

**STUDIES ON MECHANICAL PROPERTIES OF CONCRETE
CONTAINING WASTE GLASS POWDER AND POST
CONSUMER WASTE PLASTIC**

A thesis submitted in partial fulfilment of the requirements for
the award of the degree of

MASTER OF ENGINEERING
IN
CIVIL ENGINEERING
(STRUCTURES)

Submitted by
Ankur Kataria
Roll No - 800822014

Under the guidance of

Dr. Maneek Kumar
Professor & Head

Dr. Shweta Goyal
Assistant Professor



DEPARTMENT OF CIVIL ENGINEERING
THAPAR UNIVERSITY, PATIALA
JULY 2010

CERTIFICATE

This is to certify that thesis entitled “**Studies on Mechanical Properties of Concrete Containing Waste Glass Powder and Post Consumer Waste Plastic**”, being submitted by **Mr. Ankur Kataria**, Roll No **800822014** in partial fulfilment for award of degree **Master of Engineering in Civil (Structures) at Thapar University, Patiala**, is a bonafide work carried out by him under our guidance and supervision and that no part of this thesis has been submitted for the award of any other degree.



Dr. Maneek Kumar
Professor & Head
Department of Civil Engineering
TU Patiala (PUNJAB)



Dr. Shweta Goyal
Assistant. Professor
Department of Civil Engineering
TU Patiala (PUNJAB)

Countersigned by:



(Dr. Maneek Kumar)
Chairman, Board of studies
Department of Civil Engineering
TU Patiala (PUNJAB)



(Dr. R.K. Sharma)
Dean of Academic Affairs
TU Patiala (PUNJAB)

ACKNOWLEDGEMENT

I express my deep gratitude and respects to my supervisors **Dr. Maneek Kumar, Professor and Head, Civil Engineering Department & Dr. Shweta Goyal, Assistant Professor Civil Engineering Department** for their keen interest and valuable guidance, strong motivation and constant encouragement during the course of the work. I thank him for their great patience, constructive criticism and myriad useful suggestions apart from in valuable guidance to me. My first and foremost offering of thanks goes to the architect who shaped my dreams into reality.

I would like to convey my sincere gratitude to my friends and colleagues **Alok khanduri, Puneet Bhandari, Sudhanshu sood** and all friends for their support, co-operation and their timely help and valuable discussions.

I owe my sincere thanks to all the staff members of **Civil Engineering Department** for their support and encouragement. The meaning of my life and work is incomplete without paying regards to my respected parents whose blessings and continuous encouragement have shown me the path to achieve my goals.

And above all, I pay my regards to the **Almighty** for his love and blessings.


Ankur Kataria

ABSTRACT

There are many studies evaluating industrial by-products in cement as binder and aggregate in concrete industries. In the recent decades, the efforts have been made to use industry by-products such as fly ash, silica fume, ground granulated blast furnace slag (GGBS), glass cullet, etc., in civil constructions. The potential applications of industry by-products in concrete are as partial aggregate replacement or as partial cement replacement, depending on their chemical composition and grain size. The artificial aggregates from industrial wastes are not only adding extra aggregate sources to the natural and artificial aggregate but also prevent environmental pollution.

In this study, the effect of use of two such waste products on resultant properties of concrete mix are studied. These waste products are powdered glass which is used as replacement of cement in concrete, and plastics which is used as replacement of coarse aggregates. The effect is studied in terms of unit weight reduction, compressive strength, split tensile strength, Initial water surface absorption test and Alkali silica reaction test.

From the test results, it is found that the use of 20% glass as replacement of cement improves the compressive strength of the mix and increases durability of mix. Use of a combination of 20% glass and 20% plastics reduces the water absorption to the barest minimum value. Therefore, this mix is suitable from both strength and durability point of view.

CONTENTS

CERTIFICATE	(i)
ACKNOWLEDGEMENT	(iii)
ABSTRACT	(iv)
LIST OF FIGURES	(ix)
LIST OF TABLES	(xiv)
List of Notations	(xvi)

Chapter 1	Introduction	Page no.
1.1	General	1
1.2	Management of plastic waste	1
1.3	Management of glass	4
1.4	Orientation of thesis report	5
Chapter 2	PLASTICS	
2.1	Plastic	6
2.2	Types of plastics	6
2.3	Plastic concrete properties	8
2.4	Plastic recycling	8
	2.4.1 Importance of plastic recycling	9
	2.4.2 Benefits of plastic recycling	9
	2.4.3 Types of recyclable plastic products	9
	2.4.4 Recycling methods	10
	2.4.5 Construction application of plastics	12
2.5	Problems in recycling of plastics	13

Chapter 5 Literature review of Glass concrete

5.1	General	37
5.2	Fresh concrete properties	37
5.3	Hardened concrete properties	39
5.3.1	Compressive strength	39
5.3.2	Tensile strength	45
5.3.3	Flexural strength	47
5.4	Alkali silica reaction expansion	48

Chapter 6 Experimental Programme

6.1	General	57
6.2	Material used	57
6.2.1	Cement	57
6.2.2	Fine Aggregates	58
6.2.3	Coarse aggregate	59
6.2.4	Water	60
6.2.5	Plastics Aggregates	61
6.2.6	Waste Glass	61
6.3	Mixture Proportioning	61
6.4	Casting and Curing	63
6.4.1	Casting for compressive strength and split tensile strength tests	63
6.4.2	A.S.R. expansion bar mould	63
6.5	Tests conducted	64

6.5.1	Compressive strength test	65
6.5.2	Split tensile strength test	65
6.5.3	Initial Surface Absorption Test	65
6.5.4	Alkali silica reaction test	66
6.5.4.1	Length Comparator	69
Chapter 7	Results and Discussions	
7.1	General	72
7.2	Unit Weight	72
7.3	Compressive strength	74
7.3.1	Effect of percentage of glass on compressive strength of concrete	76
7.3.2	Effect of percentage of plastic on compressive strength of concrete	79
7.4	Tensile Strength	82
7.4.1	Effect of percentage of Glass on split tensile strength of concrete	82
7.4.2	Effect of percentage of plastics on split tensile strength of concrete	85
7.4.3	Failure modes of cylinders in splitting tensile test	88
7.5	Initial Surface Absorption of concrete	90
7.5.1	Effect of percentage of glass on absorption of water on concrete	90
7.5.2	Effect of percentage of plastic on absorption of water on concrete	93
7.6	Alkali silica reaction test	95
Chapter 8	Conclusions	97
	REFERENCES	98

Figure No	Title	Page No.
Fig.4.1	Bulk density versus plastic aggregates percentage	
Fig.4.2	Fresh concrete density	27
Fig.4.3	Dry density of plastic added concrete	
Fig.4.4	Air content versus plastic fiber type.	29
Fig.4.5	Effect of coarse lightweight aggregate composition on compressive stress-strain behaviour of concrete.	32
Fig.4.6.	Effect of concrete water-to-cement ratio on compressive stress-strain behaviour of concrete made with synthetic lightweight coarse aggregate in comparison to concrete made with expanded clay lightweight aggregate	33
Fig 4.7	Strength and Toughness for Various Mixes	34
Fig.4.8	Relationship between splitting tensile strength and compressive strength	36
Fig 4.9	Strength and Toughness for Various Mixes	36
Fig.4.10	Splitting tensile strength versus plastic aggregate percentage	32
Fig.4.11	Effect of GRP waste powder and super plasticizer on the tensile splitting strength of concrete.	33
Fig 4.12	Fracture surface of concrete cylinder specimen under tensile splitting load	34
Fig.4.13	Effect of silica fume on elastic modulus of plastic concrete mixes with various water to cementitious materials ratios	35
Fig.4.14	Air permeability versus fiber type	36
Fig.5.1	Variation of FC unit weights with WG dosage.	38
Fig.5.2	Variation of slump and air content with WG dosage.	38

Fig.5.3	Variation of VeBe and flow-table tests with WG content	39
Fig.5.4	Photographs of the recycled concrete aggregate and the contaminants	40
Fig.5.5	28 day strengths of the paving blocks in Series I and II.	41
Fig.5.6	Relative compressive strengths of the paving blocks at 28 days.	41
Fig5.7	Variation of compressive strength with WG dosage.	42
Fig.5.8	Compressive strength of mortar made with 25% glass pozzolan as cement replacement from (a) Pub & Club collection and (b) Bottle Bank cullet.	44
Fig 5.9	Variation of tensile strength with WG dosage.	45
Fig. 5.10	Tensile splitting strengths of the paving blocks in Series I and II.	46
Fig 5.11	Influence of using glass fibres on flexural strength of concrete	47
Fig 5.12	Comparison of length changes as measured from the mortar bars prepared with naturally shaped fine aggregate.	49
Fig 5.13	Comparison of length changes as measured from the mortar bars prepared with crushed fine aggregate.	50
Fig 5.14	Expansion for mortar bars	51
Fig 5.15	Expansion as a function of glass content of mortar bars for different ages of storage under the AMBT conditions.	52
Fig 5.16	Expansion curves for mortar bars containing different glass particle	53
Fig 5.17	Expansion time histories for mortar bars (brown glass)	54
Fig. 5.18	Expansion time histories for mortar bars (green glass)	55
Fig 6.1	A.S.R. expansion bar mould	64
Fig 6.2	The general arrangement for ISAT	66
Fig. 6.3	The Set up for ISAT	66

Fig 6.4	Length Comparator for measuring length	71
Fig 7.1	Unit weight of concrete made with different percentage of glass as Cement replacement.	73
Fig 7.2	Unit weight of concrete made with different percentage of plastic as a coarse aggregate in concrete.	73
Fig 7.3	Compression testing machine (ACTM)	75
Fig 7.4	Effect of change of percentage of glass on compressive strength of concrete.	77
Fig 7.5	Effect of change of percentage of glass on compressive strength of concrete with 20% plastic.	77
Fig 7.6	Effect of change of percentage of glass on compressive strength of concrete with 30% plastic.	78
Fig 7.7	Effect of change of percentage of glass on compressive strength of concrete with 40% plastic	78
Fig 7.8	Effect of change of percentage of glass on compressive strength of concrete with 50% plastic.	79
Fig 7.9	Effect of change of percentage of plastic on compressive strength of concrete	80
Fig 7.10	Effect of change of different percentage of plastic on compressive strength of concrete with 20% glass.	80
Fig 7.11	Effect of change of different percentage of plastic on compressive strength of concrete with 40% glass.	81
Fig 7.12	Effect of change of different percentage of plastic on compressive	81

	strength of concrete with 60% glass.	
Fig 7.13	Effect of change of different percentage of plastic on compressive strength of concrete with 80% glass	82
Fig 7.14	Effect of change of different percentage of glass on split tensile strength of concrete.	83
Fig 7.15	Effect of change of different percentage of plastic on split tensile strength of concrete with 20% plastic.	83
Fig 7.16	Effect of change of different percentage of plastic on split tensile strength of concrete with 30% plastic.	84
Fig 7.17	Effect of change of different percentage of plastic on split tensile strength of concrete with 40% plastic	84
Fig 7.18	Effect of change of different percentage of plastic on split tensile strength of concrete with 50% plastic	85
Fig 7.19	Effect of change of different percentage of plastic on split tensile strength of concrete.	86
Fig 7.20	Effect of change of different percentage of plastic on split tensile strength of concrete with 20% glass.	86
Fig 7.21	Effect of change of different percentage of plastic on split tensile strength of concrete with 40% glass.	87
Fig 7.22	Effect of change of different percentage of plastic on split tensile strength of concrete with 60% glass.	87
Fig 7.23	Effect of change of different percentage of plastic on split tensile strength of concrete with 80% glass.	88

Fig 7.24	Showing failure pattern of control and plastic concrete.	89
Fig 7.25	Failure pattern of plastic concrete	89
Fig 7.26	Effect of change of different percentage of glass on initial water surface absorption on concrete.	90
Fig 7.27	Effect of change of different percentage of glass on initial water surface absorption on concrete with 20% plastic.	91
Fig 7.28	Effect of change of different percentage of glass on initial water surface absorption on concrete with 30% plastic.	91
Fig 7.29	Effect of change of different percentage of glass on initial water surface absorption on concrete with 40% plastic	92
Fig 7.30	Effect of change of different percentage of glass on initial water surface absorption on concrete with 50% plastic.	92
Fig 7.31	Effect of change of different percentage of plastic on initial water surface absorption on concrete.	93
Fig 7.32	Effect of change of different percentage of plastic on initial water surface absorption on concrete with 20% glass.	94
Fig 7.33	Effect of change of different percentage of plastic on initial water surface absorption on concrete with 40% glass.	94
Fig 7.34	Effect of change of different percentage of plastic on initial water surface absorption on concrete with 60% glass.	95
Fig 7.35	Effect of change of different percentage of plastic on initial water surface absorption on concrete with 80% glass.	95

Table No.	Title	Page No.
Table 4.1	Cone and slump data	20
Table 4.2	Fresh concrete properties of polypropylene reinforced concrete	22
Table 4.3	Effect of GRP waste powder on the compressive strength of concrete (N/mm ²).	25
Table 4.4	Concrete mix properties for compressive test cylinders	26
Table 4.5	Lightweight concrete compression test results	27
Table 4.6	Evolution of bulk density (kg/m ³) of the composites as a function of H/C and mixing time used after haemoglobin introduction as regard of the bulk density of a mortar without haemoglobin (1865.39 kg/m ³).	29
Table 4.7	Effect of GRP waste powder on the tensile splitting strength of concrete (N/mm ²).	34
Table 4.8	Mixture proportions of studied plastic concrete mixes	36
Table 5.1	Mix proportions of SCC (kg/m ³)	39
Table 5.2	Chemical composition of cement	40
Table 5.3	Overview of the eleven mixes.	43
Table 5.4	Compressive strength results at 28 days for the eleven mixes.	43
Table 5.5.	Relative strength of mortar made with 25% washed and unwashed glass pozzolan from Pub & Club and Bottle-Bank collection cullet	44
Table 5.6	Mix proportion for concrete specimens containing glass	47
Table 5.7	Aggregate gradation used in compliance with ASTM C 1260	48

Table No.	Title	Page No.
Table 5.8	Length changes in % of the mortar bars prepared in compliance with ASTM C1260	49
Table 5.9	Chemical compositions of ground waste glass (by weight percent)	51
Table 5.10	Chemical and physical properties of waste glass	54
Table 6.1	Composition limits of Portland cement	57
Table 6.2	Physical Properties of Cement	58
Table 6.3	Physical Properties of fine aggregates	59
Table 6.4	Sieve analysis of fine aggregate	59
Table 6.5	Physical Properties of Coarse Aggregates (10 mm)	60
Table 6.6	Sieve Analysis of Coarse Arregates (10mm)	60
Table 6.7	Chemical characteristics of glass powder	61
Table 6.8	Various mix proportions	62
Table 6.9	Aggregate gradation used in compliance with ASTM C 1260	69
Table 7.1	Showing the unit weight and percentage reduction from control mix.	74
Table 7.2	Change in compressive strength from 7 to 28 days	75
Table 7.3	Length changes in % of the mortar bars prepared in compliance with ASTM C1260.	76

List of Notations

MP0MG0 - Control	MP1MG2 - 20% Plastic 40% Glass
MP1MG0 - 20% Plastic	MP2MG2 - 30% Plastic 40% Glass
MP2MG0 - 30% Plastic	MP3MG2 - 40% Plastic 40% Glass
MP3MG0 - 40% Plastic	MP4MG2 - 50% Plastic 40% Glass
MP4MG0 - 50% Plastic	MP1MG3 - 20% Plastic 60% Glass
MP0MG1 - 20% Glass	MP2MG3 - 30% Plastic 60% Glass
MP0MG2 - 40% Glass	MP3MG3 - 40% Plastic 60% Glass
MP0MG3 - 60% Glass	MP4MG3 - 50% Plastic 60% Glass
MP0MG4 - 80% Glass	MP1MG4 - 20% Plastic 80% Glass
MP1MG1 - 20% Plastic 20% Glass	MP2MG4 - 30% Plastic 80% Glass
MP2MG1 - 30% Plastic 20% Glass	MP3MG4 - 40% Plastic 80% Glass
MP3MG1 - 40% Plastic 20% Glass	MP4MG4 - 50% Plastic 80% Glass
MP4MG1 - 50% Plastic 20% Glass	ASR - Alkali Silica Reaction

CHAPTER 1

INTRODUCTION

1.1 GENERAL

There are many studies evaluating industrial by-products in cement as binder and aggregate in concrete industries. In the recent decades, the efforts have been made to use industry by-products such as fly ash, silica fume, ground granulated blast furnace slag (GGBS), glass cullet, etc., in civil constructions. The potential applications of industry by-products in concrete are as partial aggregate replacement or as partial cement replacement, depending on their chemical composition and grain size. Artificially manufactured aggregates are more expensive to produce and the available source of natural aggregates may be at a considerable distance from the point of use, in which case the cost of transporting is a disadvantage. There are, however, other factors to be considered. The continued and expanding extraction of natural aggregate is accompanied by serious environmental problems. Quarrying of aggregates leads to disturbed surface area, etc. The artificial aggregates from industrial wastes are not only adding extra aggregate sources to the natural and artificial aggregate but also prevent environmental pollution. In the last 20 years, a lot of works concerning the use of several kinds of urban wastes in building materials industrial process have been published. Many researchers have been extended to study new kinds of wastes to investigate deeply some of the basic aspects. It has been found that the apart from the addition of wastes, environmental benefits, also produces good effects on the properties of final products. Few of the new waste materials used in the concrete industry is recycled plastic and glass used as partial replacement of aggregates. (www.hinduonnet.com)

1.2 MANAGEMENT OF PLASTIC WASTE

A marvel of polymer chemistry, plastics have become an indispensable part of our daily life. But repeated reprocessing of plastic waste, and its disposal cause environmental problems, pose health hazards, in addition to being a public nuisance.

The importance of this sector to the national economy can be gauged from the fact that the domestic demand crossed 4 million tonnes by 2001-2002, confirming plastics as the material of choice in numerous applications due to depletion of already scarce natural resources. Packaging is the major application, accounting for nearly 52 per cent of plastic consumption.

The balance unutilised waste remains uncollected lying strewn on the ground, littered in open drains or in garbage dumps, often resulting in chokage of municipal sewers and storm water drains. It should be remembered that collection of plastic waste is a source of livelihood for innumerable "rag-pickers", or waste collectors. Plastic waste collection is a lucrative business when compared with that of other items. A typical kabadiwala displays the following rates:

Newspapers in English: Rs. 4-5/kg

Newspapers in Hindi: Rs. 3-4/kg

Magazines: Rs. 3-3.50/kg

Iron scrap: Rs. 5.50/kg

Plastic waste: Rs.12-15/kg

Beer bottle (per bottle): Rs. 2.

It can be seen that plastic waste commands the highest rate in the recycled market. However there are environmental issues associated with the use of plastics. The disposables which generate waste and cause environmental problems when their useful life ends, include plastic packaging/carrybags/bottles/containers/trash bags/ health and medicare/ hotels and catering industry/air, rail and road travel etc.

Polythene carrybags have environmental implications from cradle to grave. While carrybags made from virgin plastics are accepted as user-friendly, the problem arises when plastics are recycled for repeated use. The basic question is whether polythene bags should at all be manufactured using recycled materials, and if so what grade - first, second, third and so on. For consumer acceptance, recycled material of the first grade should be used. In respect of other cases when second grade material is used, they will find greater acceptance by blending virgin and recycled plastics in 50: 50 ratio. Carry bags manufactured using third and lower

grade recycled materials are unacceptable and are the main environmental culprits. An interesting economic fact is that recycled polythene bags are generally priced between Rs. 45 and 50 per kg, while bags made out of virgin plastics command a price of around Rs. 80 per kg.

In respect of health and medicare items, though there is the possibility of organised picking around hospitals and garbage dumps, stringent environmental legislation for management of bio- medical wastes, including plastic waste, is in place.

Until recently no legislation was framed to deal specifically with issues connected with plastic waste management. The Government of Himachal Pradesh was one of the earliest to introduce legislation prohibiting the throwing or disposing of plastic articles in public places. The Union Ministry of Environment and Forests has recently notified the "Recycled Plastic Manufacture and Usage Rules, 1999". These rules require that carry bags or containers used for purposes of storing shall be made of virgin plastic and be in natural shade or white. These items when made of recycled plastic, and used for purposes other than storing and packaging of foodstuffs. They shall use pigments and colourants as per Indian Standards. Recycling of plastics shall also be undertaken strictly in accordance with specifications prescribed by the Bureau of Indian Standards, and shall carry a mark that the product is manufactured out of recycled plastic. The thickness of carry bags shall not be less than 20 microns. Finally and most importantly, Rule 4 prohibits all vendors from using carry bags or containers made out of recycled plastics for storing, carrying, dispensing or packaging of foodstuffs. In other words all vendors are required to use carry bags and containers manufactured to specifications prescribed in the 1999 Rules.

The issue boils down to management of plastic waste, and more precisely carry bags and containers made out of recycled plastic waste material. It is said that any strategy for effective management of plastic wastes should have three R's - reduction, reuse, and recycle, and include a package of prevention, promotion, and mitigation measures.

In Agenda 21 of the U.N. Conference in Rio in 1992, recycling has been assigned a position as important as conservation of natural resources and saving energy. The more that is recycled, the longer will natural resources be available for future generations. Eco-efficiency is a continuous challenge involving search for new techniques which combine resource conservation, energy saving, and economic viability.

Recycling of plastic waste is a major activity in India through which thousands of families earn a livelihood. Any decision to suddenly restrict this sector will have serious economic and social repercussions. At the same time the environmental issues involved need to be addressed. The challenge for environmental administrators lies in reconciling these two aspects. (www.hinduonnet.com)

1.3 MANAGEMENT OF GLASS

A huge amount of solid waste is disposed of at the landfills every year and the landfill capacity is expected to be exhausted within 6–10 years time. The reuse and recycling of solid waste is high on the agenda of sustainable waste management. Waste glass, especially waste glass beverage bottles, is a potential candidate for recycling. Generally, in other parts of the world, it is known that most of recycled glasses collected, especially beverage bottles, are re-melted and used to reproduce new glass. However, not all the waste glasses are suitable for new glass production, because some waste glasses are contaminated with papers and other substances or colour mixed, which make these glasses not suitable for glass bottle re-production. A number of studies were conducted in the 1960s to try to use crushed waste glasses as aggregates for concrete. In the past 10 years, the use of glass as concrete aggregates has again attracted much research interests due to high disposal costs for waste glasses and environmental regulations. Waste E-glass particles were obtained from electronic grade glass yarn scrap by grinding. There are quite a number of applications of using recycled glass in the construction industry over the world. The application includes using glass in asphalt concrete (glass-phalt), normal concrete, back-filling, sub-base, tiles, masonry blocks, paving blocks and other decorative purposes. But practical applications of using recycled glass in structural concrete are limited. (*Pike et al.,(1960)*)

1.4 OBJECTIVES

The objectives of this thesis are

- To study the mechanical properties of concrete containing waste glass powder as a replacement of cement in various proportions.
- To study the mechanical properties of concrete containing post consumer waste plastic as a replacement of coarse aggregate in concrete in various proportions.
- To study the initial water surface absorption of concrete containing waste glass powder and post consumer waste plastics.

- To study the expansion due to possible reaction between alkali in cement and silica in glass.

1.5 ORIENTATION OF THESIS REPORT:

This thesis is presented in eight chapters as detailed below:

Chapter-1 Gives the introduction about recycled material.

Chapter-2 Gives the introduction about plastics and the use of recycled plastic waste in concrete.

Chapter-3 Gives the use of waste glass in concrete.

Chapter-4 Literature review presents the work done by various researchers in the field of plastic concrete structure.

Chapter-5 Literature review presents the work done by various researchers in the field of glass concrete structure.

Chapter-6 Details the scheme of experimentation, materials used, variables involved, concrete mixes, mix design, casting and testing of specimens and materials.

Chapter-7 Gives results of various parameters studied and are compared with control concrete.

Chapter-8 Gives the major conclusions made in the study.

References

CHAPTER 2

PLASTICS

2.1 PLASTIC

Plastic is the general common term for a wide range of synthetic or semi synthetic organic amorphous solid [*plastic chemistry daily*] materials used in the manufacture of industrial products. Plastics are typically polymers of high molecular mass, and may contain other substances to improve performance and/or reduce costs.

The word is derived from the Greek *πλαστικός* (plastikos) meaning *fit for molding*, and *πλαστός* (plastos) meaning *molded*. It refers to their malleability, or plasticity during manufacture, that allows them to be cast, pressed, or extruded into a variety of shapes—such as films, fibers, plates, tubes, bottles, boxes, and much more.

The common word *plastic* should not be confused with the technical adjective *plastic*, which is applied to any material which undergoes a permanent change of shape (plastic deformation) when strained beyond a certain point. Aluminium, for instance, is plastic in this sense, but not a plastic in the common sense; in contrast, in their finished forms, some plastics will break before deforming and therefore are not plastic in the technical sense.

2.2 TYPES OF PLASTICS

There exist about 50 different types of plastics. Broadly plastics can be classified into two types, namely Thermosetting and Thermoplastic.

The Thermosetting Plastics are those that cannot be softened again, after being exposed to heat and pressure. On the action of heat and pressure, the molecular chain of thermosetting plastics become cross-linked, due to what it forbids the slippage when pressure and heat are reapplied.

The Thermoplastic are those that can be softened again and again and therefore, can be re made by the action of heat and pressure. On the action of heat and pressure, the molecular chain of thermoplastics undergoes change and the polymers slide past each other, that results

in the property of plasticity. Some of the different thermoplastic and thermosetting plastics are mentioned below.

- **Vinyl Plastics** :- Vinyl plastics belong to the thermoplastic group. Vinyl plastics are the sub-polymers of vinyl derivatives. These are used in laminated safety glasses, flexible tubing, molded products etc.
- **Polyurethane Plastics** :- Polyurethane plastics belong to the group that can be thermosetting or thermoplastic. Polyurethane is the only plastic which can be made in both rigid and flexible foams. The flexible polyurethane foam is used in mattresses, carpets, furniture etc. The rigid polyurethane foam is used in chair shells, mirror frames and many more. Due to the property of high elasticity, some polyurethane plastics are used in decorative and protective coatings. The high elasticity makes these polyurethane plastics resistant to a chemical attack.
- **Polyacrylics Plastics** :- Polyacrylics belong to the group of thermoplastics. Polyacrylics are transparent and decorative. Polyacrylics plastics can be shaped in any form like the windshields for airplane.

Apart from these, plastics have been also divided into seven different types by the plastic industry. These seven types of plastics are :-

1. **Polyethylene Terephthalate (PETE)** :- PETE is one the most recycled plastic. It finds usage in various bottles like that of soda and cooking oil, etc.
2. **High Density Polyethylene (HDPE)** :- HDPE is generally used in detergent bottles and in milk jugs.
3. **Polyvinyl Chloride (PVC)** :- PVC is commonly used in plastic pipes, furniture, water bottles, liquid detergent jars etc.
4. **Low Density Polyethylene (LDPE)** :- LDPE finds its usage in dry cleaning bags, food storage containers etc.
5. **Polypropylene (PP)** :- PP is commonly used in bottle caps and drinking straws.
6. **Polystyrene (PS)** :- PS is used in cups, plastic tableware etc.
7. **Other** :- This category of plastics include those plastics which are different from the six aforesaid types of plastic. These plastics are usually used in food containers and in Tupperware. [www.indian-plastic-industry.com]

2.3 PLASTIC CONCRETE PROPERTIES

Plastic concrete properties are those manifested from mix to setting. To successfully construct pavements that achieves all the desired properties, the designer, ready mix provider, contractor, and owner need to understand how their decisions can affect the many interrelated properties of the concrete system. Plastic properties, such as uniformity, workability, segregation, bleeding, and setting, affect the ease of placement (www.cptechcenter.org/publications/imc).

Therefore, contractors need to control these properties by

- Maximizing uniformity.
- Maximizing workability.
- Minimizing segregation.
- Controlling bleeding.
- Controlling setting.
- Early-age cracking can be highly influenced by controlling additional fresh concrete properties.
- Optimizing strength gain.
- Understanding modulus of elasticity.
- Controlling temperature.
- Controlling shrinkage.

2.4 PLASTIC RECYCLING

Plastic recycling is the process of reprocessing used scrap and waste plastic into new plastic material. Recycling old plastic products uses 20%-40% less **energy** than manufacturing it from new. Plastic is created by combining petroleum or natural gas with oxygen or chlorine. This process requires the burning of large amounts of oil. If we recycled all of our plastics we could reduce our oil consumption and save 25% of our landfill space.

2.4.1 Importance of plastic recycling.

There are three main arguments for recycling:

- It preserves the precious natural resources;
 - It minimizes the transportation and its associated costs; and
 - It avoids the environmental load caused by waste material, i.e. space requirement.
- The great strides have been made to increase recycling rates worldwide in recent years. The major consideration to support recycling all over the world is the expansion of infrastructure for recycling. The need to recycle plastics is clear. Over 22 million tons of plastics are discarded each year in the trash. While plastics account for only 9.2% (in 2000) of the trash Americans generate each year, plastic products do not decompose in landfills and are difficult to reduce in size. There are a few technological and economic constraints that currently limit the full and efficient recycling of plastic wastes into useful products.

