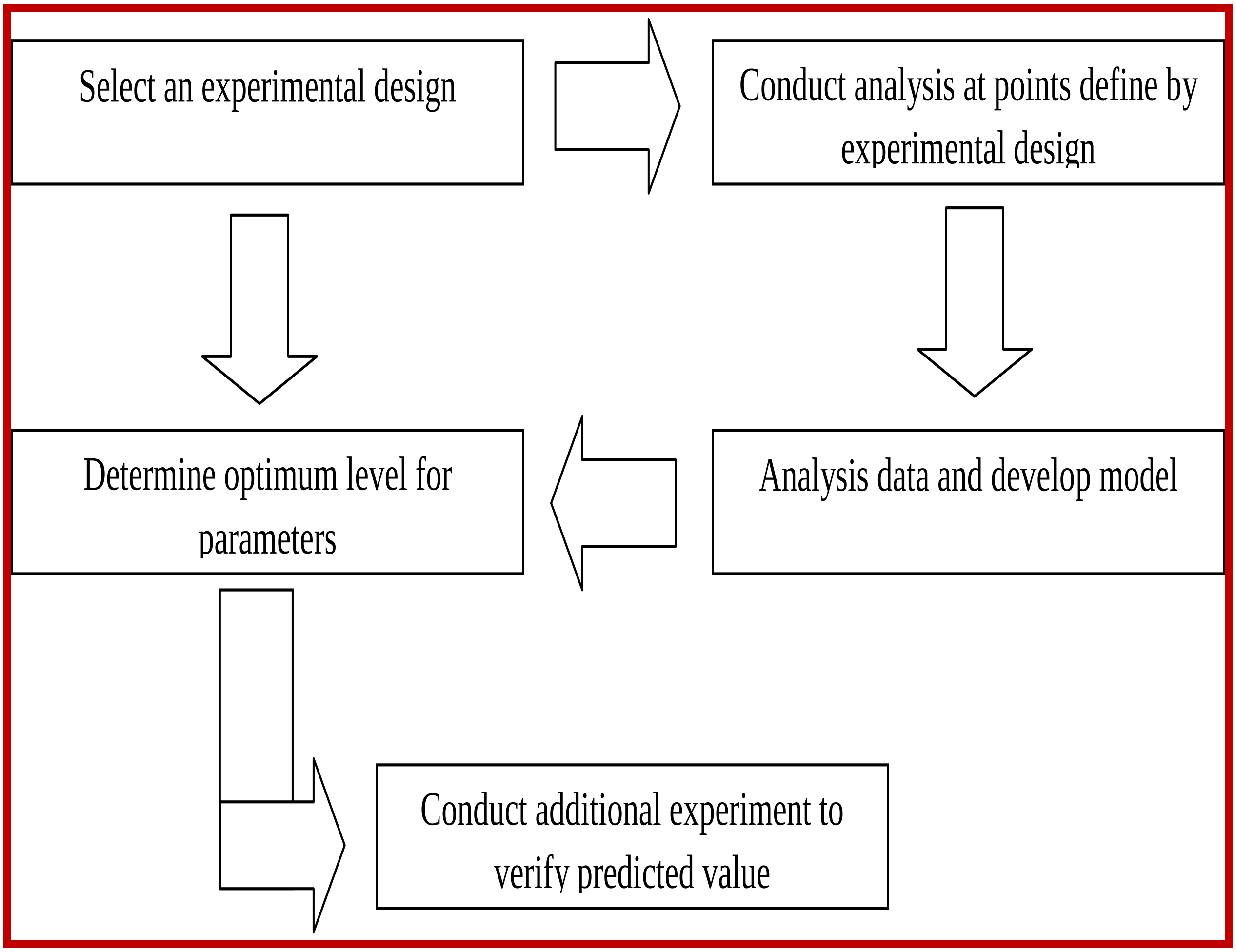


Figure 19 Flow Chart of Response Surface Methodology (RSM)

Statistical analysis were performed to develop counter and 3d response surface for flexure strength, split tensile strength an pull out strength . Chose three best possible options from statistical analysis and verified it by experimental tests.