2.4.2 Benefits of plastic recycling

Some of the benefits of recycling plastic are as follows;

- Recycled plastic can be made into plastic lumber, which is more durable.
- Reduces greenhouse gas emissions.
- Can be used to make toys, park benches, car parts, drainage pipes and more.
- For every 7 trucks it takes to deliver paper bags, it only take 1 truck to deliver plastic bags.
- Recycled soda bottles can be reused to make filling for pillows and jackets.
- The plastic recycling business creates over 200,000 jobs in the U.S alone.
- By recycling of plastic millions of useful new products can be created.

2.4.3 Types of recyclable plastic products.

The American Society of Plastics has recognized seven different types of plastic and has given each category a number, which can be found on the bottom of the plastic container, [\[www.greenstudentu.com/encyclopedia/recycling/plastic\]](http://www.greenstudentu.com/encyclopedia/recycling/plastic) The two most recyclable categories are:

Marked “1”

This category contains PET or PETE (Polyethylene Terephthalate) plastics. These plastics include:

- Soda and water bottles
- Mouthwash bottles
- Plastic wrap
- Peanut butter and other food jars
- Salad dressing bottles

Marked “2”

This category contains HDPE (high-density polyethylene) plastics. These plastics include:

- Milk containers
- Trash bags
- Yogurt containers
- Liquid laundry detergent containers
- Shampoo bottles
- Juice containers

2.4.4 Recycling methods

The recycling of plastic before we use it in concrete includes the some modification and processing techniques some of the methods as given below:-

1) Chemical modification. Plastic can be recycled by chemical modification or depolymerisation. The two ways to achieve depolymerisation are hydrolysis (Chemical Decomposition) and pyrolysis (thermal decomposition). For example, PET (polyethylene terephthalate) can be chemically modified to produce unsaturated polyester, thermosets polyester typically used in bathtubs, boat hulls, and automobile exterior panels. Another example is the thermal decomposition of acrylic wastes into methyl methacrylate (MMA), a monomer typically used in aircraft windows and neon signs. The technology of depolymerising single condensation polymers such as urethanes, PET (polyethylene

terephthalate), nylon, and polymethyl methacrylate is relatively easy. However, it is much more complicated to chemically modify mixed plastics to produce useful and economical chemical feedstock.

2) Mechanical recycling.

Mechanical recycling of plastics refers to processes which involve melting, shredding or granulation of waste plastics. Plastics must be sorted prior to mechanical recycling. Technology is being introduced to sort plastics automatically, using various techniques such as X-ray fluorescence, infrared and near infrared spectroscopy, electrostatics and flotation. Following sorting, the plastic is either melted down directly and moulded into a new shape, or melted down after being shredded into flakes and then processed into granules called regranulate. The chemical and physical properties of these recycled materials were compared with similar products manufactured from virgin resins. The properties of a blow-moulded bottle prepared from 100% post-consumer high-density polyethylene (HDPE). This recycled polymer exceeded the materials specifications for virgin plastics designs. Similarly, a sample of thermoplastic polyolefin (TPO, 100% polypropylene), obtained entirely from shredder residue (SR), displayed sufficient material strength for future separation and reprocessing. A range of feedstock recycling technologies is currently being explored. These include: pyrolysis, hydrogenation, gasification and thermal-cracking. Feedstock recycling has a greater flexibility over composition and is more tolerant to impurities than mechanical recycling, although it is capital-intensive and requires very large quantities of used plastic for reprocessing to be economically viable.

3) Thermal reprocessing. Thermal reprocessing consists of heating a thermoplastic at very high temperatures, thus making the plastic flow. The plastic is then converted into a new product as it cools. This method does not involve the modification of the chemical composition of the plastics. For example, PET, being thermoplastic polyester, can be heated and reprocessed into building panels, fence posts, or fibers for carpeting. This process cannot be repeated indefinitely since repeated thermal reprocessing may eventually adversely affect the plastic properties. Thermal reprocessing is quite straightforward if it is applied to relatively pure thermoplastics. However, thermal reprocessing could not be applied to

thermosets (such as cross linked polyesters) because they cannot soften at high temperatures without degrading. Thermal reprocessing becomes much more involved if various thermoplastics are mixed together. One way of doing is to separate the various plastics. Separation of various plastics can be easy or complicated depending on the source of the waste. The other way to thermally reprocess mixed plastics is to use special equipment that takes into account the different thermal properties or makes few demands on the melting behaviour of the plastic wastes (i.e., compression molding or melting in salt bath) and does not require meticulous removal of non-plastic wastes. Systems/ mechanisms have been developed to reprocess mixed or commingled plastic wastes where plastics with lower melting point act as a matrix that carries other plastics and contaminants into the mould. Chemical agents, called compatibilizers, could be used to improve the adherence between different polymer phases.

2.4.5 Construction application of plastics

1) Fillers. Plastic waste can also be used as fillers with virgin resins or other materials like concretes or as fill material in road construction. In such applications, chemical composition of the plastics is generally not very significant. This is an easy way to recycle thermosets or contaminated plastics in second grade applications. One such use is thermoplastic wastes that are melted and coextruded or co-injected into mouldings with virgin resins. These virgin resins with superior properties are forced into the perimeter of the mold while the recycled plastics, with inferior properties, are injected in the center of the mold. Plastic wastes may also be used with some effectiveness as a partial replacement of inorganic aggregates in concrete applications to decrease the dead weight of structures. Similarly, recycled rubber can be used in asphaltic concrete mixes.

2) Roads

S.S. Verma (2008) The plastic wastes could be used in road construction and the field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems. With the industrial revolution, mass production of goods started and plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, communication or infotech has been

virtually revolutionised by the applications of plastics. Plastic use in road construction is not new. It is already in use as PVC or HDPE pipe mat crossings built by cabling together PVC (polyvinyl chloride) or HDPE (high-density poly-ethylene) pipes to form plastic mats. The plastic roads include transition mats to ease the passage of tyres up to and down from the crossing. Both options help protect wetland haul roads from rutting by distributing the load across the surface. Recent studies in this direction have shown some hope in terms of using plastic-waste in road construction i.e., Plastic roads. Plastic roads mainly use plastic carry-bags, disposable cups and PET bottles that are collected from garbage dumps as an important ingredient of the construction material. When mixed with hot bitumen, plastics melt to form an oily coat over the aggregate and the mixture is laid on the road surface like a normal tar road.

2.5 PROBLEMS IN RECYCLING OF PLASTICS

Plastics can be degraded very slowly. Photo degradation can breakdown plastic resin, but this process can take decades. Even longer, biodegradation of plastics takes centuries.

The largest problem in recycling plastics is separating the plastics by type and number. In the current recycling system, the plastics must be separated by type. During the reprocessing of plastic containers, if the plastic is not of a uniform type, the raw plastic resin is unusable in the manufacturing industry.

2.6 ADVANTAGES AND DISADVANTAGES OF USING PLASTICS

Advantages of using plastics in concrete

The growth in the use of plastic is due to its beneficial properties, which include:

- Extreme versatility and ability to be tailored to meet specific technical needs.
- Lighter weight than competing materials reducing fuel consumption during transportation.
- Durability and longevity.
- Resistance to chemicals, water and impact.
- Excellent thermal and electrical insulation properties.

- Comparatively lesser production cost.
- Unique ability to combine with other materials like aluminium foil, paper, adhesives.
- Far superior aesthetic appeal.
- Material of choice – human life style and plastic are inseparable.
- Intelligent features, smart materials and smart systems.
- Reduction of municipal solid wastes being land filled and
- An alternative to pressure-treated lumber that leaches toxic chemicals into water.

Disadvantages of plastics

The followings are the main disadvantages of using the plastics in concrete are as follows:-

- Plastics are having low bonding properties so that the strength of concrete gets reduced such as compressive, tensile and flexural strength.
- Its melting point is low so that it cannot be used in furnaces because it gets melt as its comes in contact with the heat at high temperature.

CHAPTER 3

GLASS

3.1 GLASS

Glass is a hard material normally fragile and transparent common in our daily life. It is composed mainly of sand (silicates, SiO_2) and an alkali.

These materials at high temperature (i.e. molten viscous state) fuse together; then they are cooled rapidly forming a rigid structure, however not having enough time to form a crystalline regular structure.

3.2 GREEN BLAST OR CRUSHED GLASS

Greenblast is a crushed glass grit made from 100% post-consumer recycled glass. It is crushed, cleaned, sized and packaged to provide the ideal blast media for many applications (www.optaminerals.com/Abrasives/Greenblast.html). Its angular shape allows Greenblast to cut through rust, paint and oil, and yet it is lightweight enough to create a low profile on the surface. Crushed glass is used for a wide variety of blast cleaning operations, such as the blasting of:

- Autobodies and auto parts
- Trucks
- Fibreglass and plastics
- Wood
- Stainless steel
- Pipelines
- Concrete
- Graffiti removal
- Construction equipment and many other sensitive surfaces.

3.3 MAIN PROPERTIES OF GLASS

These are the main characteristics of glass:

- Solid and hard material
- Disordered and amorphous structure
- Fragile and easily breakable into sharp pieces
- Transparent to visible light
- Inert and biologically inactive material.
- Glass is 100% recyclable and one of the safest packaging materials due to its composition and properties.

Glass is used for architecture application, illumination, electrical transmission, instruments for scientific research, optical instruments, domestic tools and even textiles. Glass does not deteriorate, corrode, stain or fade and therefore is one of the safest packaging materials. These properties can be modified and changed by adding other compounds or heat treatment.

3.4 RECYCLING OF GLASS

Postconsumer glass containers have traditionally been disposed of either in domestic refuse, which ends up in landfill, collected in designated collection spots for reuse/recycling, or collected from kerbside and then transported to collection sites. The major aim of environmental authorities is to reduce, as far as possible, the disposal of postconsumer glass in landfill and diversion to economically viable glass product streams. Glass is a unique inert material that could be recycled many times without changing its chemical properties. In other words, bottles can be crushed into cullet then melted and made into new bottles without significant changes to the glass properties. Most of the glass produced is in the form of containers, and the bulk of what is collected postconsumer is again used for making containers. The efficiency of this process depends on the method of collecting and sorting glass of different colours. If different colour glass (clear, green and amber) could be separated, then they could be used for manufacturing similar colour glass containers.

However, when the glass colours get mixed, they become unsuitable for use as containers and are then used for other purposes or sent to landfill. Reindl reported the many non container uses of glass cullet, which included road construction aggregate, asphalt paving, concrete aggregate, building applications (glass tiles and bricks, wall panels, etc.), fibre glass insulation, glass fibre, abrasive, art glass, agricultural fertiliser, landscaping, reflective beads, tableware, hydraulic cement, among other applications. The utilisation of glass in concrete is of particular interest for the work reported here.

A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica-rich glass particles and the alkali in the pore solution of concrete, i.e., alkali-silica reaction (ASR). This reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimise its effects. Such preventative actions could be achieved by incorporating a suitable pozzolanic material such as fly ash, silica fume (SF) or ground blast furnace slag in the concrete mix at appropriate proportions. The susceptibility of glass to alkali implies that coarse glass or glass fibres could undergo ASR in concrete, possibly with deleterious effects. However, it would be expected that fine ground glass (i.e., glass powder, GLP) would exhibit pozzolanic properties such as those of the materials named above and would be an effective ASR suppressant, preventing ASR damage to concrete in the presence of reactive aggregates (*Shayan et al.,(2004)*).

3.5 PROCEDURE TO MIX GLASS IN CONCRETE

Step 1

Decide where you want to use your mix of recycled glass and concrete. Do not use it where it will be structurally weight-bearing since the glass combination has not been proven to be as structurally sound as stone aggregate and a home mixture is likely to be less perfected.

Step 2

Use broken pieces of recycled glass, called ‘cullet’ or buy tumbled glass for surfaces where sharpness is an issue; surfaces that will not be smoothed or top coated. You can order it from companies that specialize in supplying tumbled glass and glass cullet. Choose single colors, families of colors or buy mixtures.

Step 3

Wash your glass before using it as even small residues of sugar can create an uneven drying time or affect the strength of the finished product.

Step 4

Use glass cullet or tumbled glass mixed with water and Portland cement in the same proportions as you would use stone aggregate. In some mixes you may be adding polymers, particularly for countertops and other refined finishes. Bonding materials are used in commercial and professional applications for long-term durability

Step 5

Use low alkali Portland cement to avoid the silica from glass combining with the alkali of the cement and forming a gel that will absorb water, swell and form cracks or weaken the mixture.

Step 6

Reducing the water ratio slightly will also help avoid potential problems with sugar content that might remain on the glass.

Step 7

Mix the recycled glass with your Portland cement and water so the cement is evenly moistened. Let it set for a few minutes before paving or molding your concrete to whatever application you want.

Step 8

Smoothing the surface by washing as the concrete sets, or sanding or scraping the surface will expose more of the reflective colours of the glass. Like any other concrete, slow down drying time if the environment is hot or dry by lightly misting for the first couple of days. Wash off any residue on the surface once dry. Recycled glass mixed in concrete will offer a decorative, resilient and long-lasting surface you can use indoors or for landscaping (<http://www.ehow.com>).

3.6 ADVANTAGES OF GREENBLAST - CRUSHED GLASS

The following are advantages of crushed glass.

- Powerful – angular shape cuts through rust, paint and oil Gentle - lightweight enough to clean surfaces without damaging underlying material
- Non-metallic – won't contaminate your surface
- Environmentally friendly

CHAPTER 4

LITERATURE REVIEW OF PLASTIC CONCRETE

4.1 GENERAL

In this chapter the research work concerning to the various application and methods used for testing of the concrete made by replacing aggregate with plastic are discussed. This chapter gives a comprehensive review of the work carried out by various researchers in the field of using plastic in concrete as partial or full replacement of aggregates.

4.2 FRESH CONCRETE PROPERTIES

4.2.1 Workability

Al-Manaseer and Dalal (1997) determined the slump of concrete mixes made with plastic aggregates. They reported that there was increase in slump when plastic aggregates were incorporated in concrete. The concrete containing 50% plastic aggregates had a slightly higher cone slump than the concrete without plastic aggregates. Along with the slump test, K-slump test was also carried out. K-slump consistency results showed a similar pattern to that obtained from the cone slump. They concluded that the plastic aggregates neither absorbed nor added any water to the concrete mix. Due to this non-absorptive characteristic, concrete mixes containing plastic aggregates will have more free water. Consequently, the slump increased as shown in Table 4.1 *Al-Manaseer and Dalal, (1997)*.

Table 4.1. Cone and slump data (*Al-Manaseer and Dalal, 1997*)

Plastic aggregate (%)	Consistency(mm)			Workability(mm)			Cone slump(mm)		
	w/c	w/c	w/c	w/c	w/c	w/c	w/c	w/c	w/c
	0.28	0.40	0.50	0.28	0.40	0.50	0.28	0.40	0.50
0	65	70	70	50	55	55	178	190	-
10	60	73	65	55	60	45	-	190	-
30	75	70	75	60	45	50	178	-	-
50	73	83	80	55	60	50	206	216	-

Choi et al. (2005) investigated the influence of waste polyethylene terephthalate (PET) bottles lightweight aggregate (WPLA) on the workability (slump) of concrete. Mixture proportions of concrete were planned so that the water–cement ratios were 0.45, 0.49, and 0.53, and the replacement ratios of WPLA were 0.0, 0.25, 0.50, and 0.75 by volume of fine aggregate. They reported that slump value of waste PET bottles lightweight aggregate concrete (WPLAC) increased with the increase in water–cement ratio and the replacement ratio. The improvement ratios of workability represent 0.52, 1.04, and 1.23 in comparison with that of normal concrete at the water–cement ratios of 0.45, 0.49, and 0.53, respectively. This may be attributed to not only the spherical and smooth shape but also to the absorption of WPLA

4.2.2 Density of Concrete

The density of concrete is studied in terms of bulk density, fresh density and dry density and the same is discussed here under.

Bulk density

Al-Manaseer and Dalal (1997) investigated the effect of plastic aggregates on the bulk density of concrete. They concluded that the bulk density of concrete decreased with the increase in plastic aggregates content (Fig. 4.1). The reduction in bulk density was found to be directly proportional to the plastic aggregates content, density of concrete reduced by 2.5%, 6%, and 13% for concrete containing 10%, 30%, and 50% plastic aggregates, respectively. Reduction in density was attributed to the lower unit weight of the plastics.

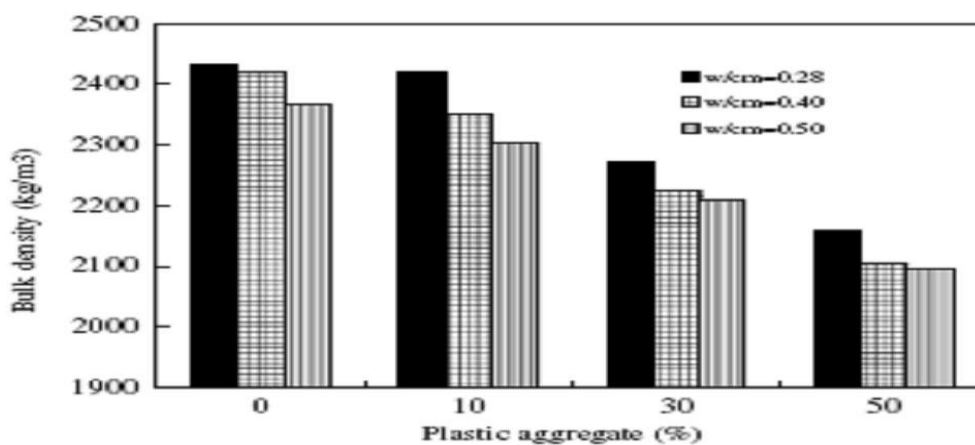


Fig.4.1 Bulk density versus plastic aggregates percentage (*Al-Manaseer and Dalal,1997*)

Fresh density

Ismail and Al-Hashmi (2007), has found that the fresh density tends to decrease by 5%, 7%, and 8.7% as compared to the reference mix, when the percentage of plastics, used as replacement of sand is increased from 10% to 20% (as shown in Fig.4.2). This trend may be attributed to the density of the waste plastic being lower than the sand by 69.7%, which leads to a reduction in the fresh density.

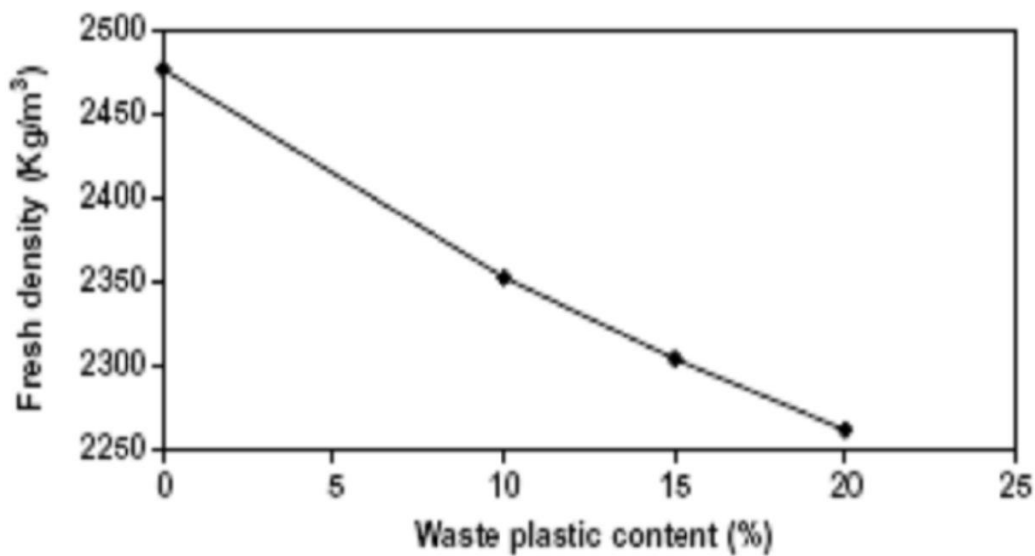


Fig.4.2 Fresh concrete density (*Ismail and Al-Hashmi ,2007*)

Dry density

Ismail and Hashmi (2007), studied that the dry density at each curing age tend to increase with increasing the waste plastic ratio in each concrete mixture, but the dry densities tend to increase with time for each concrete mixture at all curing ages as shown in Fig.4.3. It is clear that at 28 days curing age, the lowest dry density (2223.7 kg/m³) exceeds the range of the dry density for structural lightweight concrete. The use of waste plastic for each curing age reduced the dry densities of all mixtures with increasing the waste plastic ratio, because the density of plastic is lower than that of sand by 69.7%.

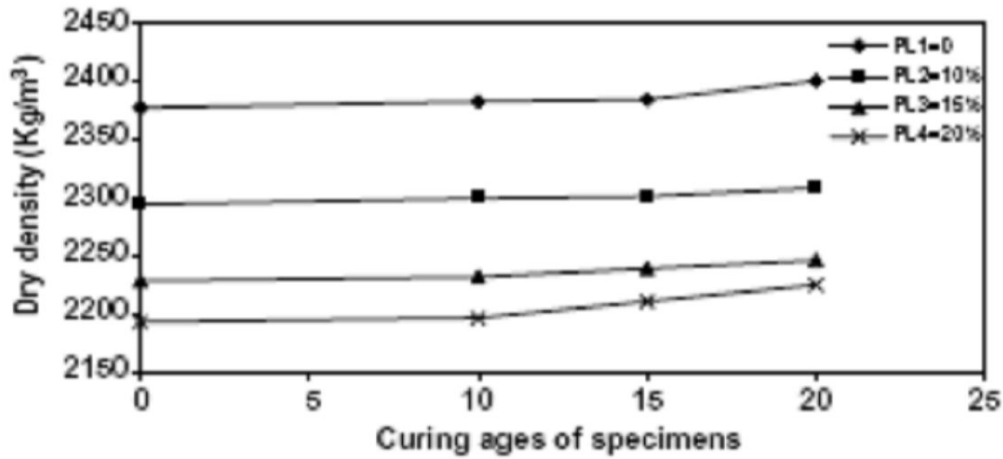


Fig.4.3 Dry density of plastic added concrete (Ismail and Hashmi, 2007)

4.2.3 Air content

Bayasi and Zeng (1993), studied the effect of polypropylene fibers on the air content of concrete. They reported that air content increased with the inclusion of polypropylene fibers, and there was no detectable effect on air content of fresh concrete at volume below 0.3%.

Table 4.2 Fresh concrete properties of polypropylene reinforced concrete (Bayasi and Zeng,1993)

Mix no.	Fiber length(mm)	Fiber volume fraction (%)	Air content (%)
1	-	0	2.0
2	12.7	0.1	1.5
3	12.7	0.3	2.5
4	12.7	0.5	4.5
5	19.0	0.1	1.5
6	19.0	0.3	3.5
7	19.0	0.5	5.0

Soroushian et al. (2003), reported that inclusion of recycled plastic in concrete resulted in the reduction of air content. The dosages of various virgin and recycled discrete reinforcement systems considered in this investigation. The air content of concrete made by using different types of recycled plastics is shown in Fig. 4.4. It can be seen from the figure that the use of recycled plastic fibres causes a significant loss (approximately 1%) in air content.

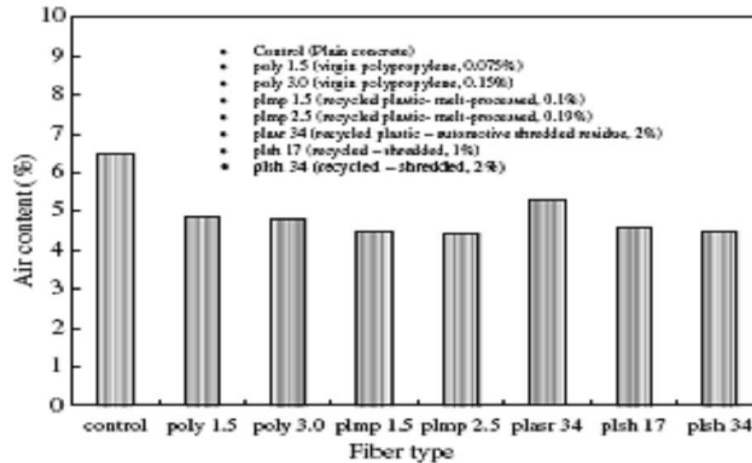


Fig. 4.4 Air content versus plastic fiber type (Soroushian et al., 2003).

4.3 HARDENED CONCRETE PROPERTIES

4.3.1 Compressive strength

Asokan Et al. (2009), Studied the Compressive strength of concrete specimens developed with and without GRP waste powder and superplasticiser, as per the specifications and procedure laid out in BS EN 12390- 3:2002 using the Denison 7230 Compression Testing Machine at 28 days of curing. Table 4.3 shows the details of triplicate experiments/specimens and their testing results on the compressive strength of concrete. The outcome of their research showed improved performance of the GRP waste powder filled concrete using superplasticiser as compared to the normal concrete recommended for structural applications (i.e. 45 N/mm²). They showed that the addition of 2% superplasticiser (2% of cement content) considerably reduced the water cement ratio from 0.57 to 0.38 with 15% GRP waste powder and 0.55 to 0.37 with 5% GRP waste powder addition and significantly improved its workability. Their study revealed that the mechanical properties of 5–15% GRP waste powder filled concrete was significantly improved due to addition of 2% superplasticiser and the high range of water reducer influenced to enhance the 28 days mean compressive strength as high as 70.25±1.43–65.21± 0.6 N/mm² which is about 43–47% higher than that obtained without the addition of superplasticiser and 10–12% higher than that of the control concrete (normal concrete without GRP waste) with 2% superplasticiser. The results from their study showed that the compressive strength of concrete was proportionally higher with water curing as compared to oven curing. The increased in compressive strength was due to the addition of

superplasticiser which might have influenced the formation of polymer film leading to good bonding between aggregate and on the concrete surface. The study confirmed that the incorporation of superplasticiser with GRP waste powder significantly increased the compressive strength of concrete due to the presence of CaO, Al₂O₃ and SiO₂ and other polymeric compound followed by short glass fibre.

Table 4.3 Effect of GRP waste powder on the compressive strength of concrete (N/mm²).

Experiments/ specimens	GRP waste powder content (%)	Water cured specimens					Oven cured specimens				
		L (mm)	B (mm)	Area (mm ²)	Load (KN)	Comp. strength (N/mm ²)	L (mm)	B (mm)	Area (mm ²)	Load (KN)	Comp. strength (N/mm ²)
1R1	0	100	100	10,000	6082	60.82	99	100	9900	5480	55.35
1R2	0	100	100.5	10,050	6220	61.89	100	101	10,100	5474.0	54.20
1R3	0	100	101	10,100	6226	61.64	100	100	10,000	5486.0	54.86
Mean		100	100.50	10,050	6176	61.45	99.67	100.33	10,000	5480.00	54.80
SD		0.00	0.50	50.00	81.46	0.56	0.58	0.58	100.00	6.00	0.58
2R1	5	99	100	9900	7045	70.47	99	100	9900	6538	65.38
2R2	5	99	100	9900	6873	68.73	99	100	9900	6624	66.24
2R3	5	100	100	10,000	7156	71.56	100	99	9900	6689	66.89
Mean		99.3	100.00	9933	7025	70.25	99.33	99.67	9900	6617	66.17
SD		0.58	0.00	57.74	143	1.43	0.58	0.58	0.00	76	0.76
3R1	15	100	100	10,000	6503	65.03	100	99	9900	5885	59.44
3R2	15	100	99	9900	6407	64.72	100	100	10,000	5972	59.72
3R3	15	100	99	9900	6523	65.88	100	99	9900	6016	60.16
Mean		100	99.33	9933	6478	65.21	100.00	99.33	9933	5958	59.77
SD		0.00	0.58	57.74	62.0	0.60	0.00	0.58	57.74	67	0.36

Byung-Wan et al. (2008), used unsaturated polyester resins from recycled polyethylene terephthalate (PET) plastic waste, microfillers and recycled concrete aggregates

The specimens were mixed and cured at room temperature for 7 days prior to testing. Likewise, in order to consider the influence of curing age on compressive strength of the specimens, curing ages of 1, 3, and 7 days for the RPC were also considered. The size of the concrete cylinders for compressive strength, split tensile strength, and modulus of elasticity testing was 76 mm in diameter and 152 mm in length. The result shows that recycled-PET polymer concrete with recycled concrete aggregates (RPC), a gradual reduction in strength was observed as the recycled aggregate content increased. This effect was due to the weaker bond of the old mortar adhering to the recycled concrete aggregate, which may have caused a reduction in the strength of the RPC. RPC with a resin content of 17% by weight showed little to no decrease in strength, showing that particular resin contents filled the voids in the old mortar attached to the recycled aggregate. The result shows compressive strength of RPC increased with resin content; however, beyond a certain resin content (approximately 13–17% resin) the strength did not change appreciably with increasing resin content.

Robert Malloy et al. (2003), investigated for compressive strength using 100 mm Ø x 200 mm cylinders that were cured for 28 days. In each case, only the coarse aggregates were of the lightweight variety. The fine aggregates were conventional normal weight aggregate (natural river sand). A coarse aggregate “volume” fraction of 30% was used for all of the concrete test samples. The mix proportions for the compressive cylinder data presented in this paper are given in [Table 4.4](#). The compressive test data in [Table 4.5](#) and [Figures 4.6](#) and show how the compressive properties of polyethylene based SLA lightweight concrete compare to that produced with expanded clay lightweight aggregate. Results are also presented for concrete produced with the mixed plastic SLA.