4.5.1 Response surface methodology for flexure strength of Rcc beam

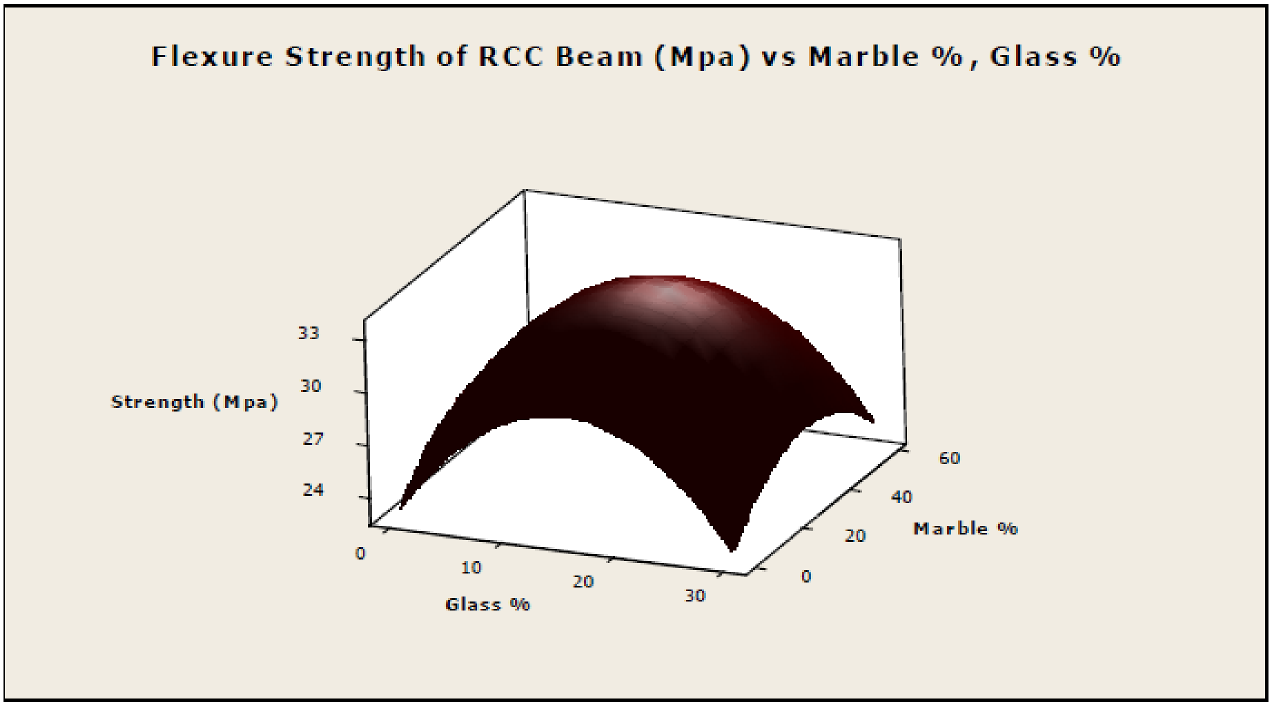


Figure 20 Response Surface for Flexure Strength of Rcc Beam

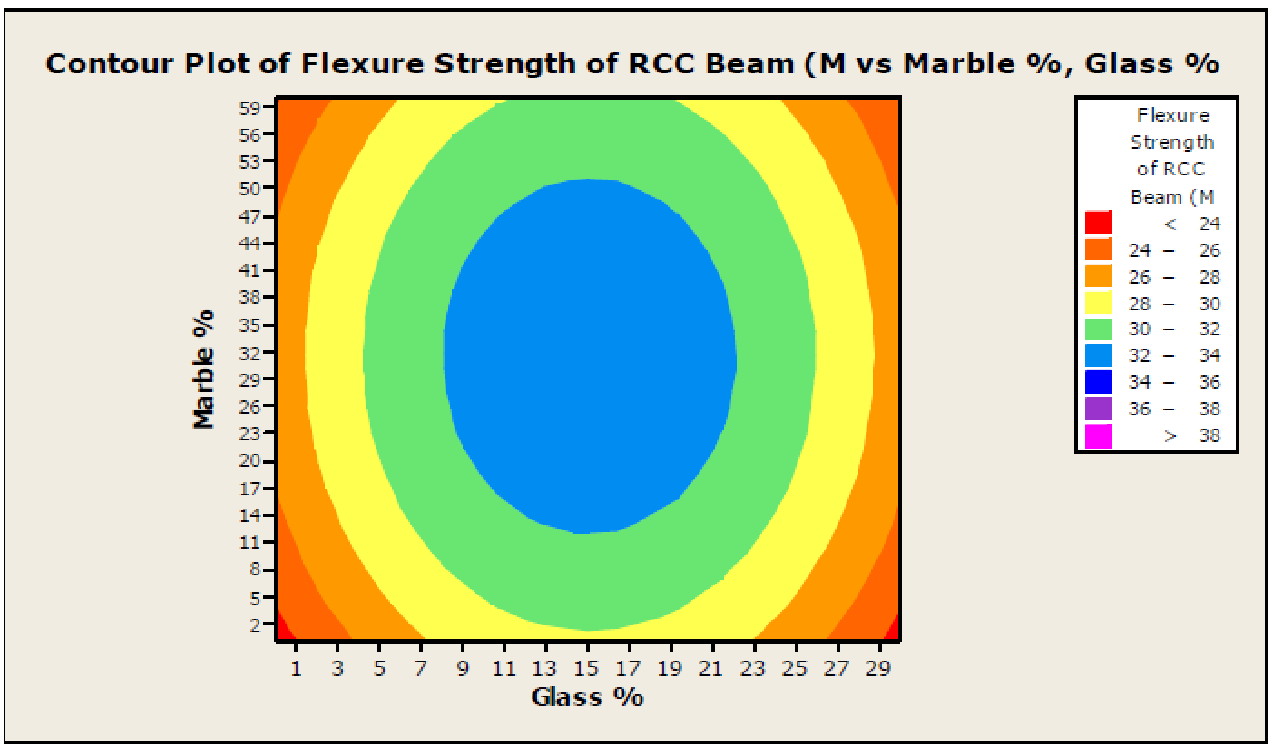


Figure 21 Contour Map for Flexure Strength of Rcc Beam

4.5.2 Response surface methodology for split tensile test

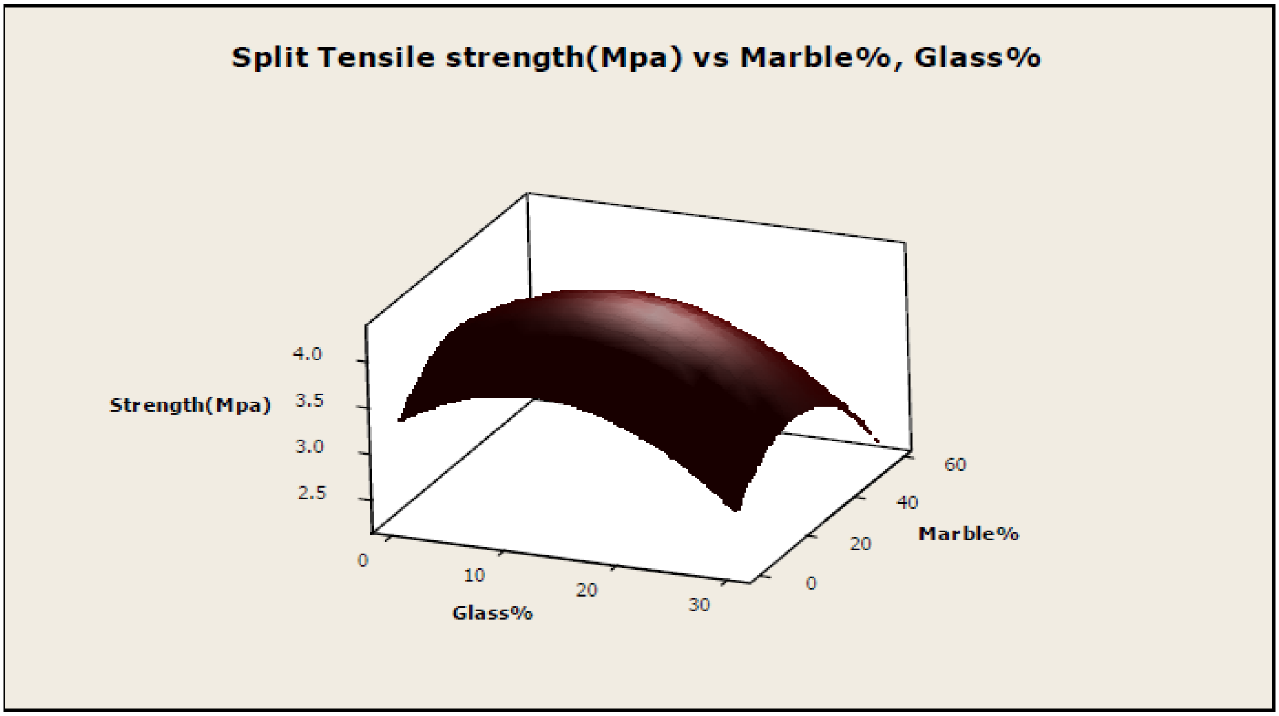