In the final portion of this study, concrete compressive test cylinders were prepared using both conventional foamed clay aggregate (as a control) and the SLA’s. Lightweight aggregate was used only for the coarse aggregate portion of the concrete mix. [Figures 4.5](#) and [4.6](#) shows that the compressive strength and compressive modulus of the lightweight concrete produced with the HDPE aggregate (the medium stiffness binder) were both significantly lower than those obtained using the stiffer expanded clay aggregate. While their strength and stiffness were lower, the concretes produced with the SLA’s were more ductile than the concrete produced with expanded clay. The concrete produced with the 80% HCFA / HDPE aggregate was significantly stronger and stiffer than that produced with neat HDPE aggregate.

By experimenting with various concrete mix ratios (specifically water to cement ratios), it was possible to produce a very lightweight concrete with a 30 MPa compressive strength using mixed plastic / HCFA SLA. Lightweight concrete produced using mixed plastic / HCFA coarse SLA has been produced with a compressive strength as high as 30 MPa.

Table 4.4 Concrete mix properties for compressive test cylinders *Robert Malloy et al. (2003)*

Properties	Concrete Batch		
	Expanded Clay	Neat HDPE	20% HDPE 80%HCFA
Cement (kg)	415	418	402
Water (kg)	221	227	195
Coarse Aggregate, SSD (kg)	441	275	515
Fine Aggregate, SSD (kg)	875	873	856
Density (kg/m ³)	1953	1792	1969
Water/cement ratio	0.53	0.54	0.49
Slump (mm)	64	89	64

Table 4.5 lightweight concrete compression test results *Robert Malloy et al. (2003)*

Coarse Aggregate Type	Water Cement Ratio	Compressive Strength (MPa)	Elastic Modulus (GPa)
Expanded Clay LWA	0.50	42 ± 1	23.5
HDPE 0% Fly Ash	0.50	14 ± 1	12.5
HDPE 80% Fly Ash	0.50	20 ± 1	14.5
Mixed Plastic 80% Fly Ash	0.50	22 ± 1	14.5
Mixed Plastic 80% Fly Ash	0.42	26 ± 1	15.5
Mixed Plastic 80% Fly Ash	0.35	30 ± 1	16.0

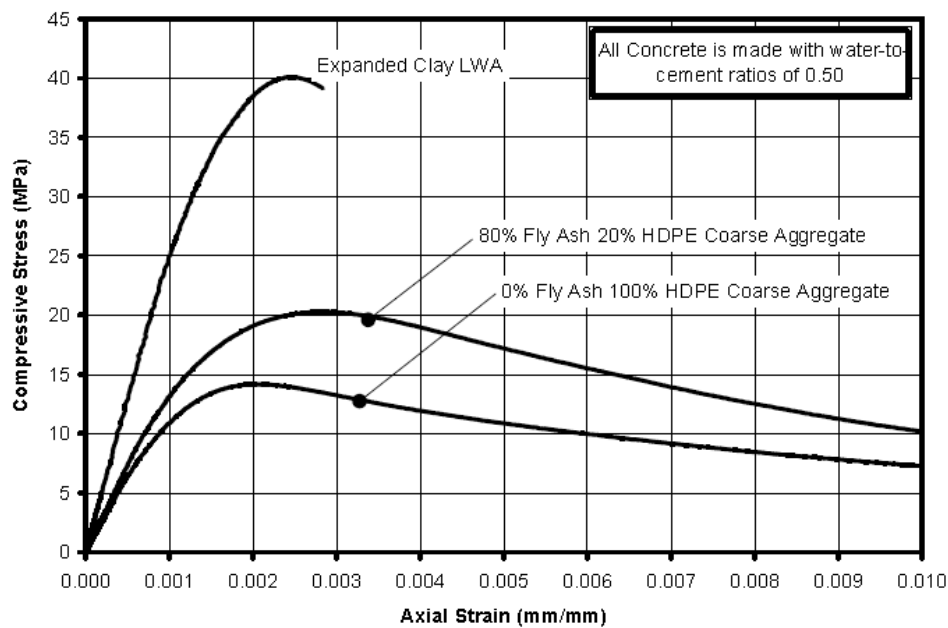


Figure 4.5 Effect of coarse lightweight aggregate composition on compressive stress-strain behaviour of concrete. *Robert Malloy et al. (2003)*

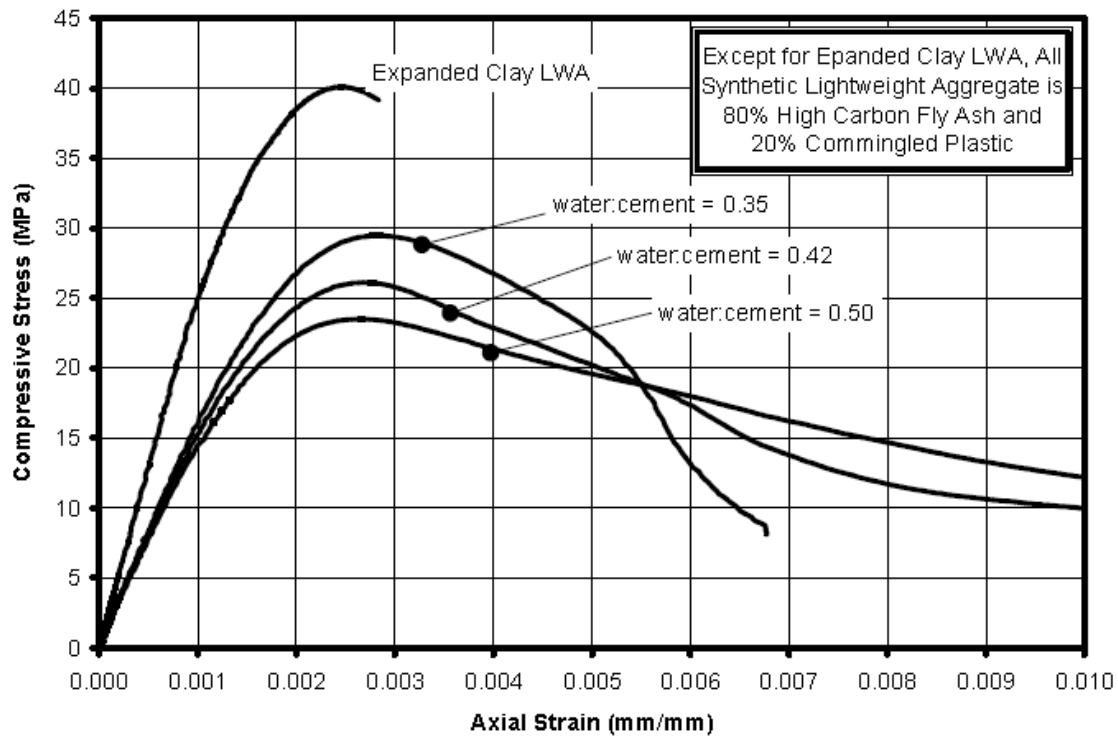


Figure 4.6 Effect of concrete water-to-cement ratio on compressive stress-strain behaviour of concrete made with synthetic lightweight coarse aggregate in comparison to concrete made with expanded clay lightweight aggregate. Robert Malloy et al. (2003)

A. Remadnia et al. (2009), used animal proteins as foaming agent in cementitious concrete composites manufactured with recycled PET aggregates. The results show that substituting sand at a level below 50% by volume with granulated PET, whose upper granular limit equals 5 mm, affects neither the compressive strength nor the flexural strength of composites.

The evolution in compressive and flexural strengths for both lightened and non lightened materials were measured at 28 days after cement hydration was stopped by drying. The evolution for various H/C ratios and mixing time after haemoglobin introduction is presented In the case of 1 min of mixing after introduction of haemoglobin, the compressive strength of new composites decreased by 54.41 % in comparison with the mortar with aggregates of PET and the decrease of flexural strength reaches 45.35%. This decrease of strengths is mainly due to the decrease of the bulk density of the composites as a function of H/C ratios (see Table 4.6). Given the mechanical properties in this case (a compressive strength greater than 3.5 MPa), these materials could be used as bearing insulators.

Table 4.6 Evolution of bulk density (kg/m³) of the composites as a function of H/C and mixing time used after hemoglobin introduction as regard of the bulk density of a mortar without hemoglobin (1865.39 kg/m³). A. Remadnia et al. (2009)

		Mixing time after hemoglobin introduction (min)		
		1	2	3
H/C ratio (%)	0.5	1540.39	1424.92	1329.84
	1	1447.19	1269.45	1130.23
	2	1421.33	1238.06	1027.58

Sobhan (2004), used more than 90% by mass of recycled waste products namely crushed aggregate, fly ash, and shredded plastics. Figure 4.7 shows the average 28-day compressive strengths for all mixtures. The maximum strength was achieved by the mixture containing 8% cement and 8% fly ash, having a compressive strength of 14 MPa (2000 psi) indicating a remarkably strong stabilized base course material despite the fact that 92% or more of this composite contains waste products. It is found that the compressive strength drops when 50% of the cement is replaced by fly ash (i.e. comparing Mixes 1 and 2), and significantly increases when the amount of cementitious material is doubled by adding fly ash to the composite (i.e. comparing Mixes 1 and 3). For all mixtures, the inclusion of fibers had a detrimental effect on compressive strength compared to a corresponding unreinforced mix.

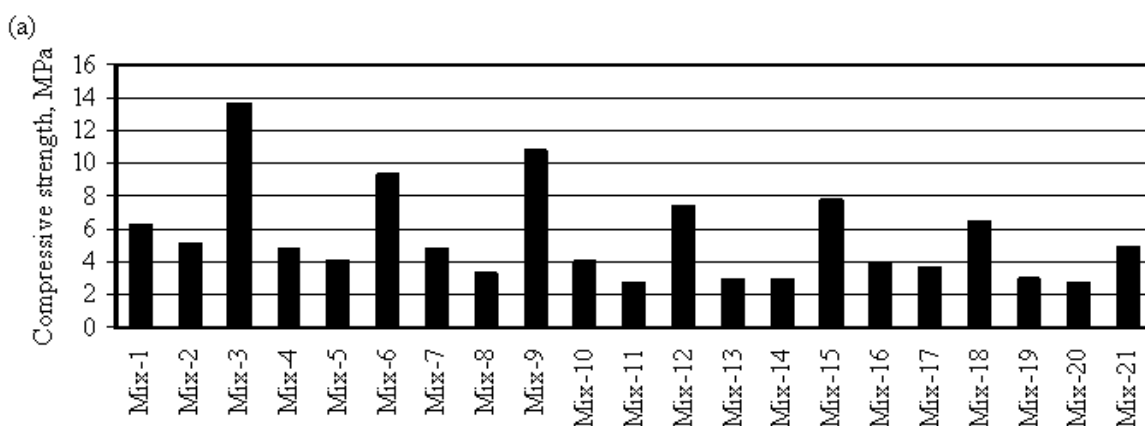


Figure 4.7: Strength and Toughness for Various Mixes

Kumar & Prakash (2007), studied about the waste plastics. In the research work he used M20 concrete & Waste plastics as modifier. The modifier was added in percentage such as

2%, 4%, 6%. In order to replace the same amount of cement and sand. Now, concrete cubes are casted, which are of standard dimension of 15 x 15 x 15cms. The specimens are kept for curing and tested for its compressive strength on different days (1, 3, 7, 14 & 28). Here, the modifier (waste plastics) is added in known percentages such as, 2, 4, 6, 7 and 8 by weight of cement. By conducting compressive strength tests on cubes casted with varying percentages of modifier, Optimum Modifier Content was found to be 5%. Further beyond 5 % these specimens did not show any appreciable gain in strength.

Concrete beam specimens of size 100X100X400mm were casted using plastic modifier at Optimum Modifier Content of 5% (by weight of cement). Similarly beams of plain cement concrete were also casted. Then specimens were subjected to repeated loading tests at the rate of 60cycles/min, at various temperatures from 25^oC to 60^oC. The stress level of half the compressive strength test value of 5% modified test specimens was applied on plain and modified concrete beams.

In the present investigation it is found that optimum plastic modifier content was 5% by weight of cement. From the test results it was observed that the compressive strength value of the concrete mix increased with the addition of modifiers. From experimental analysis, we came to conclusion that the compressive strengths of modified cement concrete increases by 20% more than that of plain cement concrete.

4.3.2 Tensile strength

Babu et al (2006), investigate the effect of polystyrene aggregate size on strength and moisture migration characteristics of lightweight concrete. Polystyrene concrete is made from a mixture of cement, sand and polystyrene aggregate (EPS or UEPS aggregates). The splitting tensile strength test was conducted on cylinders of 100 mm in diameter and 200 mm in height, at 28 days as per ASTM C 496-89. The relationship between splitting tensile strength and compressive strength ([Fig. 4.8](#)) indicates increase in splitting tensile strength with an increase in compressive strength. The figure also shows higher tensile strength in concrete containing 30% fly ash as compared to silica fume concrete. This may be due to the fact that 30% fly ash concretes were designed with lower water to binder ratios than 50% fly ash and silica fume concretes.

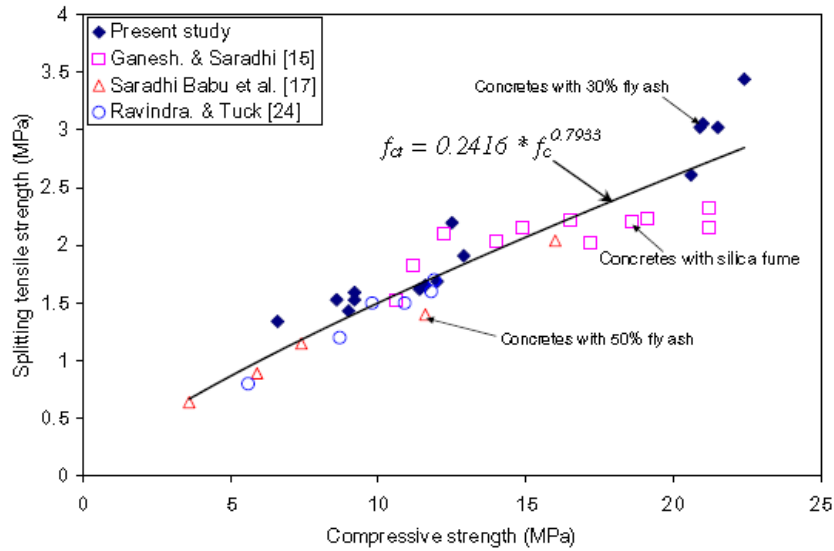


Fig. 4.8 Relationship between splitting tensile strength and compressive strength

Sobhan (2004), used more than 90% by mass of recycled waste products namely crushed aggregate, fly ash, and shredded plastics Figure 4.9 shows split tensile strengths for all mixtures. The maximum strength was achieved by the mixture containing 8% cement and 8% fly ash, a split tensile strength was 1.5 MPa (175 psi) indicating a remarkably strong stabilized base course material despite the fact that 92% or more of this composite contains waste products.

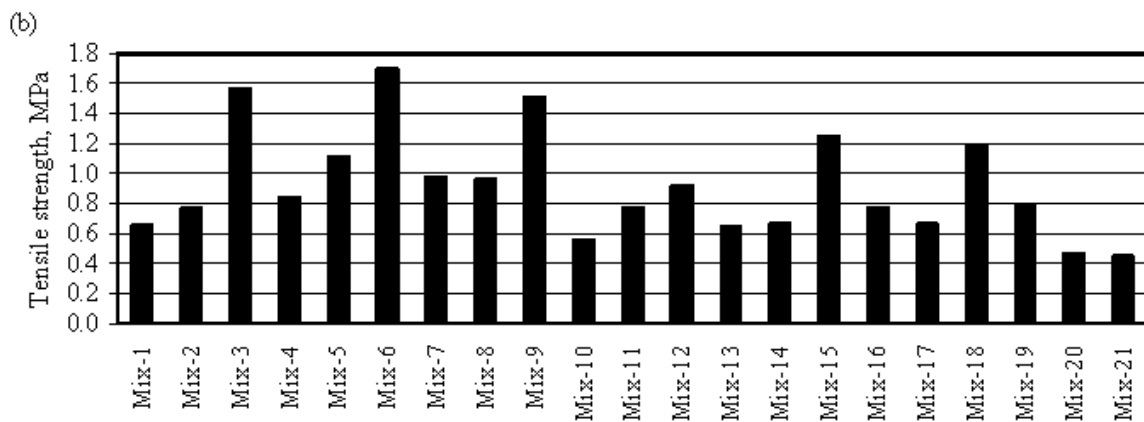


Fig 4.9 Strength and Toughness for Various Mixes

Jo et al. (2007), studied the effect of recycled aggregates and resins on tensile strength of concrete. In the case of split tensile strength they observed that there was a slight increase in the strength of RPC made with a resin content of 13% compared to RPC made with a resin content of 9%. This increase was predicted to be due to the different and complex failure mechanisms of the material in RPC under tension.

Al-Manaseer and Dalal (1997), studied the effects of plastic aggregates on the splitting tensile strength of concrete. The split tensile strength of concrete was measured at different water-to-binder ratios and for various percentages of plastic aggregates, as shown in Fig. 4.10. It was concluded that the splitting tensile strength decreased with the increase in plastic aggregates percentage (the splitting tensile strength was found to decrease by 17% for concrete containing 10% plastic aggregates). For a given plastic aggregate content, the splitting tensile strength was found to decrease when w/c ratio was increased. It was also observed that the splitting failure of concrete specimens containing plastic aggregates did not exhibit the typical brittle failure observed in the case of conventional concrete. The splitting tensile failure was more of a gradual failure as was the case for specimens tested under compression load. In general, specimens containing plastic aggregates were found to be more capable of resisting the splitting load after failure without full disintegration. The failure was found to be more ductile in nature when the percentage of plastic aggregates was increased.

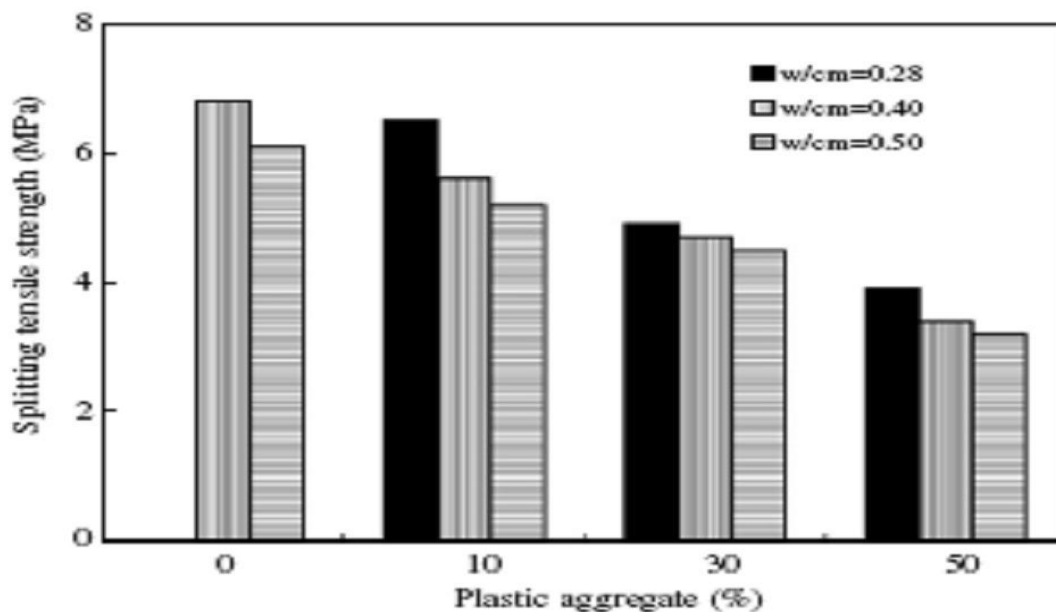


Fig.4.10 Splitting tensile strength versus plastic aggregate percentage (*Al- Manaseer and Dalal, 1997*)

Asokan et al (2009), used tensile splitting strength (cylinders specimens size of 300 mm length and 150 mm diameter) The tensile splitting strength of concrete specimens developed using different proportionate of GRP waste powder under uniform experimental conditions was performed. Results of the present study revealed that the mean tensile splitting strength of concrete under water curing attained 4.22 ± 0.02 N/mm² with 15% GRP waste powder which was higher (4.12 ± 0.087 N/mm²) than that of 5% GRP waste powder addition (Fig. 4.11). Also, the tensile splitting strength of concrete developed with 5% and 15% GRP waste powder was higher about 9.5% than that of the control concrete i.e. without GRP waste powder and with superplasticiser.

Fig.4.11 Effect of GRP waste powder and super plasticizer on the tensile splitting strength of concrete

Asokan et al (2009)

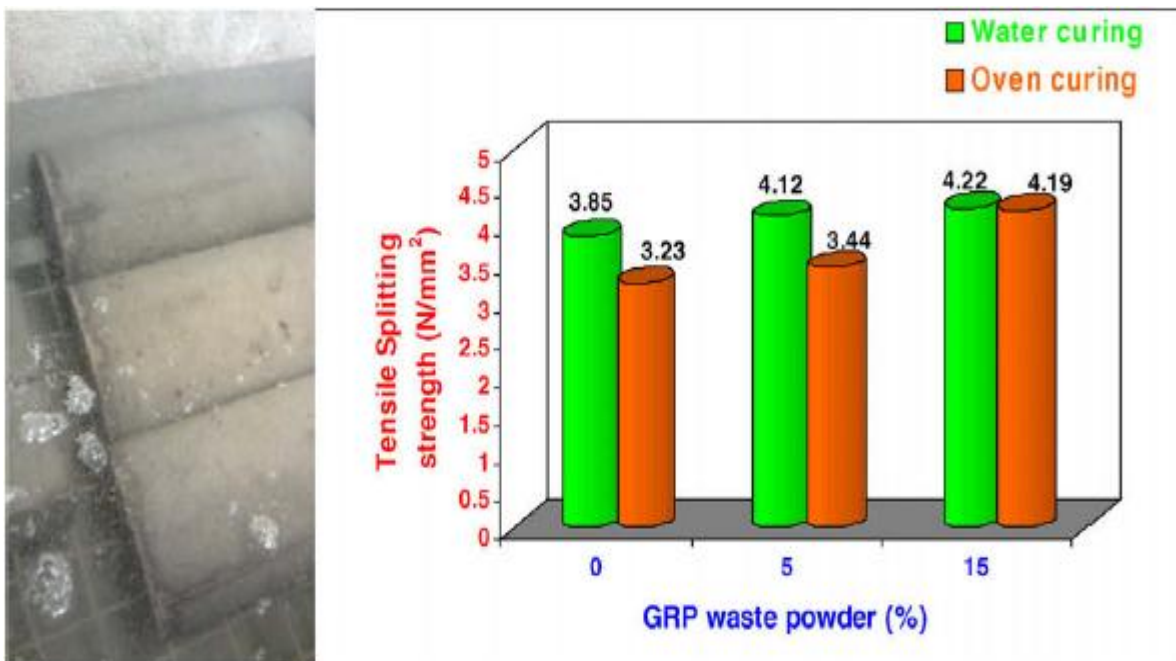


Table 4.7 Effect of GRP waste powder on the tensile splitting strength of concrete (N/mm²). Asokan et al (2009)

Experiments/ specimens	GRP waste powder content (%)	Water cured specimens					Oven cured specimens				
		L (mm)	Dia (mm)	Weight (kg)	Tensile load (KN)	Tensile splitting strength (N/mm ²)	L (mm)	Dia (mm)	Weight (kg)	Tensile load (KN)	Tensile splitting strength (N/mm ²)
1R1	0	300.0	151.0	13.56	274.9	3.86	300	151	12.92	227.6	3.20
1R2	0	300.4	151.2	13.44	269.2	3.77	300	151	13.04	234.2	3.29
1R3	0	300.0	151.4	13.90	278.9	3.91	300	151	12.98	226.9	3.19
Mean		300.1	151.2	13.6	274.3	3.85	300	151	12.987	229.6	3.23
SD		0.231	0.200	0.241	4.875	0.069	0.00	0.00	0.06	4.03	0.06
2R1	5	300.0	152.0	13.78	292.3	4.08	300	152	13.27	243.2	3.40
2R2	5	299.4	151.0	13.02	299.8	4.22	301	151	13.26	248.8	3.49
2R3	5	300.0	151.6	13.73	290.4	4.07	300.6	151.4	13.26	244.7	3.42
Mean		299.8	151.5	13.5	294.2	4.12	301	151	13.26	245.6	3.44
SD		0.346	0.503	0.424	4.989	0.087	0.50	0.50	0.01	2.90	0.05
3R1	15	301.0	152.0	13.48	301.7	4.20	301	152	13.20	292.6	4.07
3R2	15	300.0	151.0	13.40	301.5	4.24	300	151.6	13.38	306.9	4.30
3R3	15	300.4	151.6	13.44	301.6	4.22	300.2	151.4	13.29	299.8	4.20
Mean		300.5	151.5	13.4	301.6	4.22	300	152	13.29	299.8	4.19
SD		0.503	0.503	0.042	0.100	0.020	0.53	0.31	0.09	7.15	0.11



Fig. 4.12 Fracture surface of concrete cylinder specimen under tensile splitting load: (a) control concrete specimen, (b) 5% GRP waste powder admixed concrete, and (c) 15% GRP Waste powder.

4.3.3 Elastic modulus

Bagheri et al.(2008), carried out test for elastic modulus according to ASTM C469, on 15 · 30 cm cylindrical specimens with reduced load application rate. The strain was measured in the central 15 cm of each specimen. In Fig. 4.13, test results on the effect of using various replacement levels of cement with silica fume on elastic modulus of plastic concrete with the three water to cementitious materials ratios considered are given. The results show that with increasing the percentage of silica fume the elastic modulus of plastic concrete is substantially increased. The increase in elastic modulus of plastic concrete with a water to cementitious materials ratio of 1.8, containing 15% silica fume was about 180% over that of

control mix. For plastic concrete mixes with w/(c + s) of 2.6, the increase of elastic modulus due to 15% cement replacement with silica fume was 70% over control mix.

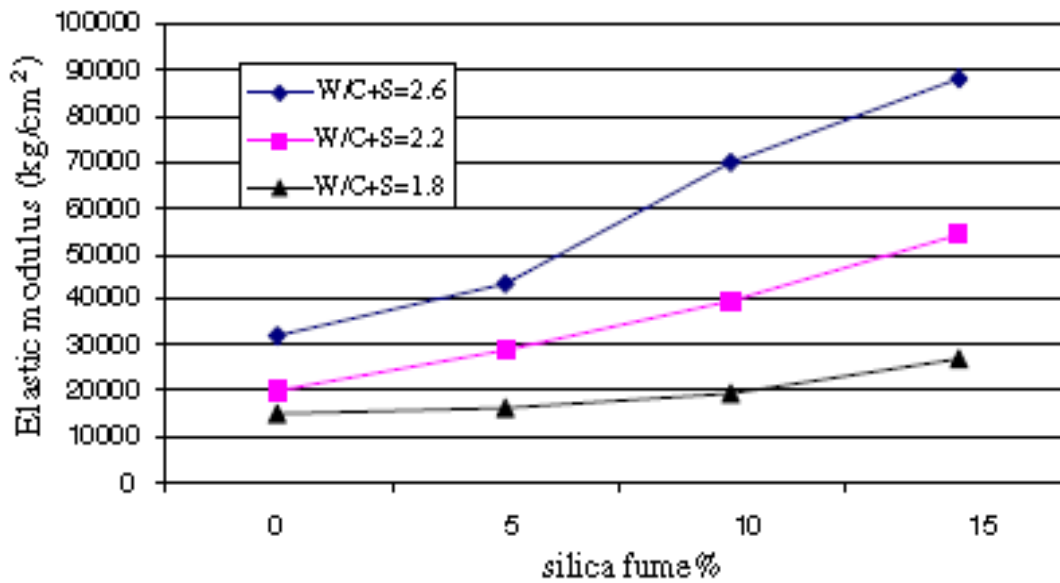


Fig. 4.13 Effect of silica fume on elastic modulus of plastic concrete mixes with various water to cementitious materials ratios. *Bagheri et al.(2008)*

4.3.4 Permeability

Bagheri et al.(2008), they carried out permeability test in accordance with test designation USBR-4913-92 on 15 × 30 cm cylindrical specimens at 90 days. for the mix with a water to cementitious materials ratio of 1.8, the use of 15% silica fume to replace cement, has resulted in the reduction of permeability coefficient from 5.8×10^{10} m/s to 7.2×10^{12} m/s, i.e. 80 times lower. The main mechanisms involved in reduction of permeability by silica fume are pore refinement and improvement of interfacial transition zone.

It is shown that increasing the confining pressure and cement factor reduces the permeability. Also increasing bentonite content reduces the permeability, but there is a threshold for bentonite content beyond which the permeability is not greatly lowered. This threshold for bentonite content depends on the bentonite properties and its composition.