Figure 22 Response Surface for Split Tensile Strength

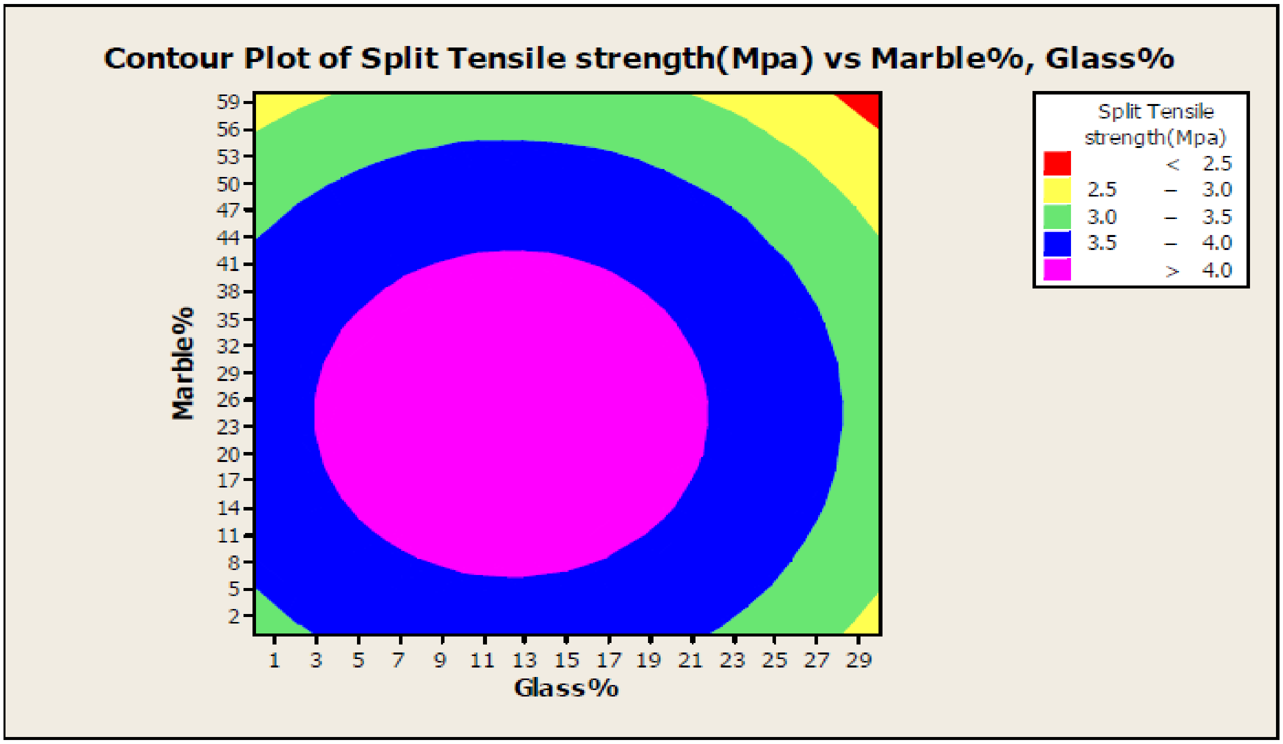


Figure 23 Contour Map for Split Tensile Strength

4.5.3 Response surface methodology for pull out test

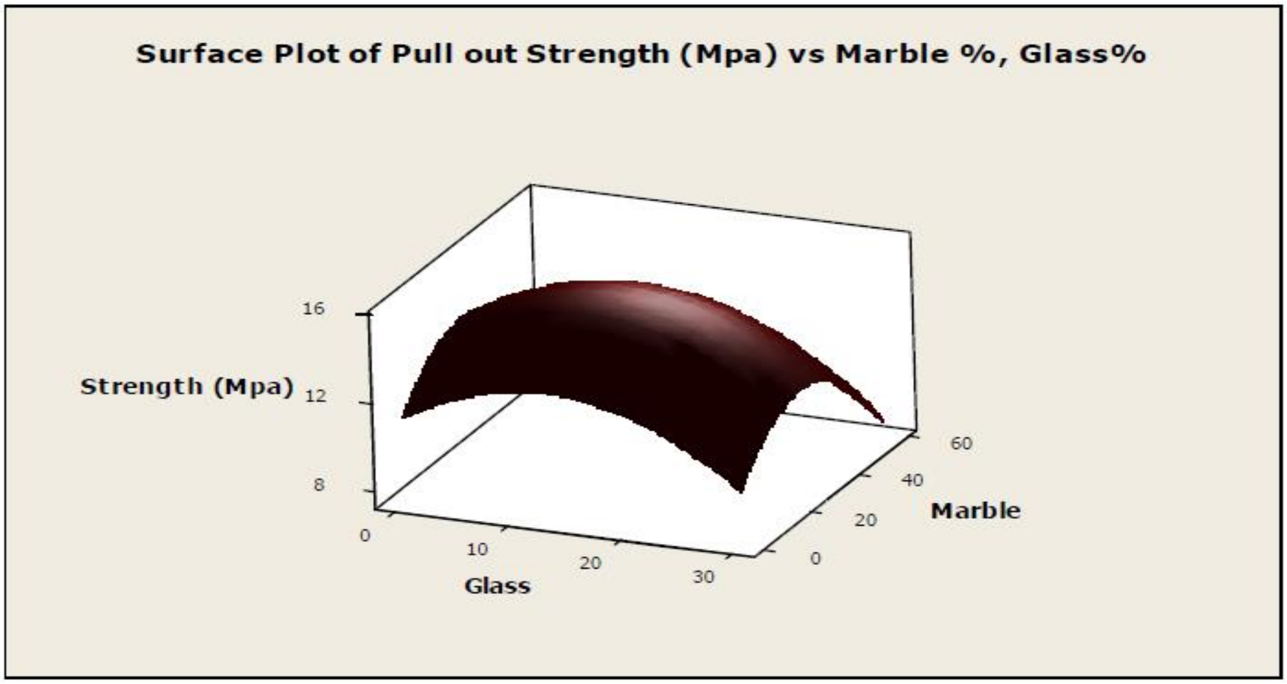


Figure 25 3D Response Surface for Pull out Strength

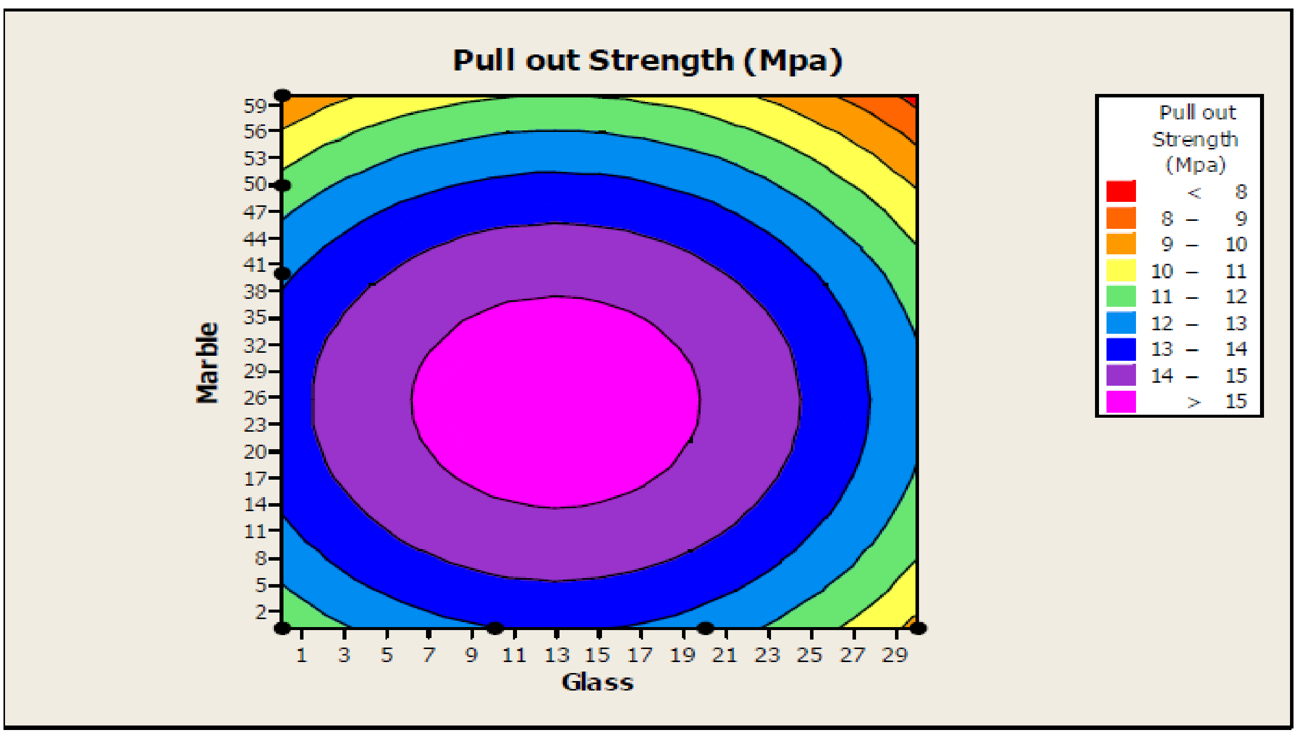


Figure 24 Contour Map for Split Tensile Strength

Table 14 Predicted Value Vs Experimental Value

Property	Percentage of Waste Glass	Percentage of Waste Marble	**Predicted Value**	Experimental Value	Percentage Difference
Flexure Strength (Mpa)	15	30	33.42	34.50	+3.23
	17	35	33.12	32.65	-1.41
	20	40	31.9	30.55	-4.2
Pull out Strength (Mpa)	15	30	15.53	15.54	----
	17	35	15.39	14.77	-4.02
	20	40	14.96	13.24	-11.49
Split Tensile Strength (Mpa)	15	30	4.26	4.41	+3.52
	17	35	4.20	4.07	-3.09
	20	40	4	4.03	----

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 General

The present study investigated to evolutes the effect of waste glass and waste marble on bond strength of concrete and flexure strength of Rcc beam. Based on work results, following conclusions are drawn.

5.2 Fresh Properties

5.2.1 Workability

- Slump value increased as the percentage of waste glass and waste marble increase as compared to control mix.

5.3 Strength Property

5.3.1 Split Tensile Strength

- Split tensile strength increase as percentage of waste glass up to 20% replacement and then decreased due to dilution effect which cause ASR resulting in decreased strength while in case waste marble, split tensile strength increase up to 50% replacement and then decrease as compare to control mix.

5.3.2 Flexure Strength of Rcc Beam

- Flexure strength increase as percentage of waste glass up to 20% replacement and then decrease while in case waste marble, flexure strength increase up to 50% replacement and then decrease as compare to control mix.

5.3.3 Pull out Strength (Bond Strength)

- Pull out strength increase as percentage of waste glass up to 20% replacement and then decrease while in case waste marble, pull out strength increase up to 50% replacement and then decrease as compare to control mix.

5.4 Statistical Analysis

- From statistical analysis, highest strength (Split tensile, Flexure and Pull out Strength) were obtained at the ratio 15% glass and 30% marble (15:30) respectively.

5.5 Recommendation

- Fresh and harden Property of concrete may be check for water to cement ratio beyond 0.50.
- Other waste materials that have locally available should be used instead of waste glass and waste marble.
- Experimentally investigation of durability of concrete containing waste glass and marble in comparison with conventional concrete.
- Study of the long term performance of concrete containing waste glass and waste marble in comparison with conventional concrete.
- Study the fire resisting property of concrete containing waste glass and waste marble in comparison with conventional concrete.

REFERENCES

1. Kishore,I. S., & Chowdary, C. M. (2015).A Study on Waste Utilization of Marble Dust in High Strength Concrete Mix. International Journal of Civil Engineering and Technology, 6, 12.
2. Olumoyewa, D. A., & Obanishola, M. S. (2018). Experimental data on flexural strength of reinforced concrete elements with waste glass particles as partial replacement for fine aggregate. Science Direct, 846-859.
3. Ali, M., & Hashmi, S. M. (2014). An experimental investigation on strengths characteristics of concrete with the partial replacement of cement by marble powder dust and sand by stone dust. Int. J. Eng. Res. Appl, 4, 203-209.
4. Tavakoli, D., Heidari, A., & Karimian, M. (2017). Properties of concretes produced with waste ceramic tile aggregate. Asian Journal of Civil Engineering, 14(3), 369-382.
5. Raju,S., & Kumar, P. R. (2014).Effect of using glass powder in concrete. International Journal of Innovative Research in Science, Engineering and Technology, 31, 21-427.
6. Berwal, P. (2017). A Laboratory Study on Use of Waste Glass Powder as Partial Replacement of Cement in Concrete Production.
7. Vijayakumar, G., Vishaliny, M. H., & Govindarajulu, D. (2013). Studies on glass powder as partial replacement of cement in concrete production. International Journal of Emerging Technology and Advanced Engineering, 3(2), 153-157.
8. Vijayakumar, G., Vishaliny, M. H., & Govindarajulu, D. (2013). Studies on glass powder as partial replacement of cement in concrete production. International Journal of Emerging Technology and Advanced Engineering, 3(2), 153-157.

9. Prema Kumar, W., Ananthayya, M., & Vijay, K. (2014). Effect Of Partial Replacement Of Cement With Waste Glass Powder On The Properties Of Concrete.

10. Subramani, T., & Ram, S. S. (2015). Experimental Study on Concrete Using Cement with Glass Powder. Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University, Salem, India, 5(V3), 43-53.

11. Alyamaç, K. E., & Aydin, A. B. (2015). Concrete properties containing fine aggregate marble powder. KSCE Journal of Civil Engineering, 19(7), 2208-2216.

12. Agrawal,N and Kumar,S.(2017). Study of Strength of Concrete using Waste Marble Dust and Crushed Tiles as Partial Replacement of Fine and Coarse Aggregate. International Journal of Engineering Science.7 (5).

13. Rai, B., Naushad, K. H., Abhishek, K., Rushad, T. S., & Duggal, S. K. (2011). Influence of Marble powder/granules in Concrete mix. International journal of civil and structural engineering, 1(4), 827.

14. Sakalkale, A. D., Dhawale, G. D., & Kedar, R. S. (2014). Experimental study on use of waste marble dust in concrete. International Journal of Engineering Research and Applications (www. ijera. com ISSN: 2248-9622), 4(10), 44-50.