Table 4.8 Mixture proportions of studied plastic concrete mixes

Mix code	$\frac{W}{C+FS}$	Cement content (kg/m ³)	Silica fume content (kg/m ³)	Compressive strength (kg/cm ²)		Elastic modulus (90 days) (kg/cm ²)	Coefficient of permeability (m/s) (90 days)
				28 days	90 days		
H0	2.6	152.7	0	8.5	10.2	15,000	2.4×10^{-9}
H5	2.6	145	7.6	12.9	14.8	16,100	6×10^{-10}
H10	2.6	137.4	15.3	18.5	20.5	19,700	3×10^{-10}
H15	2.6	129.8	22.9	20	29.5	27,000	4.9×10^{-11}
M0	2.2	180.4	0	12.7	23	20,000	9×10^{-10}
M5	2.2	171.4	9.02	15.7	31	29,000	3.5×10^{-10}
M10	2.2	162.41	18.05	18	36	39,800	8.5×10^{-11}
M15	2.2	153.4	27.07	23.8	41	54,000	2×10^{-11}
L0	1.8	220.6	0	22.5	29	32,000	5.8×10^{-10}
L5	1.8	209.5	11	31.2	38.4	43,600	1.4×10^{-10}
L10	1.8	198.5	22.1	40.3	46	70,000	5.2×10^{-11}
L15	1.8	187.5	33.1	48.7	54	88,000	7.2×10^{-12}

Bayasi & Zeng (1993), investigated the effect of recycled plastic on the permeability of concrete. They concluded that 19-mm polypropylene fibers significantly increased the permeability of concrete with an inconsistent effect on the volume fraction of permeable voids; 12.7-mm long fibers somewhat increased the permeability of concrete and tend to decrease the volume of permeable voids.

Soroushian et al. (1995), demonstrated that there was decrease in air permeability with the inclusion of discrete reinforcement in concrete. The air permeability test as shown in Fig.4.14 measured the rate of air through a concrete specimen. Lower airflow rates are preferable, indicating lower permeability. Discrete reinforcement systems were used in the project to reduce permeability of concrete, which could be attributed to reduced shrinkage micro-cracking. Reduced permeability favors long-term durability of concrete systems incorporating discrete reinforcement.

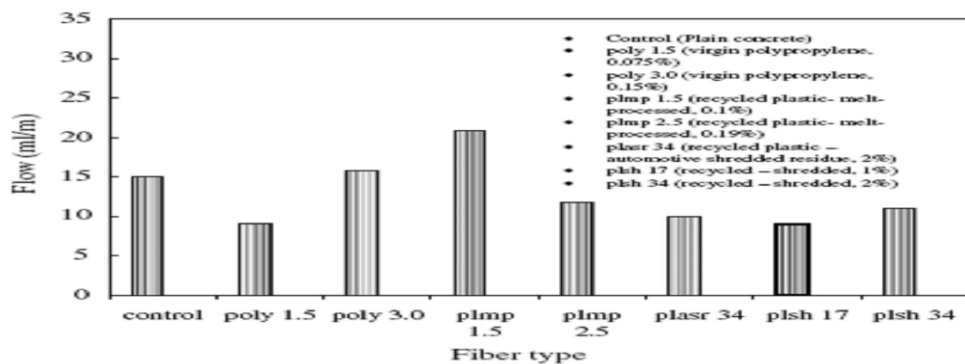


Fig 4.14 . Air permeability versus fiber type (*Soroushian et al., 2003*)

CHAPTER 5

LITERATURE REVIEW OF GLASS CONCRETE

5.1 GENERAL

In this chapter the research work concerning to the various application and methods used for testing of the concrete made by glass concrete are discussed. This chapter gives a comprehensive review of the work carried out by various researchers in the field of using glass in concrete as partial or full replacement of aggregates.

5.2 FRESH CONCRETE PROPERTIES

Kou & Poon (2008), they determined the air content of the RG–SCC in accordance with BS 1881 Part 114. The slump flow, blocking ratio, air content of the RG–SCC mixes increased with increase in recycled glass content. The initial slump flows of all the SCC mixes prepared in this study were at least 750 mm. The blocking ratios varied from 0.84 to 0.88.

Topc & Mehmet (2003), carried out the results of the tests, such as unit weight, slump, air content, VeBe and flow table test, performed with fresh concrete produced by using PKC_/B 32.5R cement and WG of various proportions, are all given in [Figs. 5.1-5.3](#). The air content of the concretes produced was 0.4–0.7%, while a high proportion of WG addition unevenly decreased air content as much as 27%. The reason for such a discrepancy was thought to result from the poor geometry of WG, as a result of which water and air voids occur in particularly lower parts. Furthermore, low air content in concrete containing a high proportion of WG was thought to be connected to the smooth surface of WG, which helps decrease porosity between WG and cement paste. While WG addition decreased the slump, air content and fresh unit weight, it increased flowing and VeBe values. This would be possible if slump was 9.1 cm, with the flow-table value 36.35 cm, VeBe value 5.96 s. and air content 0.53%.

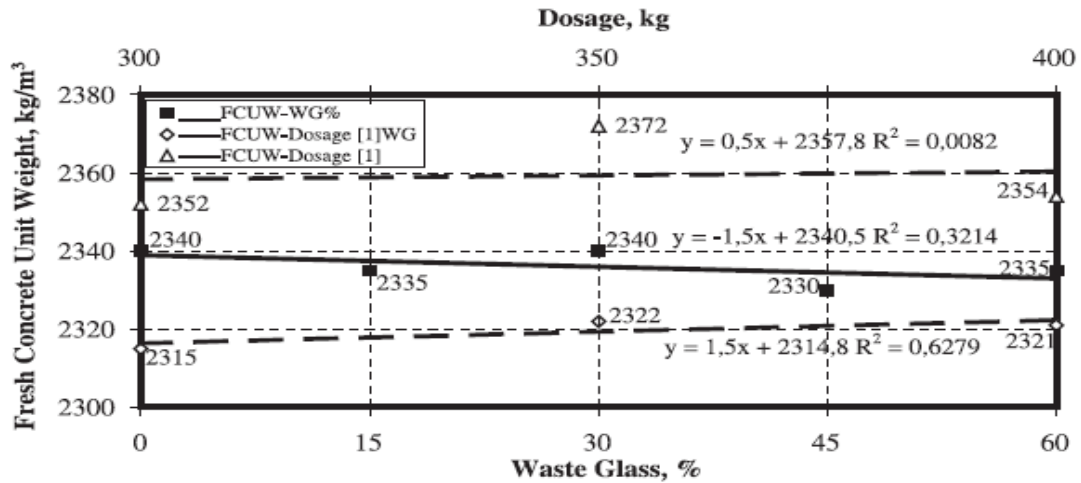


Fig. 5.1. Variation of FC unit weights with WG dosage. *Topç & Mehmet (2003)*

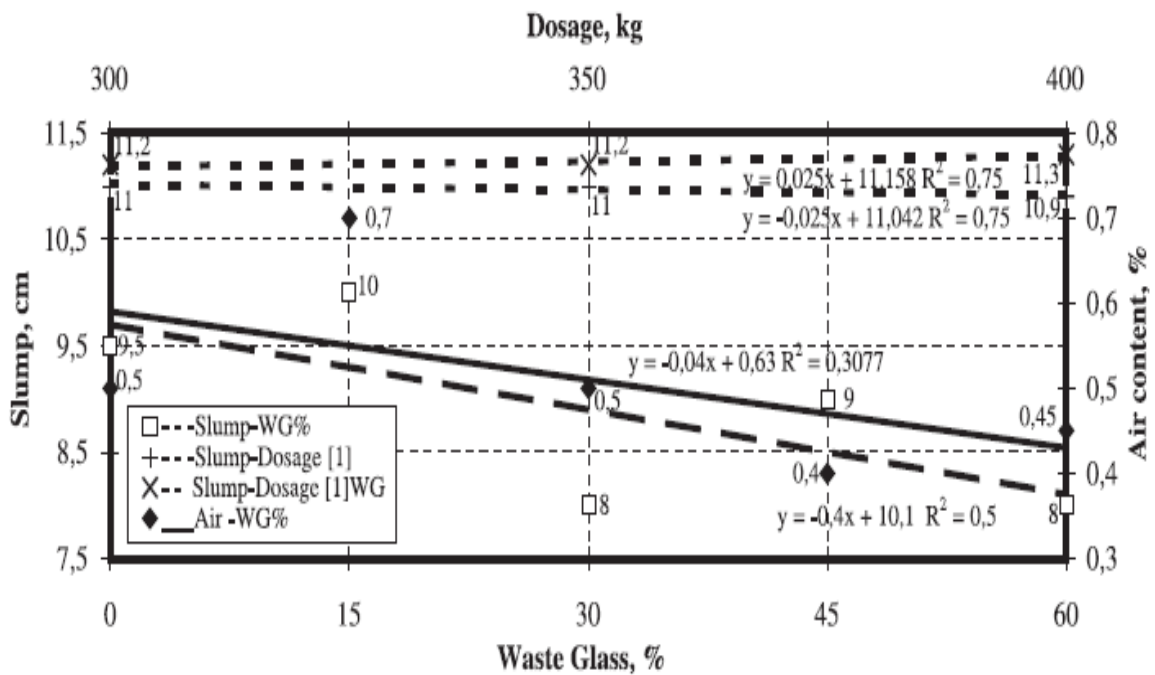


Fig. 5.2. Variation of slump and air content with WG dosage. *Topç & Mehmet (2003)*

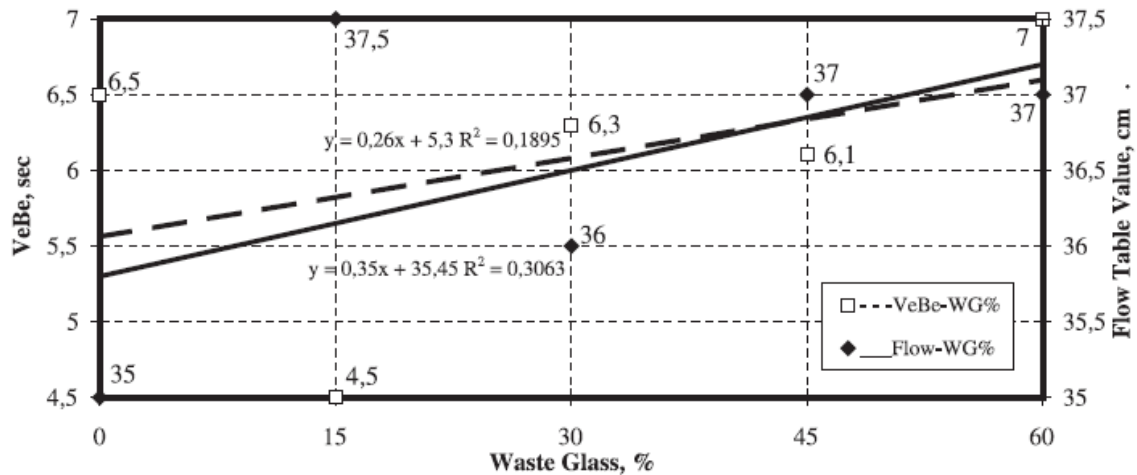


Fig. 5.3. Variation of VeBe and flow-table tests with WG content. Topç & Mehmet (2003)

Poon & Chan (2005), said the use of crushed waste glass as a coarse aggregate in concrete generally decreases the slump, the air content, water absorption and the density of fresh concrete.

5.3 Hardened concrete properties

5.3.1 Compressive strength

Kou & Poon (2008), investigated The effects of recycled glass (RG) cullet on fresh and hardened properties of self-compacting concrete A total of four SCC mixes were produced, and their detailed mix proportions are presented in [Table 5.1](#). These included one control mix, and three mixes made with RG to replace 10mm granite (at 5%, 10% and 15% levels), and river sand (at 10%, 20% and 30% levels), respectively. From each concrete mix, fifteen 100 mm cubes were cast for the determination of compressive strength. The compressive Denison compression machine with a loading capacity of 3000 kN. The loading rates applied for the compressive and tensile splitting tests were 200 kN/min and 57 kN/min, respectively. The compressive strength test was carried out at the ages of 1, 4, 7,28 and 90 days.

Table 5.1 Mix proportions of SCC (kg/m³)

Notation	OPC	PFA	20 mm	10 mm	Sand	10 mm Glass	Glass sand	Water	SP (l/m ³)	W/C
Control	375	125	422	400	860	0	0	185	8.5	0.37
G15	375	125	422	380	774	81	19	185	8.2	0.37
G30	375	125	422	360	688	162	38	185	8.0	0.37
G45	375	125	422	340	602	246	54	185	7.8	0.37

Poon & Chan (2007), used contaminated materials (tiles, clay bricks, glass, wood) commonly found in the construction and demolition waste.[29]

Table 5.2 Chemical composition of cement *Poon & Chan (2007)*

Properties	SiO ₂ (%)	Fe ₂ O ₃ (%)	Al ₂ O ₃ (%)	CaO (%)	MgO (%)	SO ₃ (%)	LOI (%)	Specific mass (g/cm ³)	Specific surface area (cm ² /g)
	19.61	3.32	7.33	63.15	2.54	2.13	2.97	3.16	3520



Fig. 5.4. Photographs of the recycled concrete aggregate and the contaminants: (a) recycled concrete aggregate, (b) crushed clay brick, (c) crushed tile, (d) crushed waste glass, and (e) wood chips. *Chi-Sun Poon (2005)*

The 28-day compressive strengths of the paving blocks with A/C ratios of 3 and 4 are shown in Fig. 5.5 and the corresponding relative strength is shown in Fig. 5.6. The presented value is the average of three measurements. Similarly, the control paving blocks had the highest 28-day strength in both Series I and II. For the mixtures with an A/C ratio of 3, the strengths of the contaminated paving blocks were between 71.5% and 82.3% of the control paving block. The 28-day strengths of the contaminated paving blocks without wood chips had relatively

uniform strengths ranging from 62.4 to 66.2 MPa or 77.5–82.3% of the control paving blocks. For the mixtures with an A/C ratio of 4, the strengths of the contaminated paving blocks were between 79.2% and 94.5% of the control paving blocks. As with the mixes prepared with wood chips significantly reduced the compressive strength of the paving blocks prepared with an A/C ratio of 4. Therefore, the compressive strengths at 28 days of mix 4B4G2T + W in both series were relatively lower than the compressive strengths of mix 4B4G2T in which the same amount of crushed brick, crushed tile and crushed waste glass were added

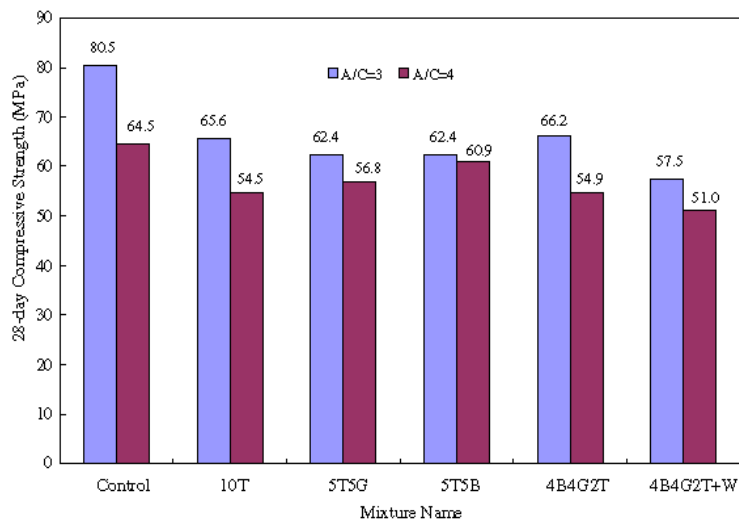


Fig. 5.5. 28-day strengths of the paving blocks in Series I and II.

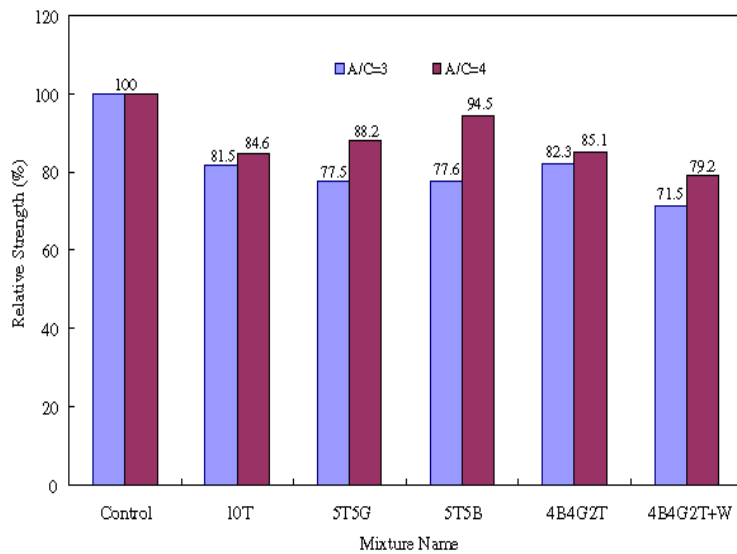


Fig. 5.6. Relative compressive strengths of the paving blocks at 28 days

Topc & Canbaz (2003), studied when waste glass (WG) is considered as coarse aggregates in the concrete, WG was used reduced to 4–16 mm in proportions of 0–60% in the production of PKC_/B 32.5/R type cement. Using PKC_/B 32.5R cement and WG of various proportions after curing for 28 days, produced concrete specimens. The test results for compressive strength, after cracking, as well as resonance frequency, ultrasonic velocity and Schmidt hardness are all presented in Fig. 5.7. The compressive strength of concrete specimen without WG, after being cured for 28 days, was 2.04–23.50 MPa. Compressive strength was observed to decrease, as the proportion of WG in concrete produced increased. In the case of using 15% addition of WG, there was a decrease of 8% in compressive strength. However, when this proportion increased to 60%, 49% of decrease in compressive strength was determined. The high brittleness of WG leading to cracks was determined to lead to incomplete adhesion between the WG and cement paste inter phase. In particular, the compressive strength decreased as much as 49% with a 60% of WG addition.

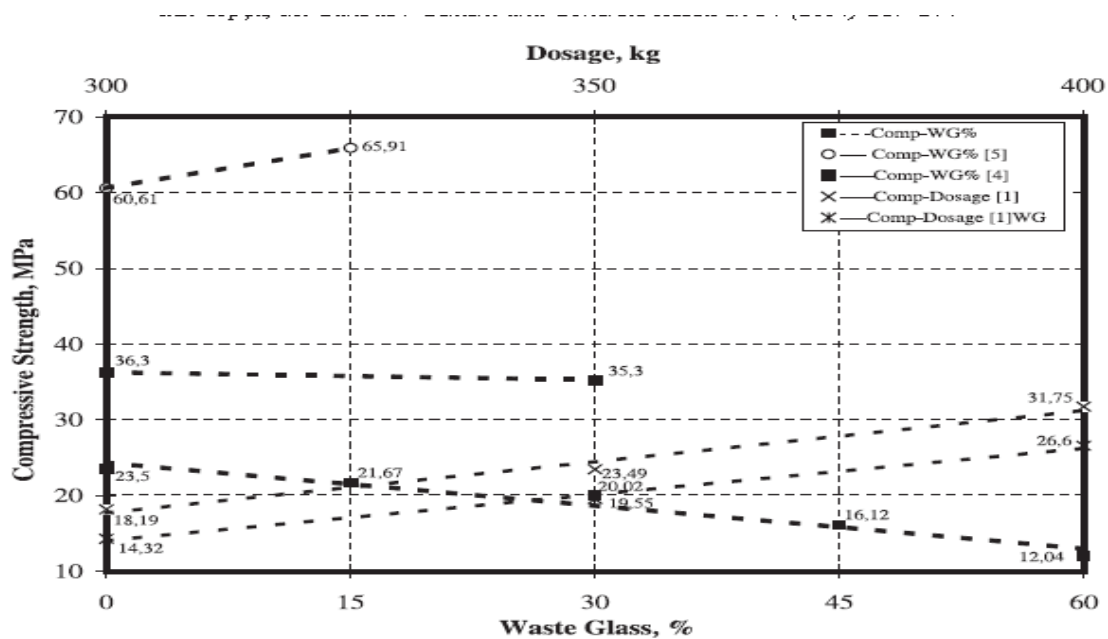


Fig 5.7 Variation of compressive strength with WG dosage *Topc & Canbaz (2003)*

Moulinier et al (2006), used Pfa part 1 fly ash, Metakaolin & Powdered glass & tested on 100 mm cubes. Compressive strength was measured on 100 mm cubes at 28 days age (Table 5.4). Compressive strength testing completed to date showed a range of values from 30.0 MPa (high alkali mix containing 30% powdered glass or pfa cement replacement) to 61.2

MPa (low alkali mix containing 15% metakaolin cement replacement). The mixes containing powdered glass or pfa were weaker than the Portland cement mixes.

Table 5.3 Overview of the eleven mixes *Moulinier et al. (2006)*

Mix n°	description	Alkalies Na ₂ O _{eq} (kg/m ³)	Cement replacement material	
			Material	% replacement
1	lower alkali mix	2.68	-	-
2	lower alkali mix	2.68	Pfa part 1 fly ash.	30
3	lower alkali mix	2.68	Metakaolin	15
4	Below threshold	4.84	-	-
5	Below Threshold	4.84	Powdered glass	30
6	On threshold	5.5	-	-
7	Above threshold	7.0	-	-
8	Above threshold	7.0	Powdered glass	30
9	Above threshold	7.0	Metakaolin	15
10	Above threshold	7.0	Pfa part 1 fly ash.	30
11	Above threshold	7.0	Ground granulated blastfurnace slag (ggbs)	50

Table 5.4 Compressive strength results at 28 days for the eleven mixes.

Mix n°	Na ₂ O _{eq} (kg/m ³)	Cement replacement material		Cube strength* (MPa)
		Material	% replacement	
1	2.68	-	-	46.3
2	2.68	Pfa	30	38.2
3	2.68	Metakaolin	15	61.2
4	4.84	-	-	41.3
5	4.84	Powdered glass	30	34.5
6	5.5	-	-	39.0
7	7.0	-	-	37.0
8	7.0	Powdered glass	30	30
9	7.0	Metakaolin	15	50
10	7.0	Pfa	30	31.7
11	7.0	ggbs	50	37.3

Byars et al. (2004), used two post-consumer cullet sources (from pub & club and bottle bank collection), washed and unwashed prior to grinding were tested for pozzolanicity in mortars. The results suggest that washing the post-consumer glass does not lead to a clear and significant increase in the compressive strength of concrete. Table 5.5 compares relative

strength of washed and unwashed glasses in mortars to BS EN 450 and it can be seen that the target strength activity index at 28 and 90 days (75% and 85% respectively) was significantly exceeded in all cases.

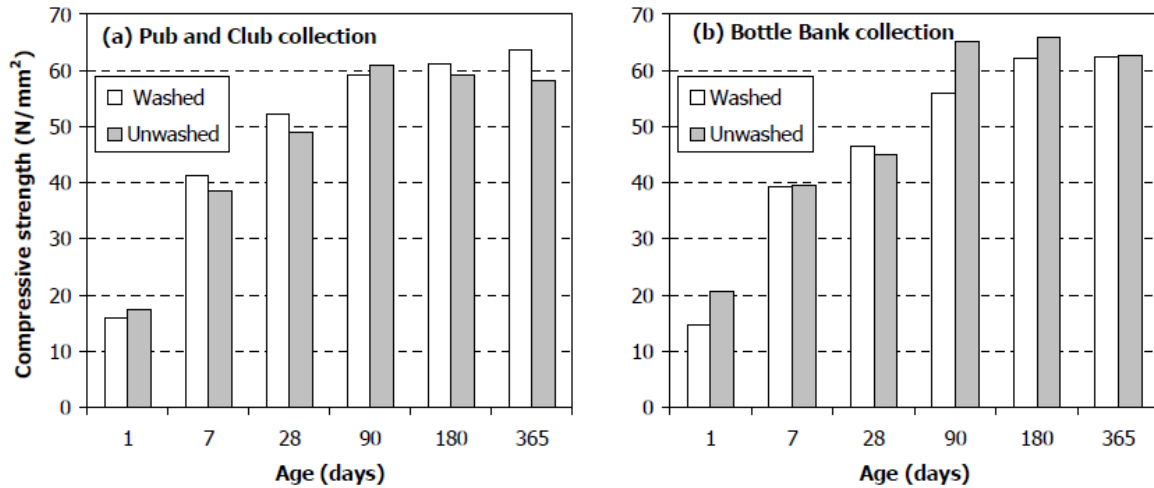


Figure 5.8. Compressive strength of mortar made with 25% glass pozzolan as cement replacement, from (a) Pub & Club collection and (b) Bottle Bank cullet (Byars *et al.*,(2004))

Table 5.5. Relative strength of mortar made with 25% washed and unwashed glass pozzolan from Pub & Club and Bottle-Bank collection cullet (Byars *et al.*,(2004))

SOURCE	PROCESS	SURFACE AREA (m ² /kg)	RELATIVE STRENGTH (%)			
			28 days	90 days	180 days	365 days
Pub & Club	Washed	787	91.6	95.2	92.2	100.0
	Unwashed	848	85.96	97.8	89.2	91.4
Bottle-Bank	Washed	798	81.8	90.0	93.5	98.1
	Unwashed	876	79.0	104.8	98.5	98.6

Tim Boniface(2006), used the Silica sand being replaced typically has a particle size of 150um and the recycled glass particle size used is 150um – 300um & tested on M90.

M90 Control Standards after 7 days

53.65 N / mm²

M90 Control Standards after 28 days

65.31 N / mm²

M90 Recycled Glass

54.34 N / mm²

M90 Recycled Glass

61.47 N / mm²

5.3.2 Tensile strength.

Topc & Canbaz (2003), studied when waste glass (WG) is considered as coarse aggregates in the concrete, WG was used reduced to 4–16 mm in proportions of 0–60% in the production of PKC_/B 32.5/R type cement. Using PKC_/B 32.5R cement and WG of various proportions after curing for 28 days, produced concrete specimens. The test results for tensile strength after cracking, as well as resonance frequency, ultrasonic velocity and Schmidt hardness are all presented in Fig 5.9. strength test results produced an indirect tensile strength of 1.63–2.59 MPa. WG addition decreased indirect tensile strength as much as 10%. Indirect tensile strength showed a decrease of 37% as a result of 60% of WG addition. When hardened concrete specimen properties were analyzed, indirect tensile strengths as well as Schmidt hardness values were determined to decrease in proportion to an increase in WG.

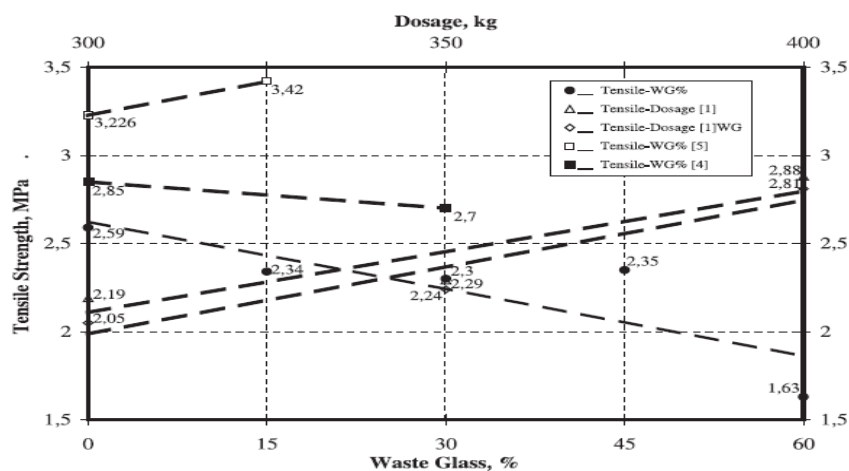


Fig 5.9 variation of tensile strength with WG dosage. (*Topc & Canbaz, (2003)*)

Poon & Chan (2007), carried out to determine the density, water absorption, 7-day and 28-day tensile splitting strength, skid resistance and abrasion resistance of the block specimens. The tensile splitting strength, water absorption, skid resistance and abrasion resistance were determined. The results were compared with the control paving blocks in which only recycled

concrete aggregate was used as the aggregate. A range of tests were carried out to determine the density, water absorption, 7-day and 28-day tensile, skid resistance and abrasion resistance of the block specimens. The tensile splitting strength was determined in accordance with BS 6717. The test was carried out along the longest splitting section (i.e., the length) of the block specimen. The tensile splitting strengths of the paving blocks with A/C ratios of 3 and 4 are shown in Fig. 5.10. The presented value is the average of two measurements. For the mixes with either A/C ratios of 3 or 4, the tensile splitting strength of mixes 10T and 5T5B were higher than that of the control. On the other hand, the tensile strength of the paving blocks in which crushed waste glass was used as one of the contaminations (mixtures 5T5G and 4B4G2T) was comparable to that of the control paving blocks. This is explained by the relatively poor bonding between the crushed waste glass and cement paste being compensated for by the beneficial effect from the good bonding between the crushed clay brick or crushed tile. Furthermore, the grading and particle density of the crushed waste glass used in this study were relatively coarser and higher compared to those of recycled concrete aggregate, and hence the overall volume of fine aggregates in the mixes was reduced.

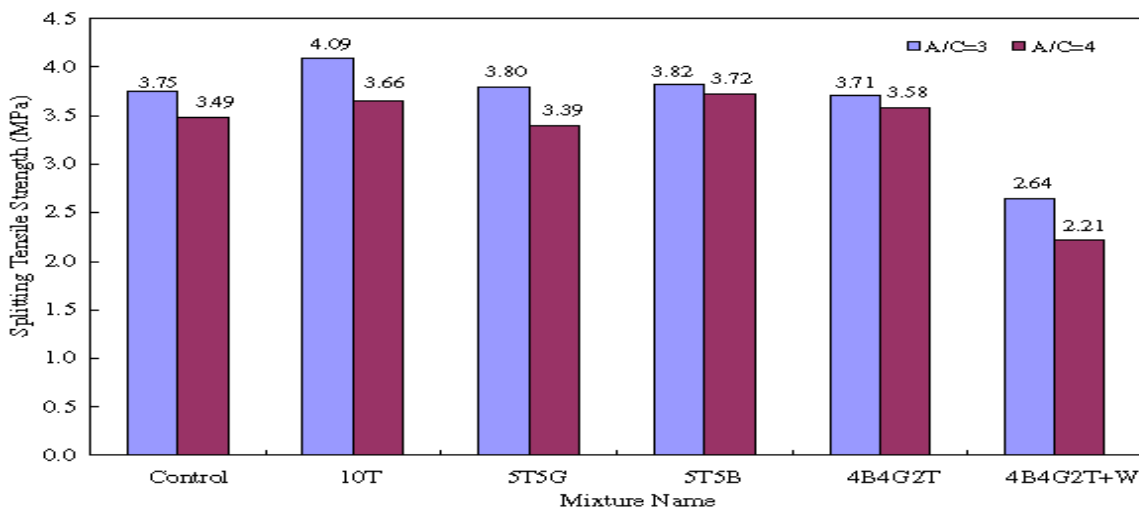


Fig. 5.10. Tensile splitting strengths of the paving blocks in Series I and II. (Poon & Chan, (2007))

Tim Boniface (2006) used the Silica sand being replaced typically has a particle size of 150um and the recycled glass particle size used is 150um – 300um & tested on M90.

M90 Control Standards after 7 days

4.22 N / mm²

M90 Control Standards after 28 days

4.22 N / mm²

M90 Recycled Glass

5.26 N / mm²

M90 Recycled Glass

5.50 N / mm²

5.3.3 Flexural strength

EA Byars et al (2004), used the concrete mixes as given in the table & was measured to BS 1881 BS EN 12390-5 [59] at 3, 7 and 28 days. It can be seen from the results, Figure 5.11, that in both cases glass fibres increased the flexural load-carrying capacity of concrete. However, the increase appears to be greater when OPC, rather than HAPC, is used.[31]

Table 5.6 Mix proportion for concrete specimens containing glass *EA Byars et al (2004)*

MIX	BINDER (kg/m ³)			WATER	W/B	AGGREGATE (kg/m ³)	
	OPC	PFA	FIBRE			FINE	COARSE
OPC/PFA	374.1	160.3	-	190	0.35	621.5	1015
OPC/PFA/FIBRE	374.1	160.3	32	190	0.35	621.5	1015
HAPC/PFA	374.1	160.3	-	190	0.35	621.5	1015
HAPC/PFA/FIBRE	374.1	160.3	32	190	0.35	621.5	1015

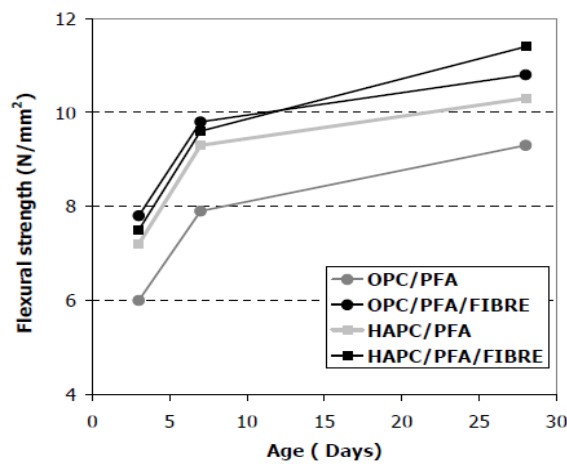


Figure 5.11. Influence of using glass fibres on flexural strength of concrete. *EA Byars et al (2004)*

5.4 Alkali silica reaction expansion

Saglik & Kocabeyler, used two types of aggregate samples, one having for about 20% and the other having more than 30% reactive silica, were prepared for the test conforming to the grading requirements of ASTM C 1260 standard. Mortar bar experiments carried out in compliance with ASTM C 1260 using both aggregates it has been proven that alkali – silica reaction is reduced to innocuous levels with the use of minimum 25% fly ash with crushed fine aggregate and 35% fly ash with naturally shaped fine aggregate.

The experiments are carried out also on the naturally shaped fine aggregate obtained from Givit source. This second sand includes a higher ratio of reactive silica in comparison with the crushed sand. The petrographic analysis results related with this aggregate are given in Table 2. In the mortar bar experiments performed using ASTM C 1260 standard, the gradation of fine aggregate has been adjusted as given in Table 5.7 here under.

Table 5.7 Aggregate gradation used in compliance with ASTM C 1260

Sieve size openings, mm		Mass, %
Passing the sieve	Retained on the sieve	
4.75 (No.4)	2.36 (No.8)	10
2.36 (No.8)	1.18 (No.16)	25
1.18 (No.16)	0.60 (No.30)	25
0.60 (No.30)	0.30 (No.50)	25
0.30 (No.50)	0.15 (No.100)	15

In the experiments, the alkali – silica reaction potential of cement – fly ash – aggregate combinations has been determined using ASTM C 1260 mortar bar method. The changes in length of the mortar bars has been measured at the end of 14th and 28th days as the result of mineral additive addition at different %s through substitution to Portland cement and assessment has been carried out in accordance with the criteria determined in ASTM C 1260 standard.

ASR can be prevented through the use of fly ash at a minimum ratio of 35%. But the harm that would be caused by ASR can be prevented with a minimum utilization ratio of 25% with

crushed sand. In the production of mass concrete, crushed stone fine aggregate shall be used. It is estimated that the fly ash utilization ratio will be around 30-35% in the mass concrete production, taking into account the other parameters.

But in order to examine the long – term effects, 180 – day results are also included in the experimental study schedule as indicated in ASTM C 227

Table 5.8 Length changes in % of the mortar bars prepared in compliance with ASTM C1260

Cement and fly ash at different %s	Length Change % s			
	Crushed fine aggregate		Naturally shaped fine aggregate	
	14th day	28th day	14th day	28th day
PÇ 42.5	0.115	0.122	0.157	0.169
PÇ + 20% FA	0.095	0.105	0.118	0.121
PÇ + 30% FA	0.081	0.088	0.096	0.102
PÇ + 40% FA	0.064	0.069	0.068	0.070
PÇ + 50% FA	0.048	0.055	0.049	0.050

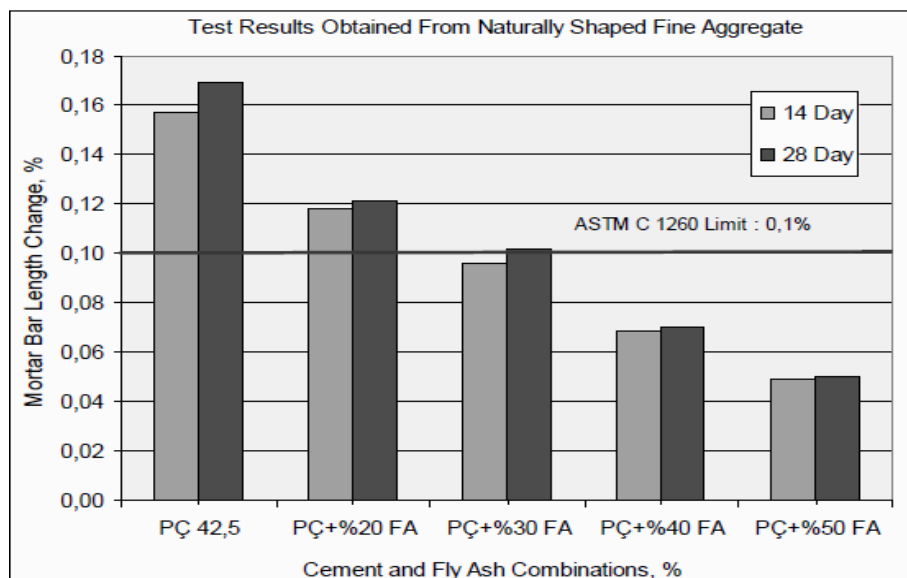


Figure 5.12. Comparison of length changes as measured from the mortar bars prepared with naturally shaped fine aggregate.

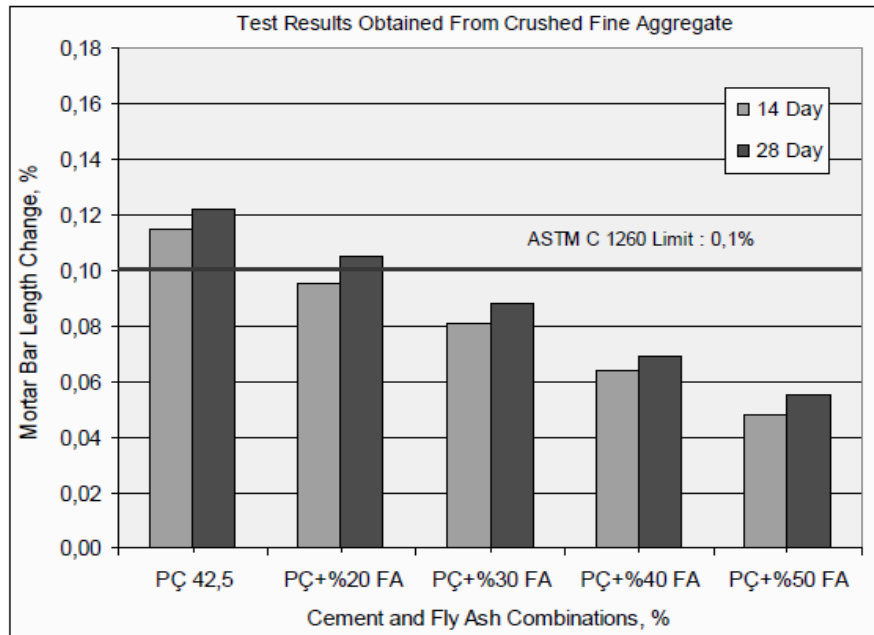


Figure 5.13 Comparison of length changes as measured from the mortar bars prepared with crushed fine aggregate.

Oliveira et al., examines the possibility of using finely ground waste glass of the three most common coloured glass bottles used in Portugal as partial cement replacement in mortar and concrete. Test method described in ASTM C 1260 was applied to verify the potential expansion caused by the alkali silica reaction. The waste glass used in this study was obtained at the waste management and disposal service of Cova da Beira Municipal Association, of interior region of Portugal. The chemical composition of the glass was analyzed using an X-ray microprobe analyzer and is listed in Table 5.9

Table 5.9 Chemical compositions of ground waste glass (by weight percent)

	Flint glass	Amber glass	Green glass
Na ₂ O	9.94	10.37	10.54
MgO	0.75	0.81	1.18
Al ₂ O ₃	2.57	3.09	2.54
SiO ₂	74.07	73.27	72.25
Cl ₂ O	-	-	-
K ₂ O	1.14	1.10	1.15
CaO	11.53	11.36	12.35
TiO ₂	-	-	-
Fe ₂ O ₃	-	-	-
SO ₃	-	-	-

The three types of colored glass have a similar percentage of reactive silica, around 74%. The mortar mixtures were produced with the weight ratio of 1: 3: 0.5 (binder: sand: water). The cementitious material consisted of Portland cement blended in laboratory with each of the three different colour waste glasses. Thus, Portland cement was partially replaced by 10%, 20%, 25%, 30% and 40% of each colour and size grinded ground waste glass.

Study of expansion due to the possible reaction between the alkali in cement and silica in the glass was done in accordance with ASTM C1260. Length bar readings were then taken every day for 14 days.

Figure 5.14 shows that mortar with 25% of cement replacement by the amber ground glass has the highest expansion of all samples tested. This high expansion value is due to the cement content in the mortar which, in turn, is higher than for other mortars prepared with amber ground glass powders.

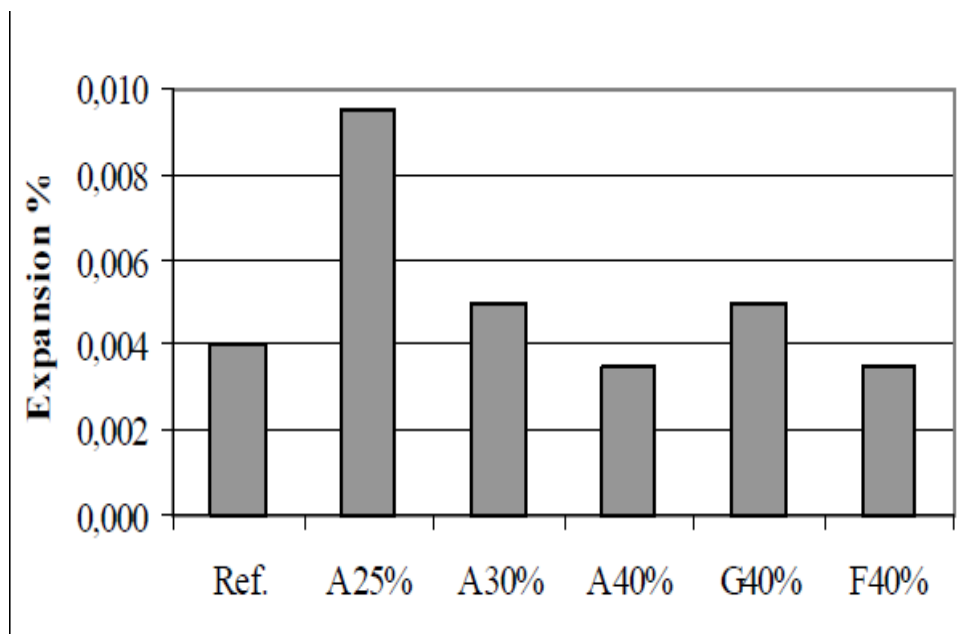


Figure 5.14 Expansion for mortar bars

Shayan & Xu (2002), included coarse glass aggregate, fine glass aggregate and GLP. The particle size range for each of these products is given below:

Product	Particle size range	Designation
Coarse glass aggregate	4.75–12 mm	CGA
Fine glass aggregate	0.15–4.75 mm	FGA
Glass powder	< 10 μm	GLP

The coarse and fine glass particles are used as replacement for the corresponding size ranges of natural aggregate materials, whereas the GLP has been studied as a pozzolanic material, i.e., the same application as for SF or fly ash.

The nature of the glass reactivity has important implications in its utilisation in concrete. The reactivity of aggregate is assessed by AMBT, conducted in 1-M NaOH at 80°C, according to ASTM C1260 or an Australian method RTA T363 (RTA, NSW Specification B80, Test Method T363). The AMBT results obtained at ARRB have shown that the larger the content of glass in mortar bars, the higher the expansion. Fig. 5.15 illustrates this effect. The criteria for this test, according to the RTA Test Method T363, are that expansion values smaller than 0.10% at the age of 21 days are associated with nonreactive aggregate (< 0.15% for sand) and expansions greater than 0.10% at 10 days are associated with reactive aggregates. Expansions smaller than 0.10% at 10 days but exceeding 0.10% at 21 days indicate slowly reactive aggregate.

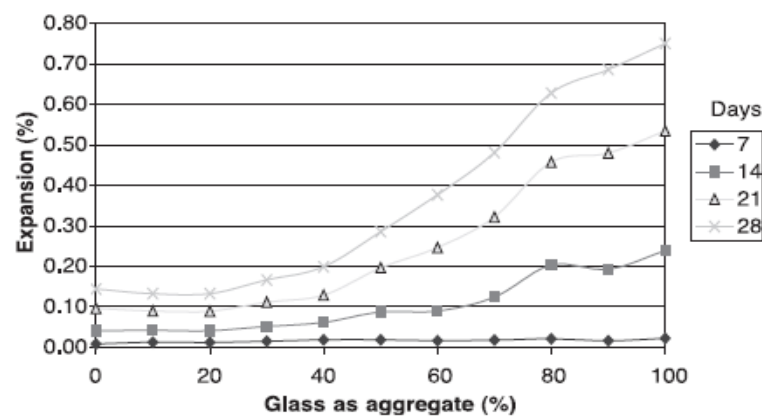


Fig. 5.15 Expansion as a function of glass content of mortar bars for different ages of storage under the AMBT conditions.

Based on these criteria, Fig. 5.15 indicates that use of up to 30% glass in the concrete may not cause deleterious effects, particularly if the alkali content of the concrete is low (below 3-kg Na₂O equivalent per cubic meter). At higher alkali contents of concrete, further expansion may result. In addition to the glass content of mortar bars, the particle size also has an effect on the expansion.

This is illustrated in Fig. 5.16 for four particle size ranges, including powder (< 10 Am), very fine sand (0.15–0.30 mm) and two coarser sand fractions. The results shown in Fig. 5.16 indicate that glass particle sizes below 0.30 mm would not cause deleterious expansions whereas fractions above 0.60 mm would cause significant deleterious expansions.

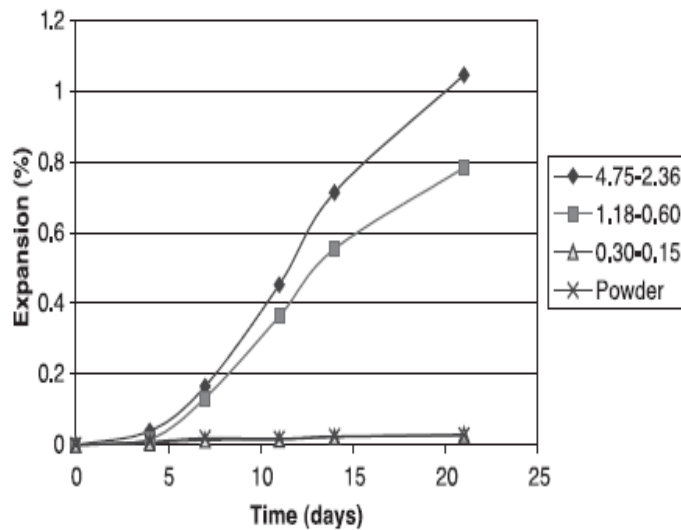


Fig. 5.16 Expansion curves for mortar bars containing different glass particle sizes.

Park & Lee (2003), showed that green waste glass was more usable than brown because its expansion was less than that of brown glass. [Table 5.10](#) reveals the chemical composition of these waste glasses. Steel or polypropylene (PP) reinforcing fiber was used to suppress the ASR expansion. The mix proportions were selected to evaluate the ASR expansion and strength characteristics of mortar containing colored waste glasses, as well as those used when reinforcing fiber, with the following parameters: (1) color of the waste glasses (green or brown); (2) content of the waste glasses [WG/(WG+S)]: 10, 20, 30, 50 or 100 wt.%); (3) type of reinforcing fibers (steel or PP); and (4) content of the fibers (steel: 0.5–1.5 vol.%, PP: 0.1–0.5 vol.%).

Table 5.10 Chemical and physical properties of waste glass

Properties		Type	
		Green glass	Brown glass
Chemical composition	SiO ₂ (%)	71.3	72.1
	Al ₂ O ₃ (%)	2.18	1.74
	Na ₂ O+K ₂ O(%)	13.07	14.11
	CaO+MgO(%)	12.18	11.52
	SO ₃ (%)	0.053	0.13
	Fe ₂ O ₃ (%)	0.596	0.31
	Cr ₂ O ₃ (%)	0.44	0.01
Physical properties	Specific gravity	2.50	2.52
	Water absorption(%)	0.41	0.40

This test was conducted in accordance with ASTM C 1260 to check the recyclability of the waste glasses and to evaluate their influence on the ASR. Three mortar specimens were made for each mixing with W/C 0.47 and S/C 2.25. Changes in the length of the mortar bars were checked for the next 14 days after their surface was dried by using a comparator, a length comparison measuring device with accuracy less than 0.002 mm.

The expansion–time history curve made by the measurements complying with ASTM C 1260 in terms of the colours of waste glasses (green or brown) and their contents (0– 100%) are shown in Figs. 5.17 and 5.18

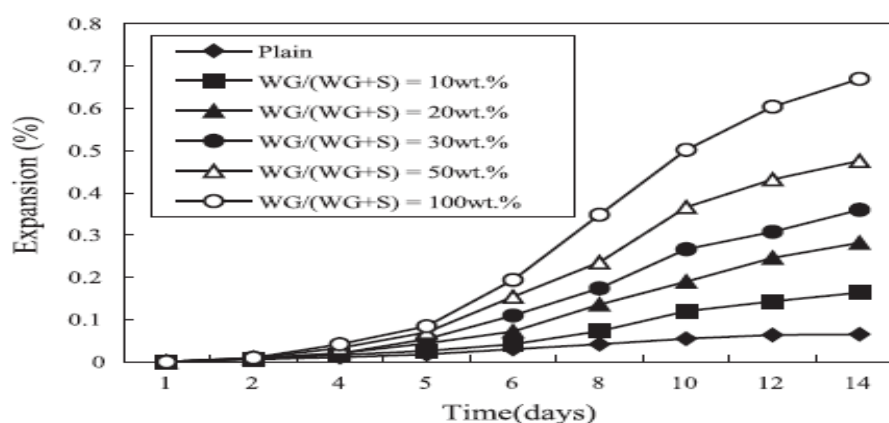


Fig 5.17 Expansion time histories for mortar bars (brown glass)

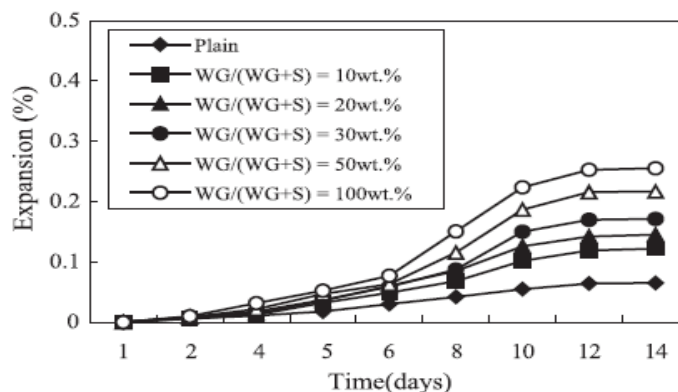


Fig. 5.18 Expansion time histories for mortar bars (green glass)

Mortar bars with waste glasses mixed in display a relatively higher expansion rate than plain bars with no waste glasses. Mortar bars containing brown waste glass showed higher expansion rates than bars containing green waste glass. expansion rate of 0.2% as required by ASTM C 1260, while the bars containing green waste glass showed an expansion rate within 0.2% up to 30% of its content.

Shi et al. (2004), deals with the morphology, fineness and pozzolanic activity of four glass powders: one (GP-fine) from the screening of crushed waste glasses, one (GP-dust) from a dust collector for the glass crushing process and two (GP-4000 and GP-6000) from further grinding of the powder from the dust collector in a ball mill. The effect of ground glass powder and fly ash on AAR expansion was evaluated by following ASTM C1260—an accelerated mortar bar method. Three 25x25x275-mm mortar bars were cast for each batch. The mortar mixtures had an aggregate-to cementitious material ratio of 2.25 and a water-to-cementitious material ratio of 0.47.

Note that the replacement of Portland cement with 20% glass powder or Class F fly ash significantly reduced expansion. The control batch exhibited an expansion of 0.50% at 14 days. The replacement of cement with 20% GP-4000 reduced the expansion to around 0.20%, which is considered to be the upper limit of expansion for “potentially reactive” aggregate, whereas the replacement of cement with 20% fly ash decreased the expansion to less than 0.2% at 14 days. It is obvious that use of the fly ash is more effective in reducing the AAR expansion than GP- 4000. Results have indicated 20% replacement of cement with coal fly ash is usually not enough to control deleterious expansion with reactive aggregate, but a minimum of 30% Class F fly ash is generally required. Detailed laboratory studies have confirmed that a minimum of 50% cement replacement with GP4000 is required to control deleterious expansion of mortars with reactive aggregates.

CHAPTER 6

EXPERIMENTAL PROGRAMME

6.1. GENERAL

The aim of the experimental program is to compare the properties of concrete made with and without plastics, used as coarse aggregates and glass as cement replacement. The basic tests carried out on concrete samples are discussed in this chapter, followed by a brief description about mix design and curing procedure adopted. At the end, the various tests conducted on the specimens are discussed.

6.2. MATERIAL USED

6.2.1. Cement

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. Basic composition of cement are shown in [Table 6.1](#).

Table 6.1 Composition limits of Portland cement

INGREDIENT	% CONTENT
CaO(Lime)	60-67
SiO ₂ (Silica)	17-25
Al ₂ O ₃ (Alumina)	3-8
Fe ₂ O ₃ (Iron Oxide)	0.5-6
MgO(Magnesia)	0.1-4
Alkalies	0.4-1.3
Sulphur	1-3

Grade 43 Ultra Tech cement was used for casting cubes and cylinders for all concrete mixes. The cement was of uniform colour i.e. grey with a light greenish shade and was free from any hard lumps. Summary of the various tests conducted on cement are as under given below in [Table 6.2](#)

Table 6.2: Physical Properties of Cement

S.No.	Characteristics	Values obtained	Standard values
1.	Normal Consistency	33%	-
2.	Initial Setting time	48 min	Not be less than 30 minutes
3.	Final Setting time	240 min	Not be greater than 600 minutes
4.	Fineness	4.8 %	<10
5.	Specific gravity	3.09	-
<i>Compressive strength:- Cement : Sand (1:3)</i>			
1.	3 days	24.5 N/mm ²	27 N/mm ²
2.	7 days	38 N/mm ²	41 N/mm ²
3.	28 days	45 N/mm ²	43 N/mm ²

6.2.2. Fine Aggregates

The sand used for the experimental programme was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. Properties of the fine aggregate used in the experimental work are tabulated in [Table 6.3](#). The aggregates were sieved through a set of sieves to obtain sieve analysis and the same is presented in [Table 6.4](#). The fine aggregated belonged to grading zone III.

Table 6.3: Physical Properties of fine aggregates

Sr. No.	Characteristics	Value
1.	Specific gravity	2.46
2.	Bulk density	1.4
3.	Fineness modulus	2.56
4.	Water absorption	0.85
5.	Grading Zone (Based on percentage passing 0.60 mm)	Zone III

Table 6.4 Sieve analysis of fine aggregate

Sr. No.	Sieve Size	Mass retained	Percentage Retained	Cumulative Percentage Retained	Percent Passing
1	4.75mm	4.0	0.4	0.4	99.6
2	2.36 mm	75.0	7.50	7.90	92.1
3	1.18 mm	178.0	17.8	25.70	74.3
4	600µm	220.0	22.0	47.70	52.3
5	300µm	274.0	27.4	75.10	24.9
6	150µm	246.5	24.65	99.75	0.25
7	2.50	0.25	0.25	$\Sigma=256.55$	

Total weight taken = 1000gm

Fineness Modulus of sand = 2.56

6.2.3 Coarse aggregate

The material which is retained on IS sieve no. 4.75 is termed as a coarse aggregate. The crushed stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 10 mm was used in our work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383-

1970. The results of various tests conducted on coarse aggregate are given in Table 6.5 and Table 6.6 shows the sieve analysis results.

Table 6.5 Physical Properties of Coarse Aggregates (10 mm)

Sr. No	Characteristics	Value
1	Type	Crushed
2	Specific Gravity	2.66
3	Total Water Absorption	0.56
4	Fineness Modulus	6.83

Table 6.6 Sieve Analysis of Coarse Arregates (10mm)

Sr. No.	Sieve Size	Mass Retained (gm)	Percentage Retained	Cummulative Percentage Retained	Percent Passing
1	20 mm	0	0	0	100
2	10 mm	2516	83.89	83.87	16.13
3	4.75 mm	474	15.8	99.67	0.33
4	PAN	10	0.33	$\Sigma = 183.54$	

Total weight taken = 3Kg

FM of 10 mm Coarse aggregate = $\frac{183.54}{500} = 6.83$

100

6.2.4 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life also usually is suitable. When water is obtained from sources mentioned above, no sampling is necessary. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided since the quality of the water could change due to low water or by intermittent

discharge of harmful wastes into the stream. In the present experimental programme, potable tap water is used for casting.

6.2.5 Plastics Aggregates

Recycled plastic was used to replace coarse aggregates for making concrete specimens.

Specific gravity of plastic aggregates = 1.1

Size of plastic aggregates = 10 mm

6.2.6 Waste Glass

Waste Glass is used in the experiments was that of coloured soda bottles, which is a type of print silk WG. Following the gathering process, these bottles were kept in water so that the labels on them was removed, and were then reduced to as fine as $< 90\mu\text{m}$. The 2.6 specific gravity of the glass is obtained by performing test in the laboratory. The Waste Glass powder used in place of cement. The chemical composition of the glass is given in table 6.7

Table 6.7 Chemical characteristics of glass powder

Oxide	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O
Percentage by mass	73,99	1,02	0,18	8,56	3,33	12,55	0,24

6.3 MIXTURE PROPORTIONING

The tests are carried out at a constant water-cement ratio 0.5. The control mix is designed with the Indian Standard Codal guidelines. For making the mixes containing plastics, the amount of plastics is calculated by using the specific gravity of plastics in place of the specific gravity of coarse aggregates & by using the specific gravity of glass, in place of the specific gravity of cement. The resultant mix proportions of all the mixes are tabulated in [Table. 6.8](#)

Table 6.8 Various mix proportions

S.No.	W/C Ratio	Water Kg/m³	Cement Kg/m³	Glass powder kg/m³	Fine Aggregates Kg/m³	Coarse Aggregates Kg/m³	Plastics Kg/m³	Mix Proportions
MP0MG0	0.50	191.6	383.2	-	570.39	1184.79	-	1:1.4:3.0
MP0MG1	0.50	191.6	306.56	76.64	566.88	1177.36	-	1:1.4:3.0
MP0MG2	0.50	191.6	229.92	153.28	563.07	1169.80	-	1:1.4:3.0
MP0MG3	0.50	191.6	153.28	229.19	559.02	1161.06	-	1:1.4:3.0
MP0MG4	0.50	191.6	76.64	306.56	554.67	1152.13	-	1:1.4:3.0
MP1MG0	0.50	191.6	383.2	-	570.39	947.83	97.99	1:1.4:2.4
MP2MG0	0.50	191.6	383.2	-	570.39	829.35	146.98	1:1.4:2.1
MP3MG0	0.50	191.6	383.2	-	570.39	710.87	195.98	1:1.4:1.8
MP4MG0	0.50	191.6	383.2	-	570.39	592.39	244.97	1:1.4:1.5
MP1MG1	0.50	191.6	306.56	76.64	566.88	941.88	97.38	1:1.4:2.4
MP2MG1	0.50	191.6	306.56	76.64	566.88	824.15	146.07	1:1.4:2.1
MP3MG1	0.50	191.6	306.56	76.64	566.88	706.41	194.77	1:1.4:1.8
MP4MG1	0.50	191.6	306.56	76.64	566.88	588.68	243.45	1:1.4:1.5
MP1MG2	0.50	191.6	229.92	153.28	563.07	935.68	96.72	1:1.4:2.4
MP2MG2	0.50	191.6	229.92	153.28	563.07	818.72	145.08	1:1.4:2.1
MP3MG2	0.50	191.6	229.92	153.28	563.07	701.76	193.44	1:1.4:1.8
MP4MG2	0.50	191.6	229.92	153.28	563.07	584.8	241.8	1:1.4:1.5
MP1MG3	0.50	191.6	153.28	229.92	559.02	928.84	98.64	1:1.4:2.4
MP2MG3	0.50	191.6	153.28	229.92	559.02	812.74	147.96	1:1.4:2.1
MP3MG3	0.50	191.6	153.28	229.92	559.02	696.63	197.28	1:1.4:1.8
MP4MG3	0.50	191.6	153.28	229.92	559.02	580.53	246.61	1:1.4:1.5
MP1MG4	0.50	191.6	76.64	306.56	554.67	921.75	95.28	1:1.4:2.4
MP2MG4	0.50	191.6	76.64	306.56	554.67	806.53	142.92	1:1.4:2.1
MP3MG4	0.50	191.6	76.64	306.56	554.67	691.31	190.56	1:1.4:1.8
MP4MG4	0.50	191.6	76.64	306.56	554.67	576.09	238.20	1:1.4:1.5

6.4 CASTING AND CURING

6.4.1 Casting for compressive strength and split tensile strength tests

For casting, all the moulds were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage of slurry. Careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. The concrete mixture was prepared by hand mixing on a non-absorbing platform. On the non-absorbing platform, the coarse and fine aggregates were mixed thoroughly. To this mixture, the cement was added. These were mixed to uniform colour. Then water was added carefully so that no water was lost during mixing. Clean and oiled moulds for each category were then placed on the vibrating table respectively and filled in three layers. Vibrations were stopped as soon as the cement slurry appeared on the top surface of the mould. For each mix 9 samples were prepared, which consists of 6 cubes for 7 and 28 days compressive strength and 3 cylinders for split tensile strength at 28 days. On the specimens prepared for 28 days compressive strength, firstly non-destructive ISAT was conducted.

The specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition. After that these were demoulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing. The ambient temperature $27^{\circ} \pm 2^{\circ}\text{C}$ was the room temperature during casting. After de-moulding the specimen by loosening the screws of the steel moulds, the cubes and cylinders were allowed to dry for one day before placing them in the temperature controlled curing tank for a period of 28 days

6.4.2 A.S.R. expansion bar mould

In this the specimen of size $25 \times 25 \times 275$ mm effective gauge length are prepared and are accurately machined faced. The sides of the mould are rigid enough to prevent spreading or wrapping. Each end plate of the mould is equipped to hold properly in place during the setting period of the stainless steel reference points.

Moulds with multiple compartments assembled on a single base plate have the advantage of casting two or four specimens of the same combinations enabling their relative study.

The reference points are either smooth or knurled and threaded, and are of stainless steel & extent into the specimen by 16 mm.



Fig. 6.1 A.S.R. expansion bar mould

6.5 Tests Conducted

The following tests were conducted on the specimens prepared.

6.5.1 Compressive strength test

Cubical specimens of size 150 mm were cast for conducting compressive strength test for each mix. The compressive strength test was carried out as per IS: 516-1979. This test was carried at the end of 7 and 28 days of curing. The compressive strength of any mix was taken as the average of strength of three cubes.

6.5.2 Split tensile strength test

For this, cylindrical specimens of size 150 mm dia × 300 mm height were cast. The test was conducted at the end of 28 days of curing and the average of three samples was taken as the representative split tensile strength of the mix.

6.5.3 Initial Surface Absorption Test

The test for initial surface absorption of concrete is a simple test to obtain data to indicate the water flow into the surface of a dry, flat concrete surface. The test is time dependant and comparative to indicate the quality of concrete to resist absorption of water. The principle of test is to determine the time taken for a quantity of water to flow through a calibrated glass tube onto a known area of concrete surface. A limitation of test is the viscosity of water that may affect the rate of flow through the tube when considering very porous concrete, resulting in high flow rate. Initial surface absorption of samples is comparable where the samples have been oven dried. Under site conditions the existing moisture level in the concrete restricts the absorption under test.

The ISAT test as specified in BS 1881 Part 5 was originally developed as a laboratory method of measuring the porosity of concrete. The test consists of the measurement of water flow into the test specimen through a known surface area. The contact area is defined by a plastic cell sealed onto the surface, as shown in Fig 6.2 and Fig 6.3. The cell is manufactured from clear acrylic to allow observation of the water level and ensure the complete renewal of air. A clear reservoir is connected to the 'inlet' of the cell. The 'outlet' of the cell is connected to a capillary tube with an affixed scale. A valve is fitted to the inlet side to isolate the reservoir. The cell is clamped to the test surface so as to ensure an even pressure and good seal around the perimeter

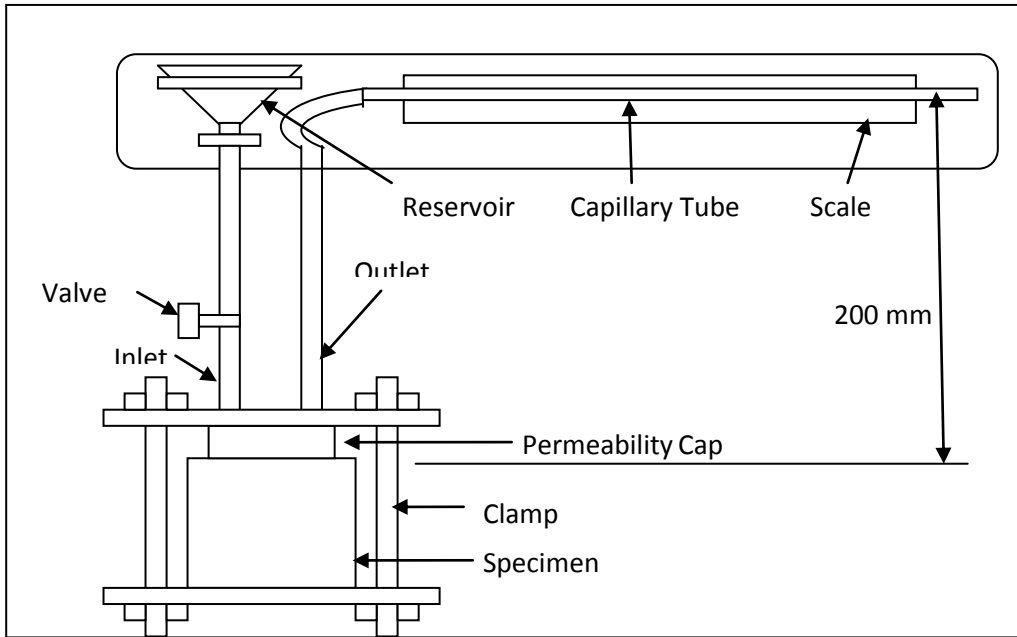


Fig 6.2: The general arrangement for ISAT



Fig. 6.3 The Set up for ISAT

If necessary the seal is improved with silicone sealant, 'Plasticine' or 'Blu-tack'. The capillary tube and reservoir are mounted 200mm above the cell. After filling the cell completely the reservoir is closed off and measurements taken of flow along the capillary tube. Sets of readings are taken at 10, 30, 60 and 120 minutes after the first wetting of the surface. For each set of readings the reservoir is closed off and the time taken for the meniscus to move back 90 divisions is recorded. The observation on the scale is marked to indicate rate of flow of water into the concrete at the rate of $0.01 \text{ ml/m}^2/\text{s}$ based on a test time of one minute. Therefore, to obtain the flow, f (in $\text{ml/m}^2/\text{s}$), from the data obtained we calculate:

$$f = 60 \times D \times 0.01/t$$

where: t = test point time in seconds

D = no of scale divisions during the period t

6.5.4 Alkali silica reaction test

Alkali silica reaction (ASR) is the reaction between the alkali hydroxide in Portland cement and certain siliceous rocks and minerals present in the aggregates, such as opal, chert, chalcedony, tridymite, cristobalite, strained quartz, etc. The products of this detrimental reaction often result in significant concrete expansion and cracking, and ultimately failure of the concrete structure.

The alkali – silica reaction occurring in concrete is a chemical phenomenon taking place between the alkalis in the cement and the aggregates including some reactive siliceous minerals. The product created as the result of the reaction – alkali – silica gel accumulates in the pores in concrete or on surface of the aggregate particles. Thereafter the water penetrating the concrete inside continues the reaction and the gel expands, as a result of this the concrete begins to crack being subject to internal tensions. The formation of cracks result in a more permeable concrete and makes it subject to harmful environmental effects.

Standard ASTM methods

The methods for determining the alkali silica reaction test are as follows:

ASTM Standard Test Methods for Potential Alkali- Silica Reactivity of Aggregate

ASTM C 289 - Chemical Method

ASTM C 227 – Mortar-Bar Method

ASTM C 1260 – Accelerated Mortar Bar Method

From the above mentioned tests we have performed on ASTM 1260 because it is a fast method to get an idea of ASR

ASTM C 1260 – *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar Bar Method)*, or more generically, the accelerated mortar bar test, has been intensively used all around the world under different codes which involve slight modifications. The test is based on the South African NBRI method proposed by Davis and Oberholster (1986). It has been very popular since it is relatively quick and easy to perform. The method requires the periodic length measurement of 25×25×275-mm mortar bars which are immersed in 1 N NaOH solution at 80°C. The length change, or expansion, after 14 days immersion (16 days since casting) is taken as the indication of potential reactivity. ASTM C1260 considers expansion of > 0.20% as reactive and < 0.10 as innocuous; expansion between 0.10% and 0.20% is inconclusive and requires additional testing.

ASR Testing – ASTM C 1260

Mortar bars were prepared using the available reactive aggregates and the laboratory produced cements. The bars were produced and tested in accordance with ASTM C 1260:

- The mortar was mixed in accordance with ASTM C 305 – *Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency*.
- The bars were cast in steel moulds
- The bars were demolded after 24 hours and cured for another 24 hours in water at 80°C.

- Initial reading was taken after demolding and zero reading was taken at the end of 24- hour hot water curing. Then the bars were transferred into 1 N NaOH solution. A 0.5 N solution was also used for the sample storage.
- The mortar bars were stored in air- and water-tight polypropylene containers in a laboratory-type oven.
- The length change of the bars was recorded periodically up 14, 28 days as recommended by the standard. The comparator used for the measurements of length as shown in fig.6.4.

Aggregate for ASTM C 1260

In the mortar bar experiments performed using ASTM C 1260 standard, the gradation of fine aggregate has been adjusted as given in Table 6.9

Table 6.9 Aggregate gradation used in compliance with ASTM C 1260

Sieve size openings, mm		Mass, %
Passing the sieve	Retained on the sieve	
4.75 (No.4)	2.36 (No.8)	10
2.36 (No.8)	1.18 (No.16)	25
1.18 (No.16)	0.60 (No.30)	25
0.60 (No.30)	0.30 (No.50)	25
0.30 (No.50)	0.15 (No.100)	15

6.5.4.1 Length Comparator

Introduction

The equipment meets the requirements of IS: 4031 and IS: 9459 and is used to measure the drying shrinkage of concrete, autoclave expansion of Portland Cement, potential expansive alkali reactivity of cement aggregate combination in mortar bars during storage. It is intended

for use with standard sizes of casted specimens with cross section varying from 25mm x 25mm to 10mm x 10mm and of gauge length 250mm. The length comparator bears ISI certification mark IS: 9459.

Description

The equipment is illustrated in the General Assembly Drawing attached. The numbers given against the components in the description below pertain to this General Assembly Drawing.

It consists of a channelled base (1) over which two vertical pillars (4) are fixed. A cross plate (5) moves up and down at the top. This plate can be locked in any desired position with the nuts. At the center of the top cross plate there is a threaded hole. A bolt with washers is screwed into it.

The dial gauge (6) 0.002mm x 12mm can be fixed to the cross plate. The plunger of the dial gauge can be located upon a 6.5mm diameter ball or other reference point cemented in the specimen. On the channelled base there is a similar recessed seating (2) in which can be channelled base. A stainless steel standardization bar (3) with 6.5mm diameter steel balls mounted at the ends is supplied. This is used as a standard of length against which the readings of the gauge can be tested, thus enabling corrections to be made for any changes in the dimensions of the apparatus between successive measurements of a test specimen.

Setting up

Mount the length comparator frames on a firm level surface. Check whether the top cross piece is parallel to the base. Adjust it if necessary and lock in place using the lock nut. Fix the dial gauge from the underside of the cross piece. See that the plunger of the dial gauge is pushed in half way when the standardization bar is mounted as this will leave sufficient margin for measurement of the test specimen. For this purpose readjust the cross piece if such adjustment is required. Remove ball end of the dial gauge plug plunger and keep it in case. Fix the ball, end when test is over.

Operation

Raise the dial gauge plunger and then place the standardization bar with one ball end seated on the lower recessed seat. Lower the plunger of the dial gauge gently on to the top ball of the standardization bar. The bar will now stay in place. Note the dial gauge reading (R1). Remove the bar and using the same procedure as above, place the test sample in its place. Note the dial gauge reading (R2). The difference between R1 and R2 gives the difference in lengths between the test sample and the length marked on the standardization bar.



Fig 6.4 Length Comparator for measuring length

CHAPTER 7

RESULTS AND DISCUSSIONS

7.1 GENERAL

In this chapter the parameters studied on the control and concrete made with replacement of glass with cement and plastic replacement as coarse aggregate in concrete are discussed. The parameters such as unit weight, compressive strength, splitting tensile strength and Alkali silica reaction test are discussed and comparison between the various mixes are represented in the following sections.

7.2 UNIT WEIGHT

The unit weight is measured for the cubes taken from the curing tank, just prior to compressive strength test. The values obtained for the control mixes and mixes with various percentages are presented in this section. For the accuracy of the results the minimum three samples of the control concrete and three samples of plastic replaced concrete were casted and tested and average of three are taken for the accuracy of results. The results of unit weight of combination of glass and plastic mixes replaced concrete are shown in Table 7.1. In order to observe the effect of additive plastic and glass separately, Fig. 7.1 and Fig. 7.2 are prepared showing effect of increase of glass and plastic respectively. It is found from the testing that there is considerable decrease in unit weight of concrete made either with glass as a replacement of cement and plastic as a coarse aggregate concrete. It is found that the glass and plastics replaced with concrete reduces the unit weight of concrete and can be used as light weight concrete. This reduction in unit weight is due to the lower density of plastics and glass as compared to the density of coarse aggregates. The similar observation was made by *Ismail and Al-Hasmi (2007)* in their research work.

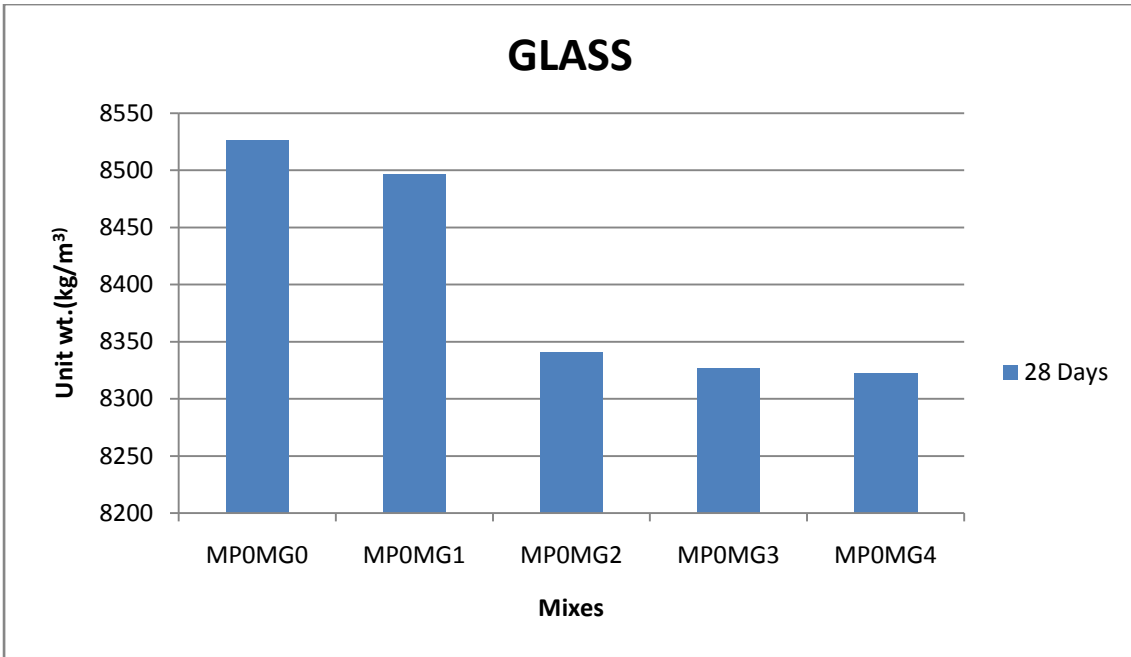


Fig 7.1 Unit weight of concrete made with different percentage of glass as cement replacement.

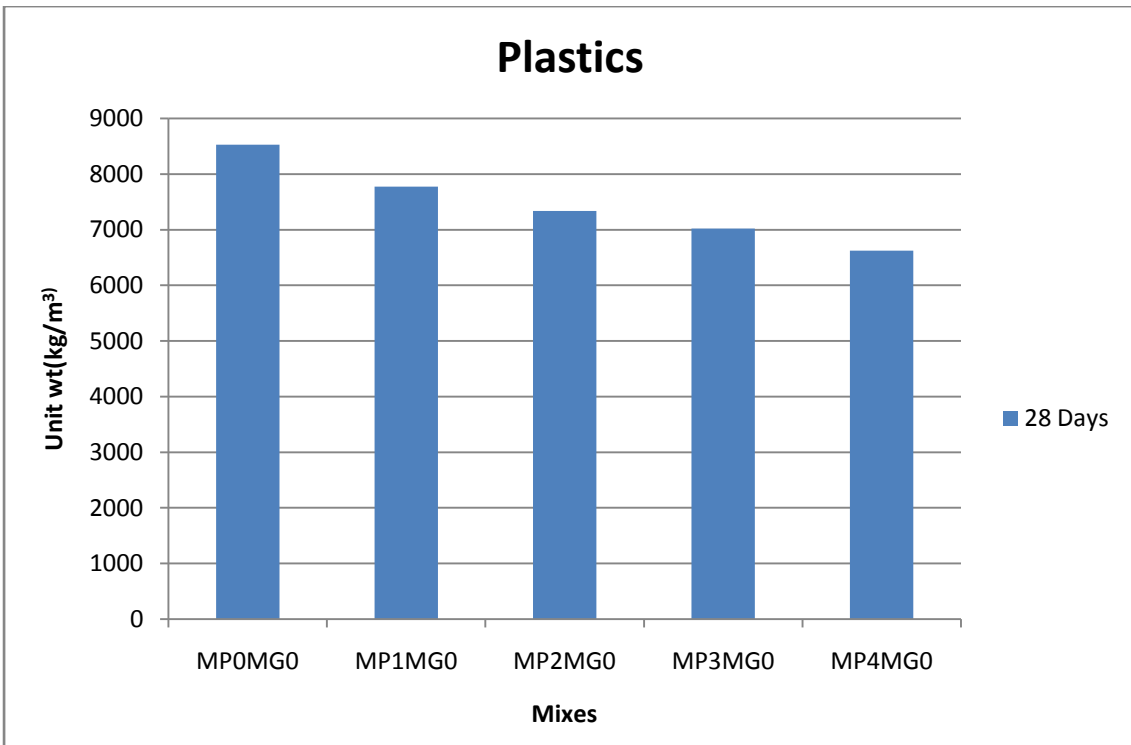


Fig 7.2 Unit weight of concrete made with different percentage of plastic as a coarse aggregate in concrete.

Table 7.1 showing the unit weight and percentage reduction from control mix.

Mixes	Unit weight/percentage reduction				
Plastics	MP0MG0	MP1MG0	MP2MG0	MP3MG0	MP4MG0
Glass					
MP0MG0	8526.3	7775.3/9.65	7338.4/16.18	7020.33/17.66	6622.3/22.30
MP0MG1	8496.25/0.35	7796.33/8.56	7580.00/11.1	6745.00/20.89	6214.30/27.11
MP0MG2	8340.67/2.17	7655.00/10.2	7281.33/14.6	7066.67/17.12	6663.00/21.80
MP0MG3	8326.30/2.34	7522.17/11.77	6978.50/18.15	6883.50/19.26	6683.00/21.60
MP0MG4	8322.45/2.39	7687.00/9.84	7200.50/15.51	6891.33/19.17	6584.30/22.77

7.3 COMPRESSIVE STRENGTH

In order to study the effect on compressive strength when glass and plastics are added into the concrete as cement replacement and as coarse aggregate replacement respectively. The cube containing different proportion of glass and plastics were prepared and kept for curing for 7 and 28 days. The test was conducted on ASTM of capacity 3000 KN. From the results it is obtained that 28 days strength of all the mixes is invariably higher than corresponding 7 days strength. This is due to continuous hydration of cement with concrete. However increase in compressive strength is very high when glass is added and is marginal when plastics are added to concrete. The table shows the percentage increase in compressive strength from 7 to 28 days for all the mixes. The following section discuss the effect of addition of glass and plastics on compressive strength separately.



Fig 7.3 Compression testing machine (ACTM)

Table 7.2 Change in compressive strength from 7 to 28 days

SR NO.	COMPRESSIVE STRENGTH(MPa)		% CHANGE
	7 DAYS	28 DAYS	
MGOMP0	21.08	33.93	37.87
MP0MG1	20.85	36.01	42.09
MP0MG2	13.99	24.55	43.01
MP0MG3	7.20	24.63	70.76
MP0MG4	5.08	11.32	55.12
MP1MG0	14.90	19.37	23.07
MP2MG0	14.14	17.32	18.36
MP3MG0	13.78	15.58	11.55
MP4MG0	11.14	11.54	3.46
MG1MP1	14.60	19.78	26.10
MG1MP2	13.97	17.18	18.68
MG1MP3	13.26	14.72	9.92

MG1MP4	10.79	11.98	9.93
MG2MP1	10.57	17.26	38.76
MG2MP2	10.07	14.32	29.67
MG2MP3	9.84	13.49	27.05
MG2MP4	9.29	11.60	19.91
MG3MP1	8.62	12.80	32.65
MG3MP2	8.10	10.54	23.14
MG3MP3	6.81	10.62	35.87
MG3MP4	5.87	10.14	42.11
MG4MP1	6.23	7.08	12.00
MG4MP2	5.68	7.29	22.08
MG4MP3	4.54	7.51	39.55
MG4MP4	3.41	5.11	33.27

7.3.1 Effect of percentage of Glass on compressive strength of concrete

Figs. 7.4-7.8 shows the effect of different percentages of glass on compressive strength of concrete Fig. 7.4 shows that as the percentage of glass replacement by cement is increased, the compressive strength first starts increasing, and then it decreases with further increase in percentage of glass replacement. For instance as can be seen from the fig. the strength increases by 5.77% with 20% glass is used as replacement of cement in comparison with control mix. With further increase in percentage of glass concrete the compressive strength decreases and at 80% glass the strength is 66.63% lower than control mix. Similar trend is observed in figs. when a combination of plastic and glass is used. The increase in strength with addition of glass indicates the pozzolanic effect of the glass as suggested by *Fragata et al. (2007), Turgut et al. (2009), Topcu et al. (2003)* According to the chemical characteristics of glass, it is an amorphous material and with a high content of silica. This characteristic along with its high specific surface makes it a reactive pozzolana. However, as the percentage of glass is further increased, the compressive strength starts decreasing. The decrease in compressive strength may be due to lack of presence of calcium hydroxide that is essential for pozzolanic reaction to take place. From the compressive strength results of all the mixes, it can be concluded that optimum replacement level of cement by glass is upto 20% from compressive strength point view.

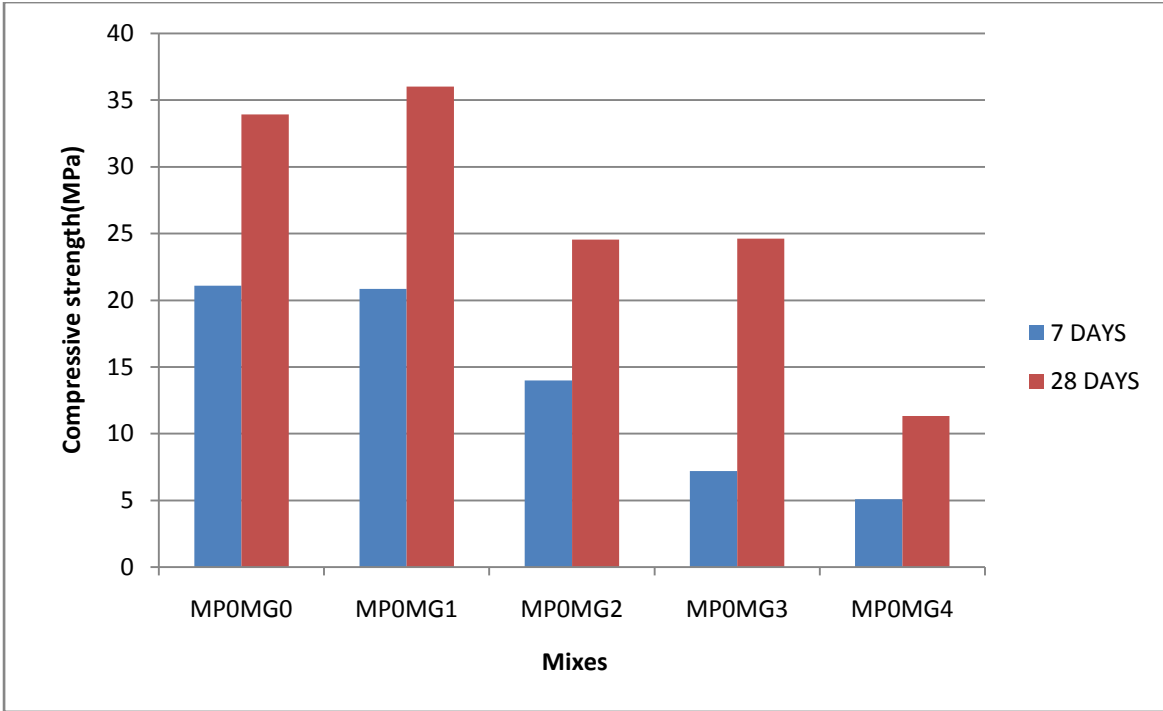


Fig. 7.4 Effect of change of different percentage of glass on compressive strength of concrete.

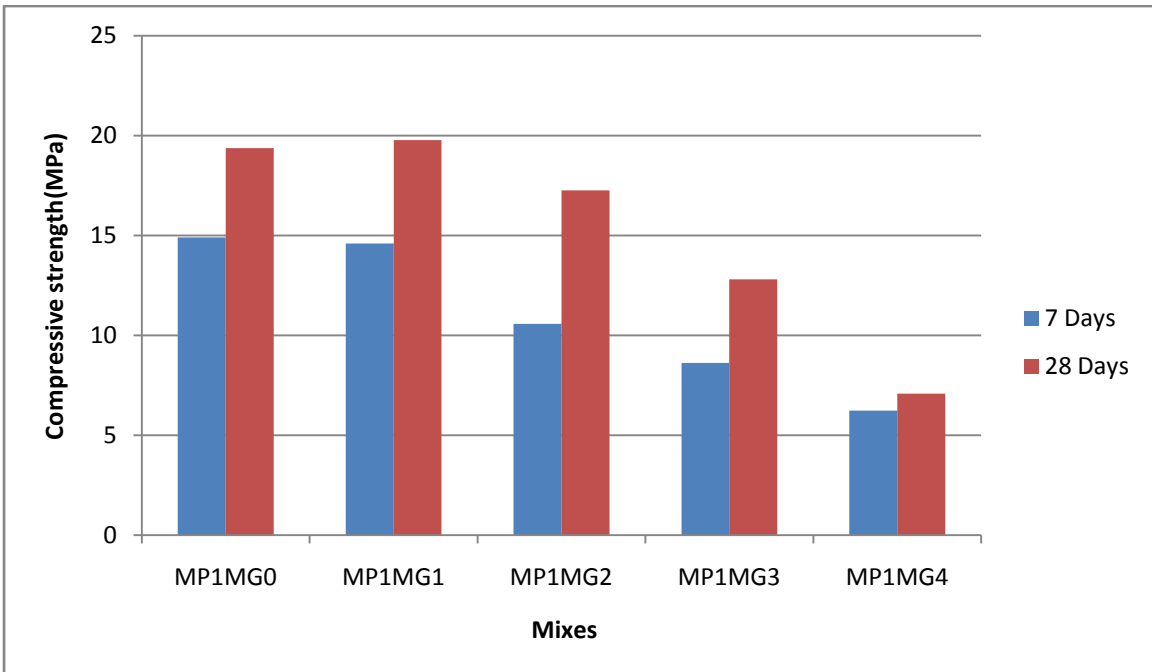


Fig.7.5 Effect of change of different percentage of glass on compressive strength of concrete with 20% plastic.

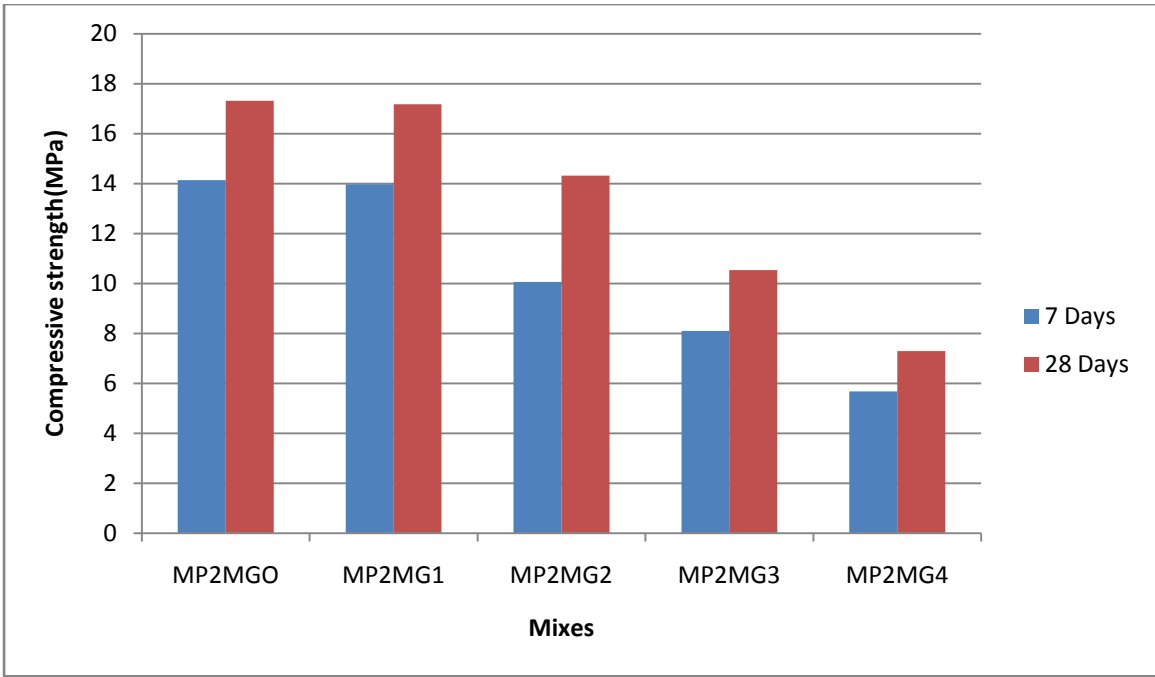


Fig. 7.6 Effect of change of different percentage of glass on compressive strength of concrete with 30% plastic.

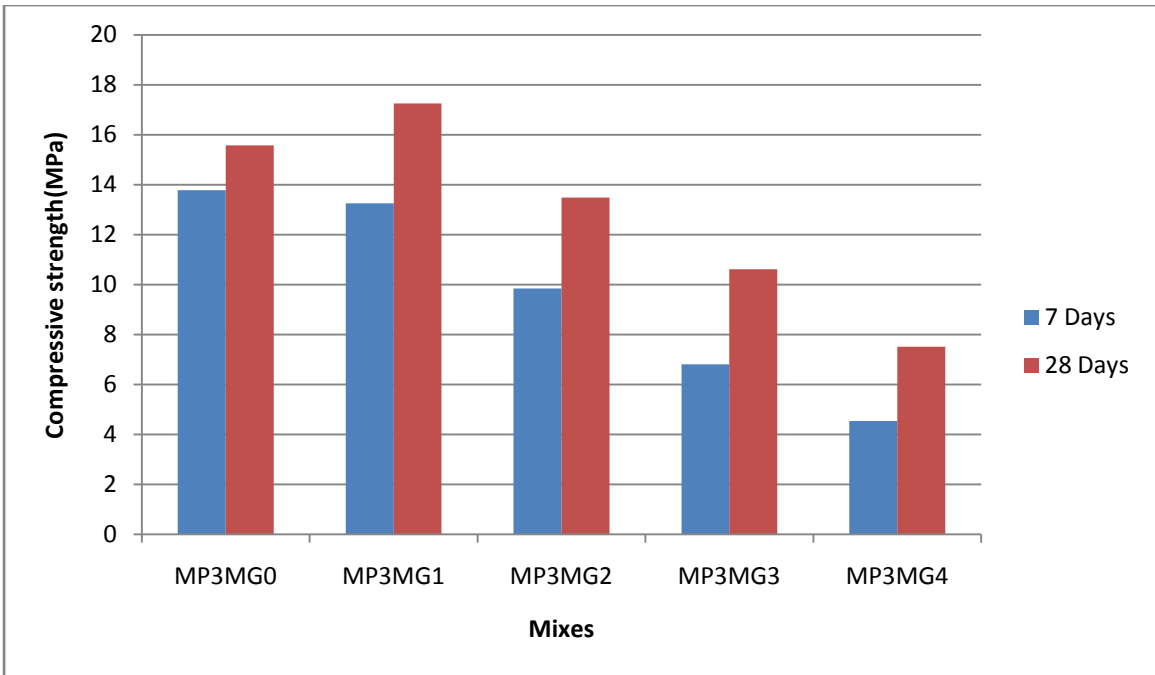


Fig. 7.7 Effect of change of different percentage of glass on compressive strength of concrete with 40% plastic.

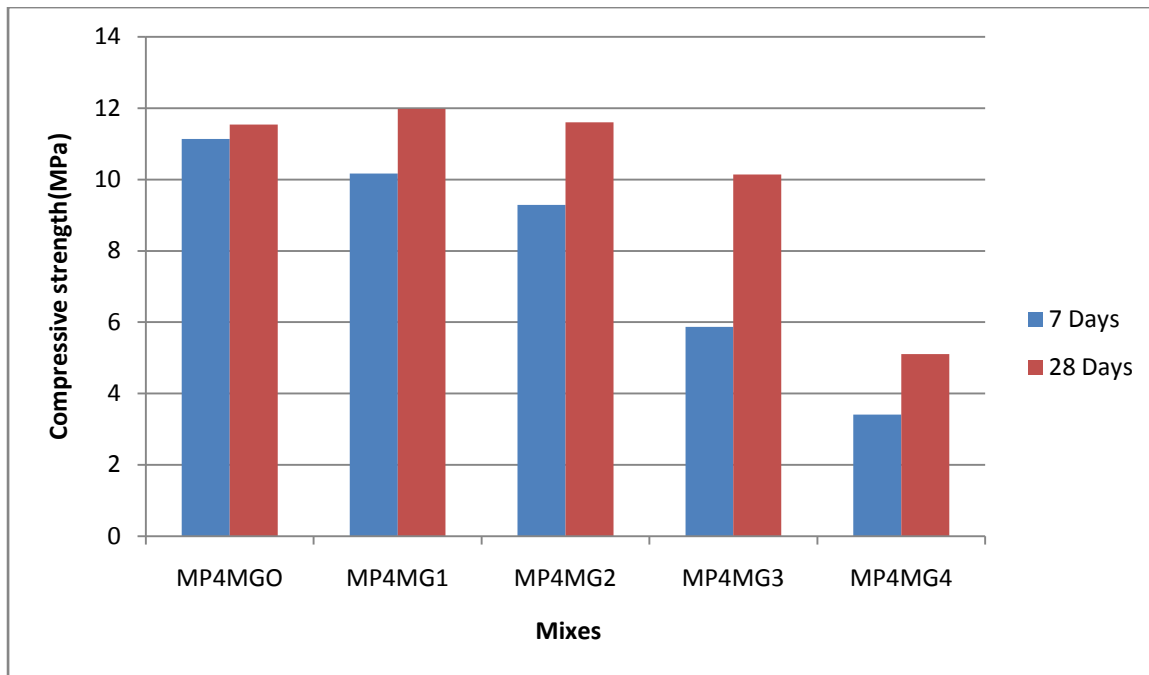


Fig. 7.8 Effect of change of different percentage of glass on compressive strength of concrete with 50% plastic.

7.3.2 Effect of percentage of plastic on compressive strength of concrete

Figs. 7.9-7.13 shows the effect of different percentages of plastics on compressive strength of concrete. It is observed from the Fig.7.9 that with the replacement of plastic as a coarse aggregate in concrete, it is observed the compressive strength decreases with comparison to the control mix. The percentage decrease at 20% plastic was 42.91% which is 19.37MPa from the control mix and the total reduction observed is 67.16% at 50% replacement of plastics. Similar trend of reduced compressive strength is observed for all the mixes containing various percentage of glass. It is observed that as the plastic aggregate is increased there is a gradual reduction in the strength. The increase in percentage of plastic may make the bond between aggregate and hydration products weaker and result in the reduced strength. This trend can be attributed to the decrease in adhesive strength between the surface of the waste plastic and cement paste. Additionally, plastic is considered as a hydrophobic material, so this property may restrict the water necessary for cement hydration from entering through the structure of concrete specimen during the curing period. Similar observations were made by *z.Ismail et al. (2007)*, *Wan Jo et al. (2008)*. However, the compressive strength of the

mixes with 20% plastic and upto 40% glass is nearly 20MPa so these mixes can be used for construction purposes.

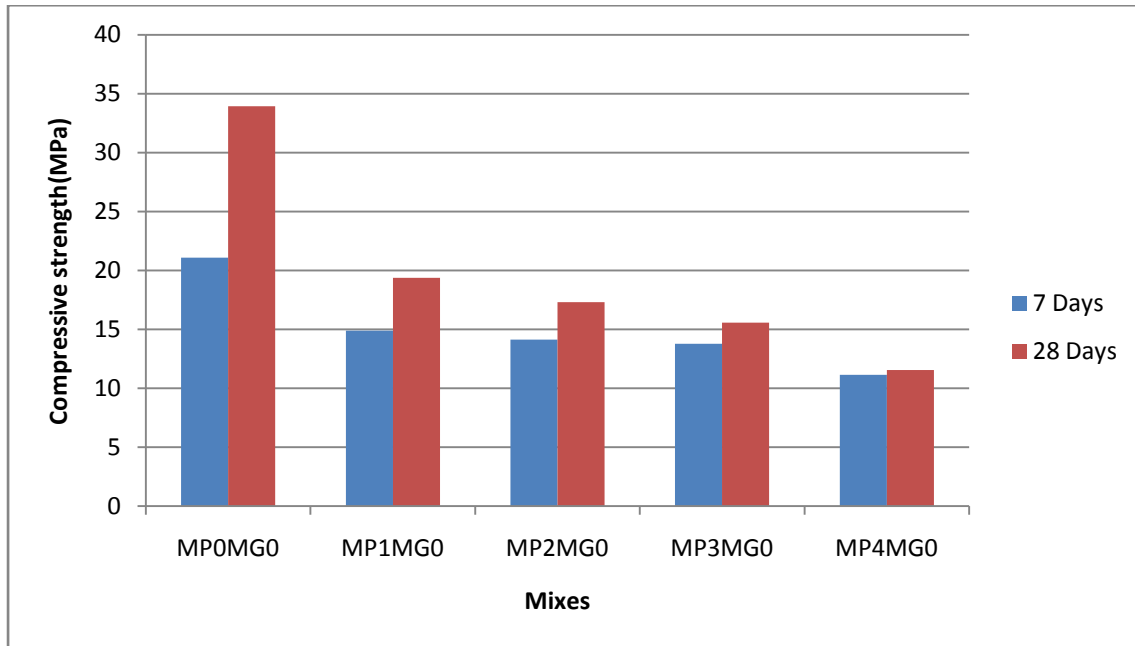


Fig. 7.9: Effect of change of different percentage of plastic on compressive strength of concrete

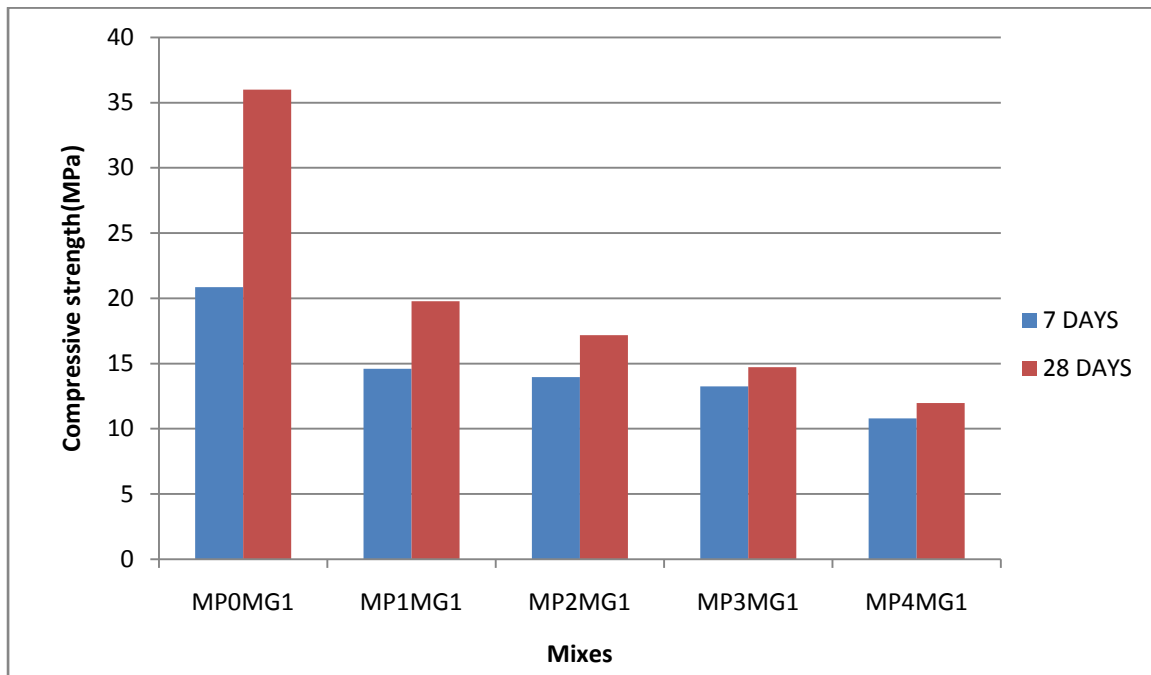


Fig. 7.10: Effect of change of different percentage of plastic on compressive strength of concrete with 20% glass.

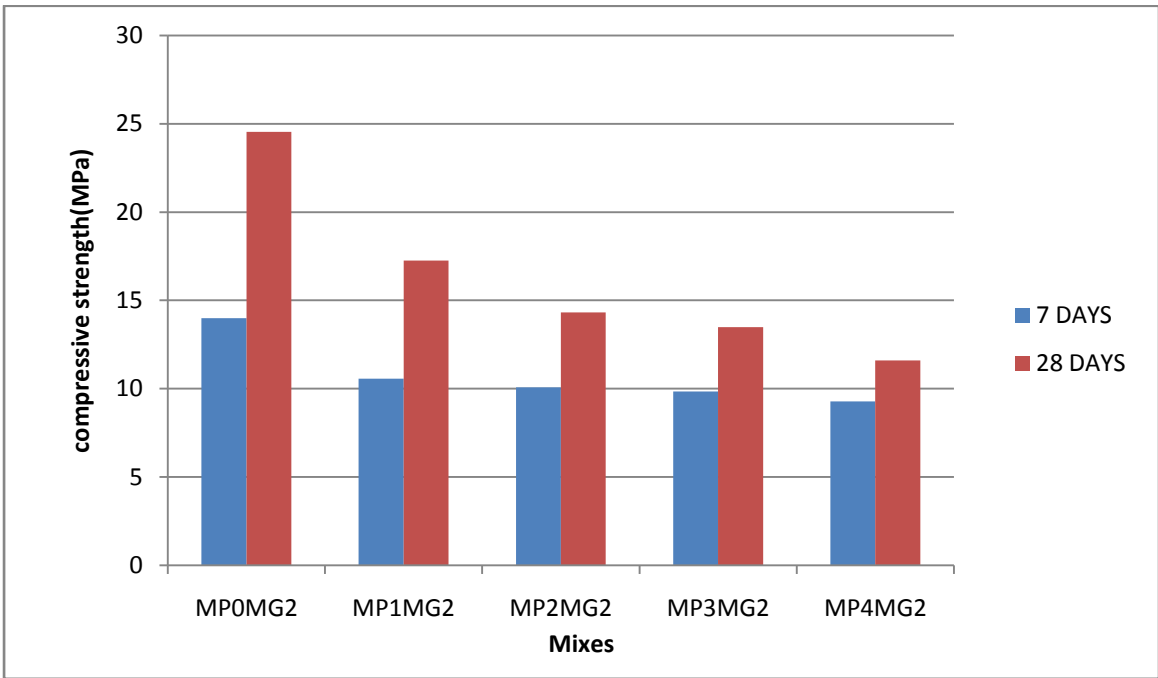


Fig. 7.11: Effect of change of different percentage of plastic on compressive strength of concrete with 40% glass.

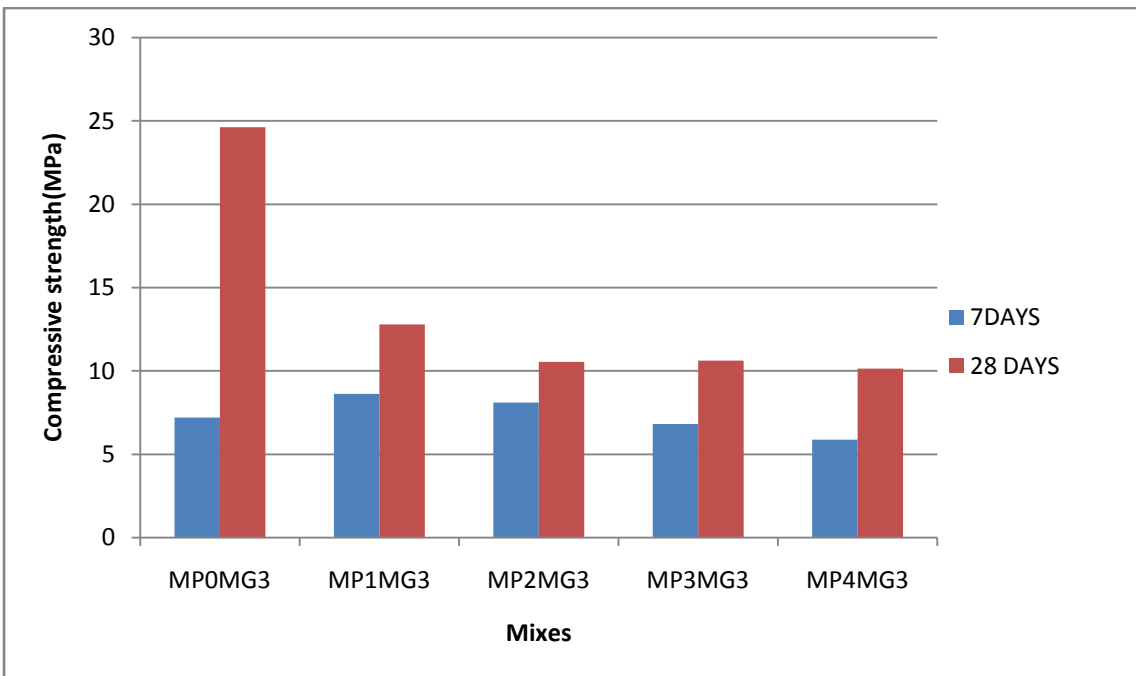


Fig. 7.12: Effect of change of different percentage of plastic on compressive strength of concrete with 60% glass.

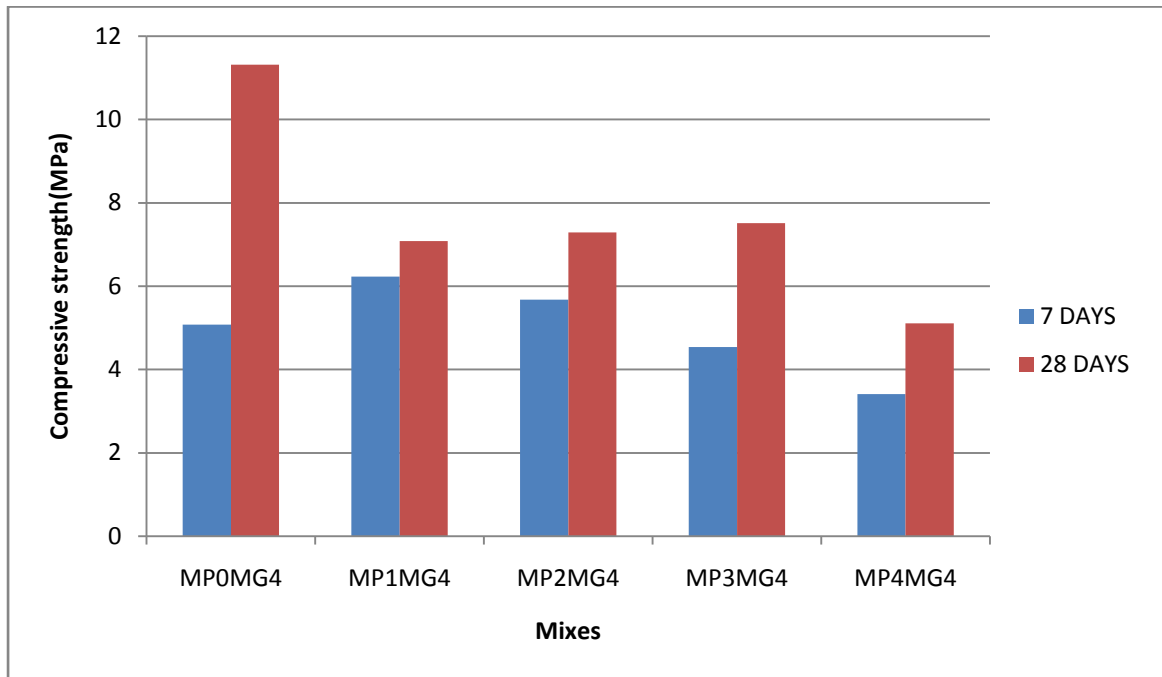


Fig 7.13: Effect of change of different percentage of plastic on compressive strength of concrete with 80% glass

7.4 TENSILE STRENGTH

Split tensile strength studies were carried out at the age of 28 days only because it is known that the tensile strength is not much effected by the age of concrete.

7.4.1 Effect of percentage of Glass on split tensile strength of concrete

Figs. 7.14-7.18 shows the tensile strength results, as a percentage of glass is increased for mixes with constant plastic content. It is observed from Fig. 7.14 as the percentage of glass is increased from 0% to 40% the split tensile strength either increases or remains almost constant. With further increase in percentage of glass the split tensile strength shows a downward trend. The maximum decrease is upto 75% when 80% of cement is replaced by glass concrete. From the results it is cleared that upto 20% replacement of cement by glass is good from both compressive strength and tensile strength point of view.

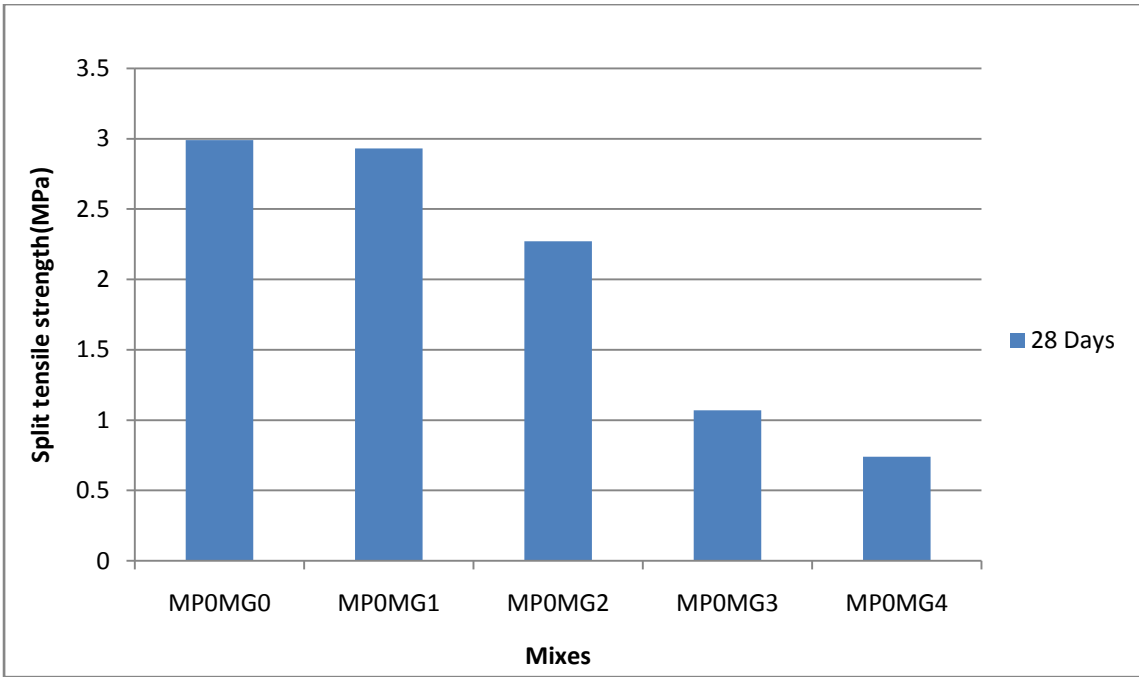


Fig 7.14: Effect of change of different percentage of glass on split tensile strength of concrete.

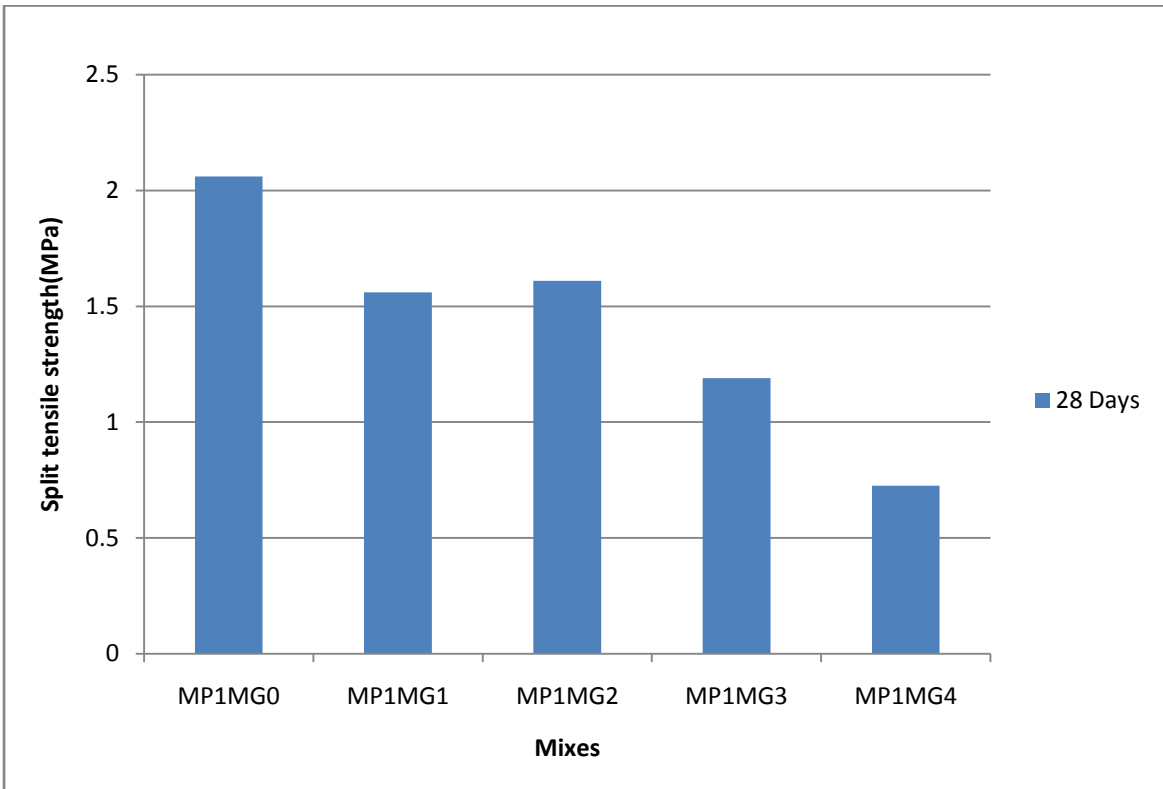


Fig 7.15: Effect of change of different percentage of plastic on split tensile strength of concrete with 20% plastic.

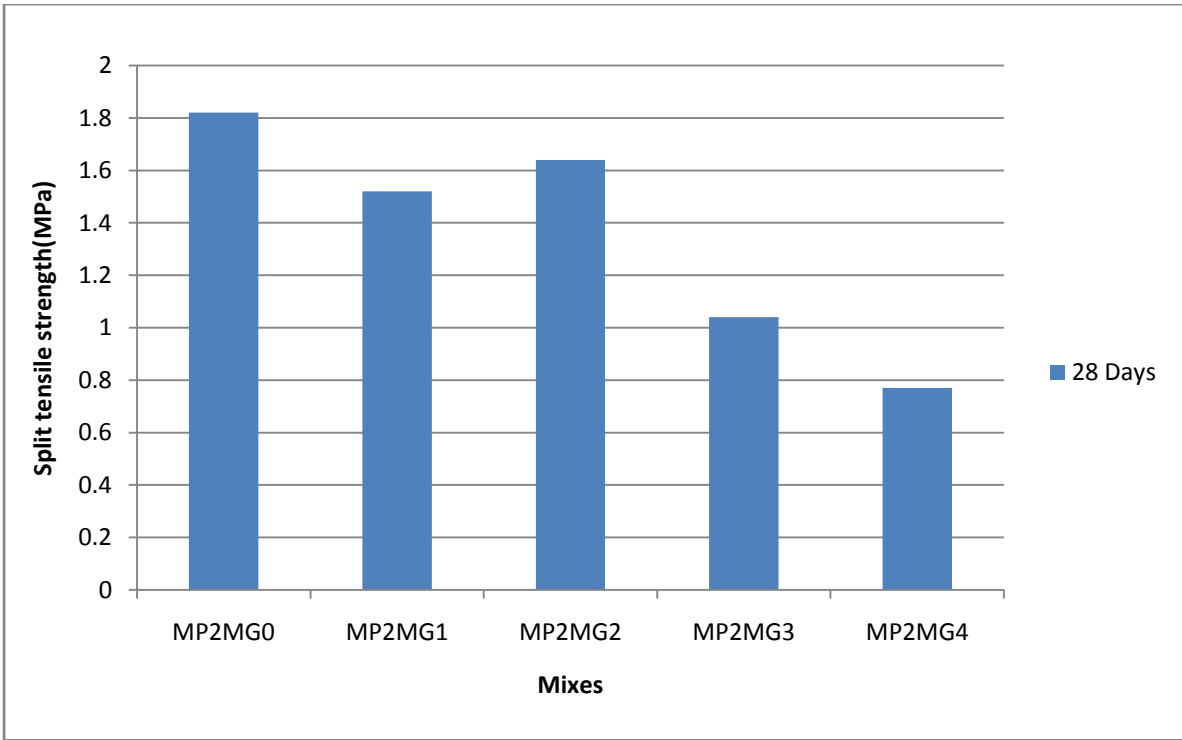


Fig 7.16: Effect of change of different percentage of plastic on split tensile strength of concrete with 30% plastic.

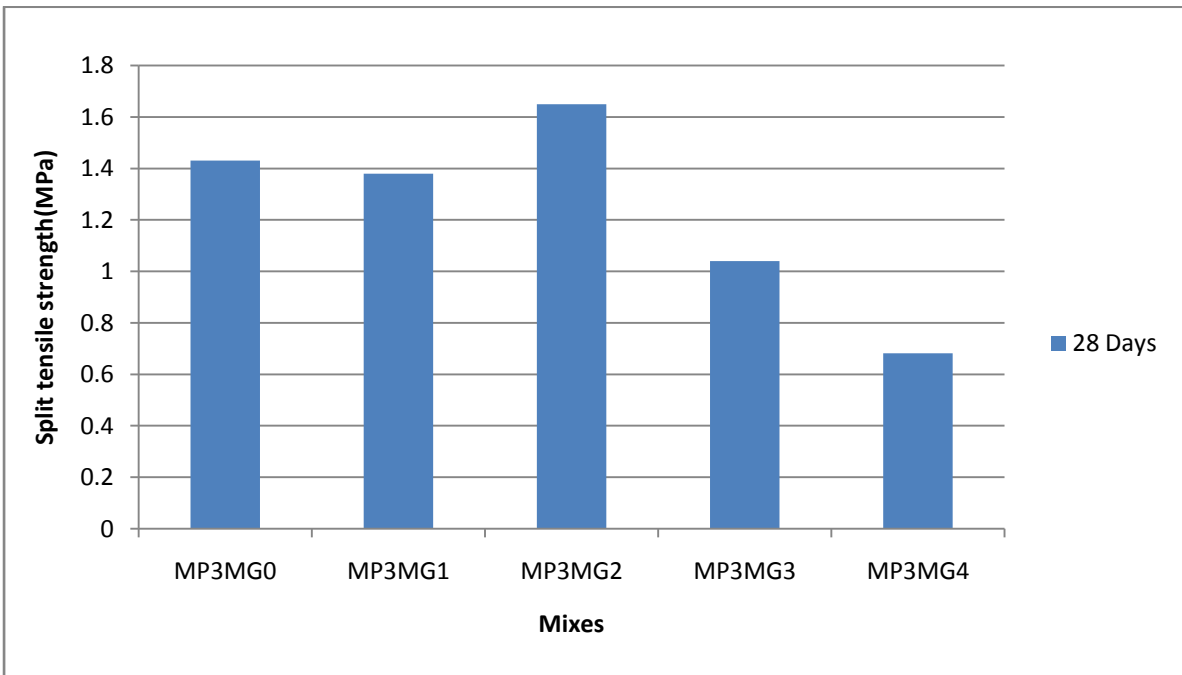


Fig 7.17: Effect of change of different percentage of plastic on split tensile strength of concrete with 40% plastic.

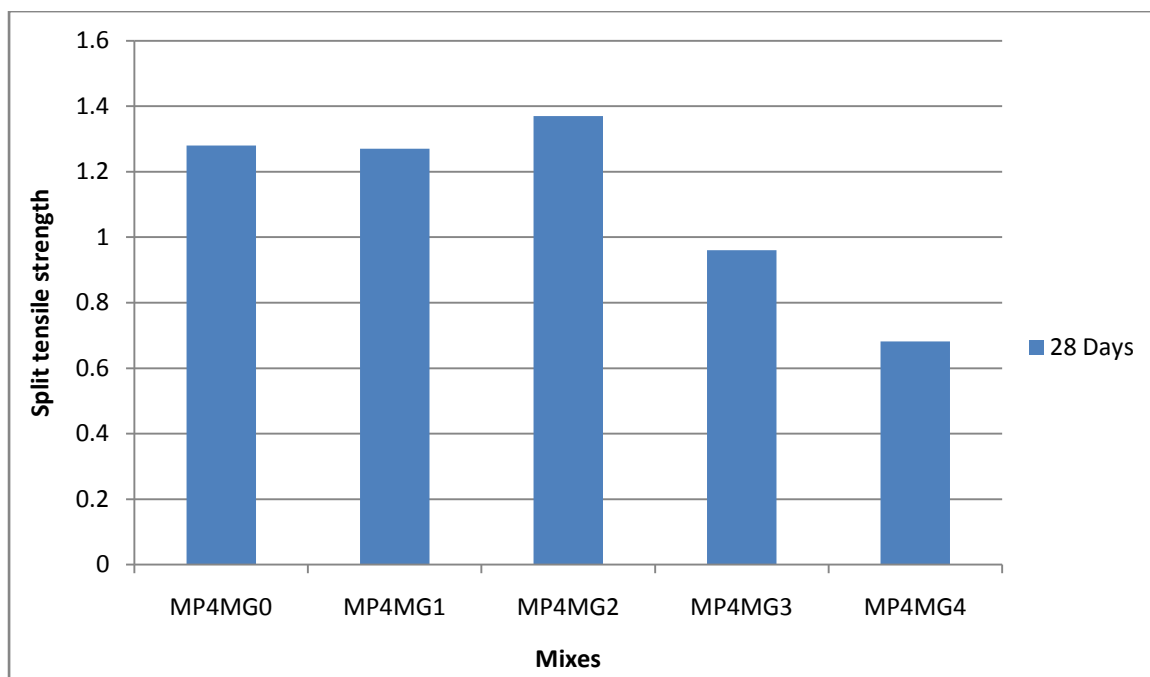


Fig 7.18: Effect of change of different percentage of plastic on split tensile strength of concrete with 50% plastic.

7.4.2 Effect of percentage of plastics on split tensile strength of concrete

Figs. 7.19-7.23 shows the tensile strength results, as a percentage of glass is increased for mixes with constant plastic content. The split tensile strength of plastic concrete decreases with the increase in the replacement of coarse aggregate by plastics. The percentage reduction at 20% replacement level was 31.10% from the control mix and 57.19% reduction at replacement of 50% plastic aggregate as shown in fig. Similar observation was made by *wan jo et al.(2008)*, *Babu et al. (2006)* However when the plastic is mixed with different proportion of glass, it is observed that in most of the mixes the split tensile strength remain same or showed a noticeable improvement up to plastic level of 40%. This increase may be due to the different and complex failure mechanisms of the material in plastic under tension. While testing for splitting tensile strength, the failure mode of concrete specimen containing plastics was different. The specimens did not exhibit the brittle failure as observed in control mix. Similar phenomenon was observed by *Eldin et al.(1993)* The failure observed was more gradual and specimens did not separate into two pieces. The following section no. 7.4.3 discuss the change in failure mode when plastics are added.

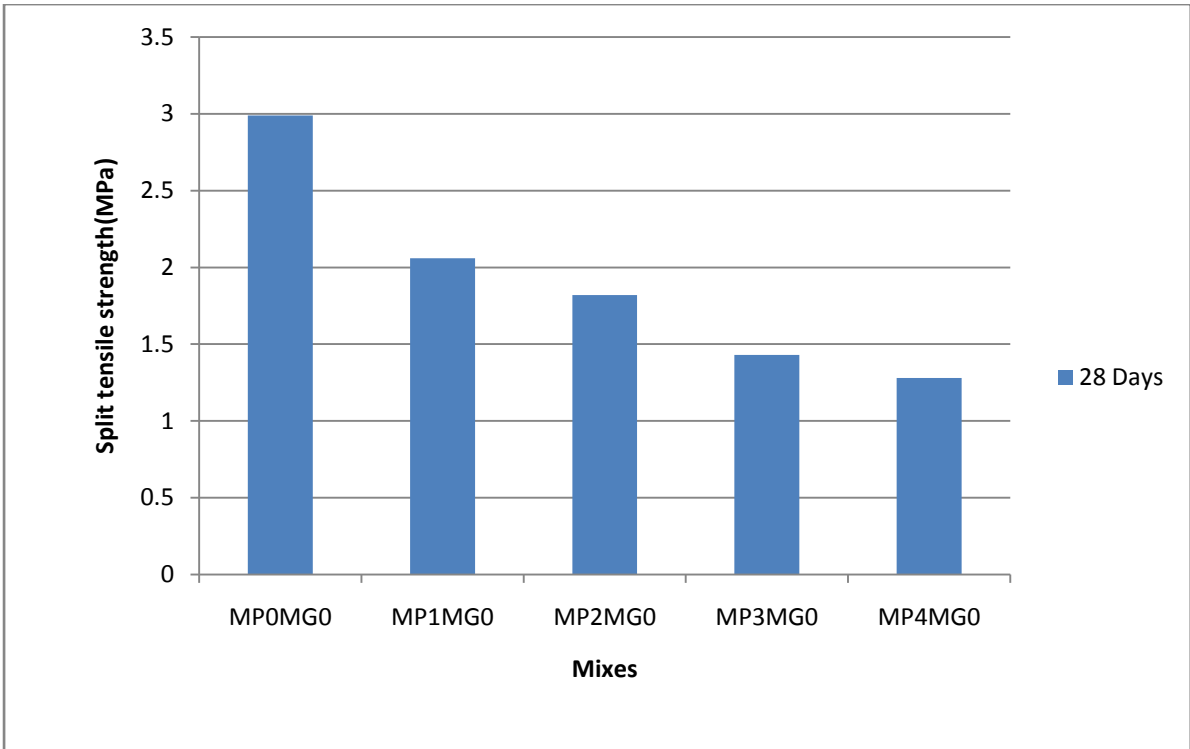


Fig 7.19: Effect of change of different percentage of plastic on split tensile strength of concrete.

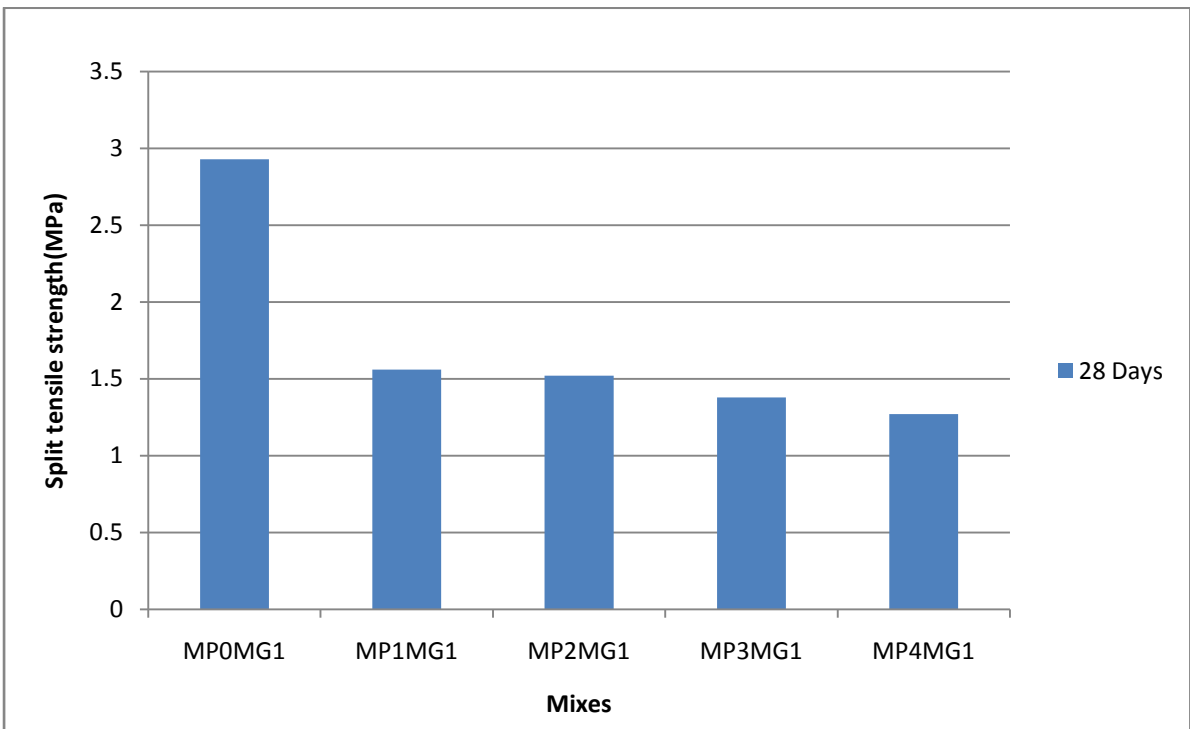


Fig. 7.20: Effect of change of different percentage of plastic on split tensile strength of concrete with 20% glass.

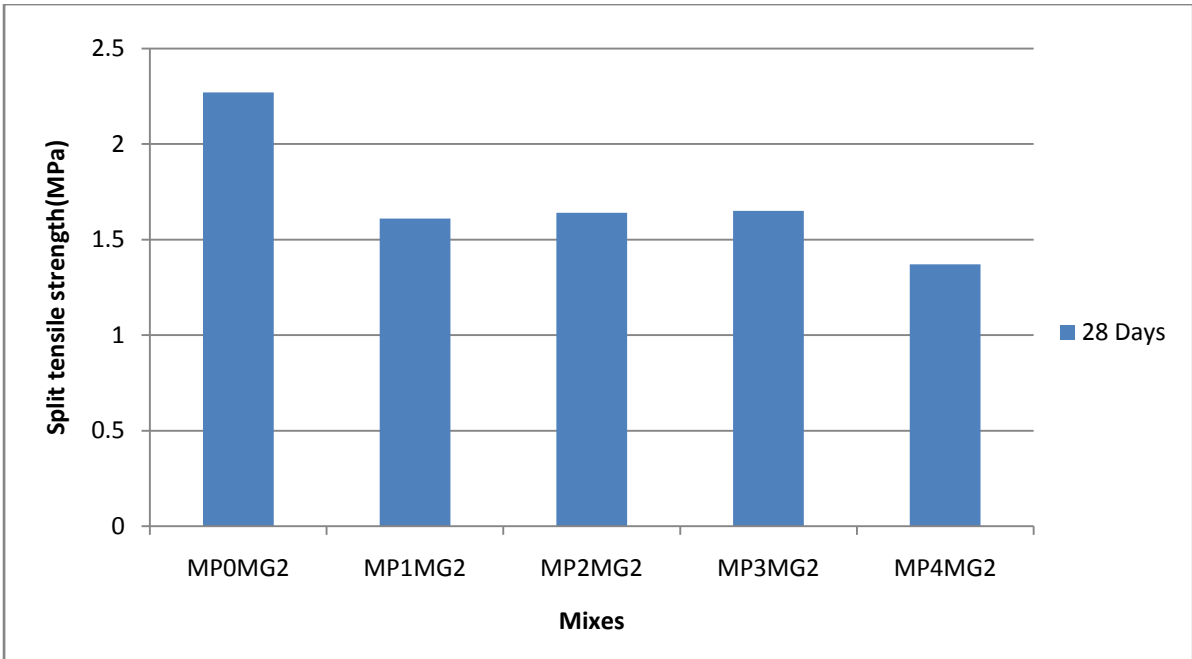


Fig 7.21: Effect of change of different percentage of plastic on split tensile strength of concrete with 40% glass.

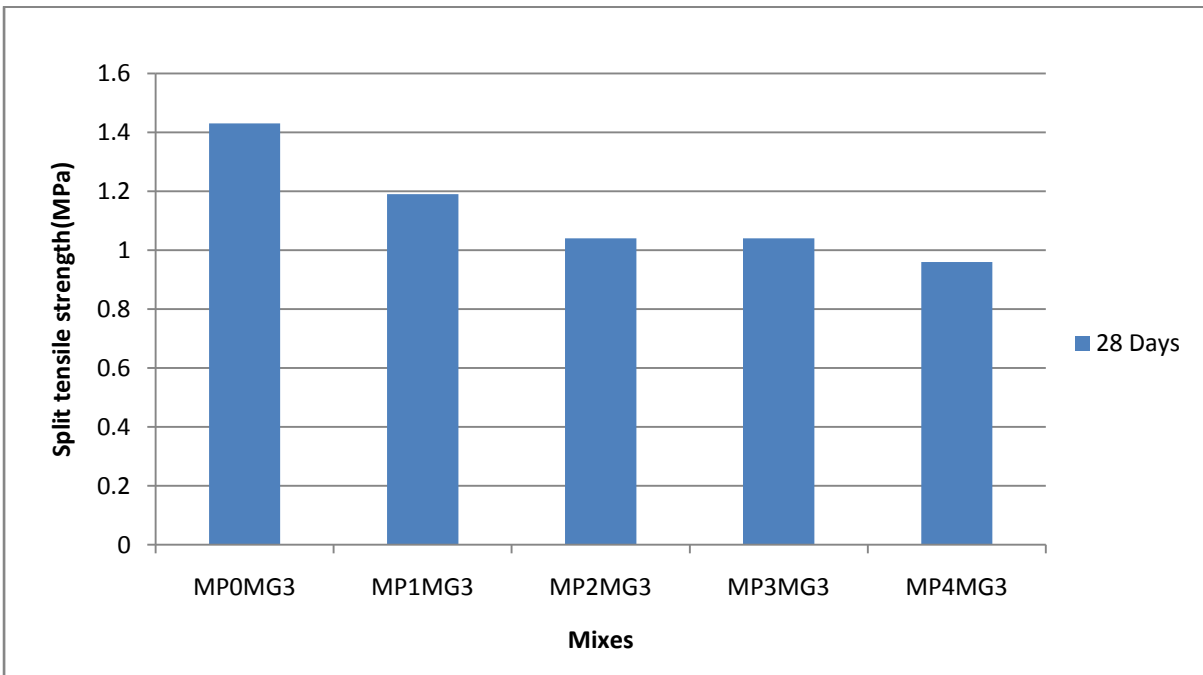


Fig 7.22: Effect of change of different percentage of plastic on split tensile strength of concrete with 60% glass.

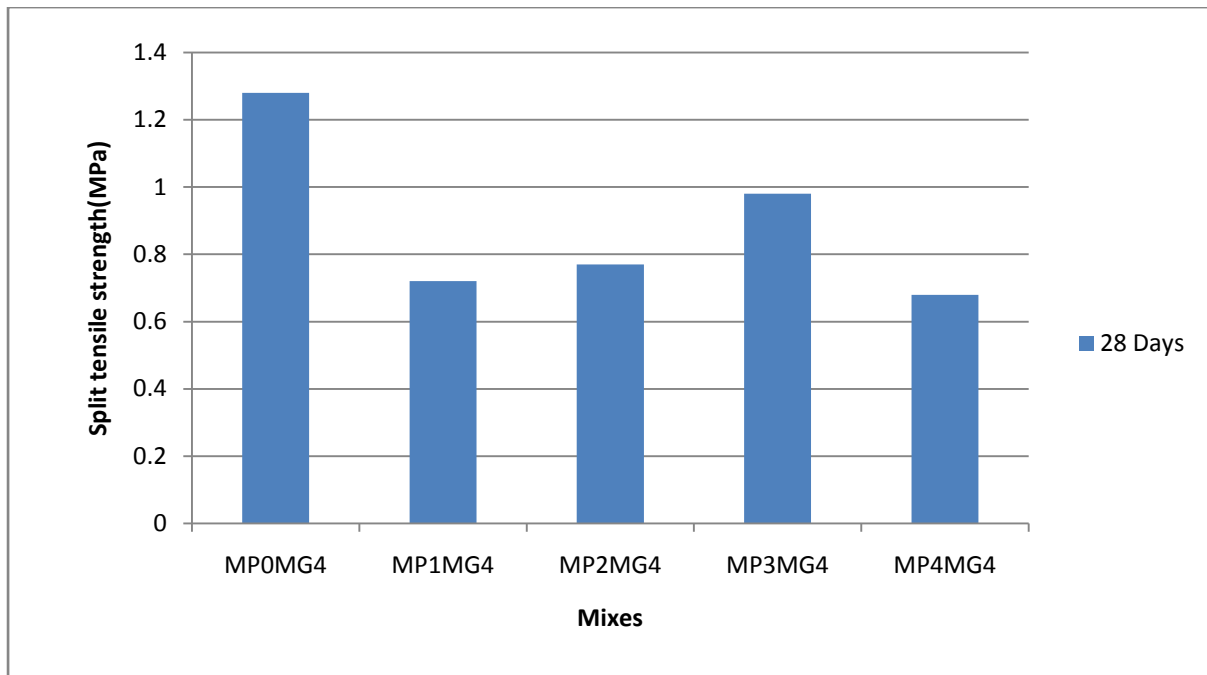


Fig 7.23: Effect of change of different percentage of plastic on split tensile strength of concrete with 80% glass.

7.4.3 Failure modes of cylinders in splitting tensile test

Figs. 7.24-7.25 shows the test set up of cylinders for doing the split tensile test. The failure patterns of control concrete and plastic concrete are shown in fig respectively. The plastic aggregate has the ability to undergo large elastic deformation before failing. Therefore a tension crack starts at the cement paste or at a mineral aggregate particle and propagates until it reaches to plastic aggregate. From the failure pattern, it can be seen that in the case of plastic concrete, the crack does not occur in the plastic, but goes around the plastic aggregate. This fact also indicates the poor bond strength between the cement paste and the plastic aggregates. In the case of control concrete, the failure took place right through the aggregates, indicating higher bond strength between the cement paste and the coarse aggregates. It was also noticed that the control concrete specimens had the brittle type failure, that is, sudden breakage accompanied by sound. But for the specimens that had plastic aggregates in place of normal aggregates, the failure occurred smoothly failure without any noise during breakage. It also indicates that the addition of plastic aggregates will induce ductility into the concrete system. Therefore, when added in proper proportion, the concrete can be made ductile with the addition of plastics in concrete.



Fig 7.24: Showing failure pattern of control and plastic concrete.



Fig 7.25: Failure pattern of plastic concrete

7.5 Initial Water Surface Absorption of Concrete

Initial water surface absorption results are presented in fig. for various percentages of glass as cement replacement and plastics as coarse aggregate replacement the following section discuss the effect of addition of various percentage of glass and plastics on water absorption.

7.5.1 Effect of percentage of glass on absorption of water on concrete

As can be observed from Figs. 7.26-7.30 as the percentage of glass is increased the initial water absorption reduces drastically. However with further increase in percentage of glass the surface absorption starts increasing. The initial absorption of concrete with 20% glass replacement was 0.0018 ml/m²/sec which is about 60% less than the control mix. This shows that application of glass powder as replacement of cement has positive effect on initial water surface absorption and hence durability of concrete. It is due to densification of concrete with adhesive of glass due to pozzolanic reaction of glass powder with calcium hydroxide released during hydration of cement. As the percentage of glass is increased beyond a limit the pozzolonic reaction would not take place because of absence of calcium hydroxide in mix. Due to the absence of the bond between the cementitious products large sized voids are formed that leads to higher water absorption. As can be seen in Figs. 7.27-7.30 the water absorption values at 80% glass replacement are even higher than control mix. Similar observation was made by *Poon et al.(2005)*

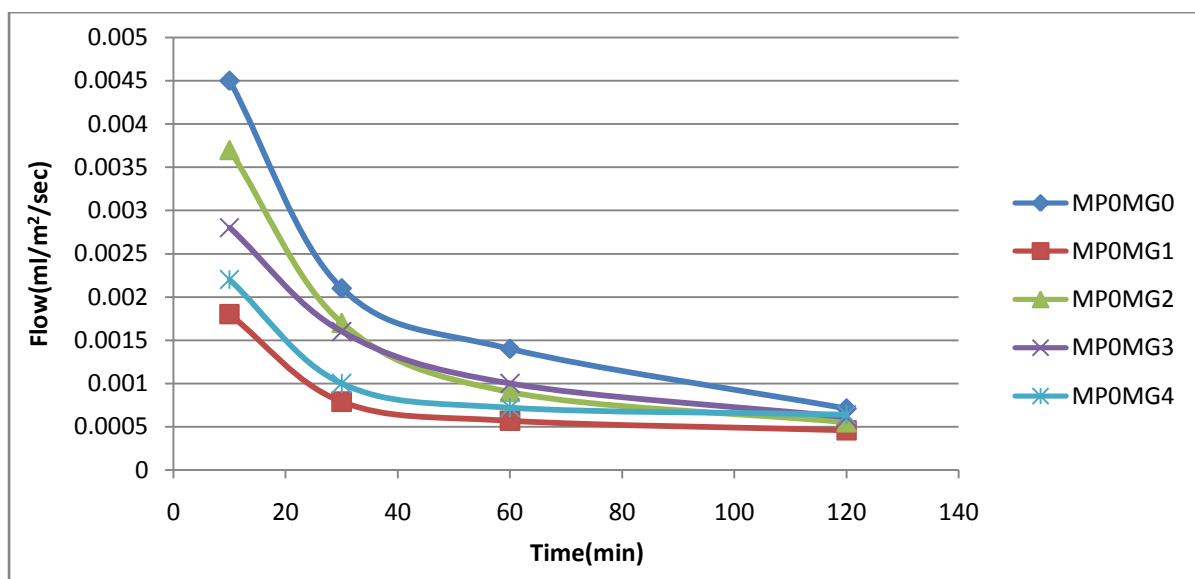


Fig 7.26 Effect of change of different percentage of glass on initial water surface absorption on concrete.

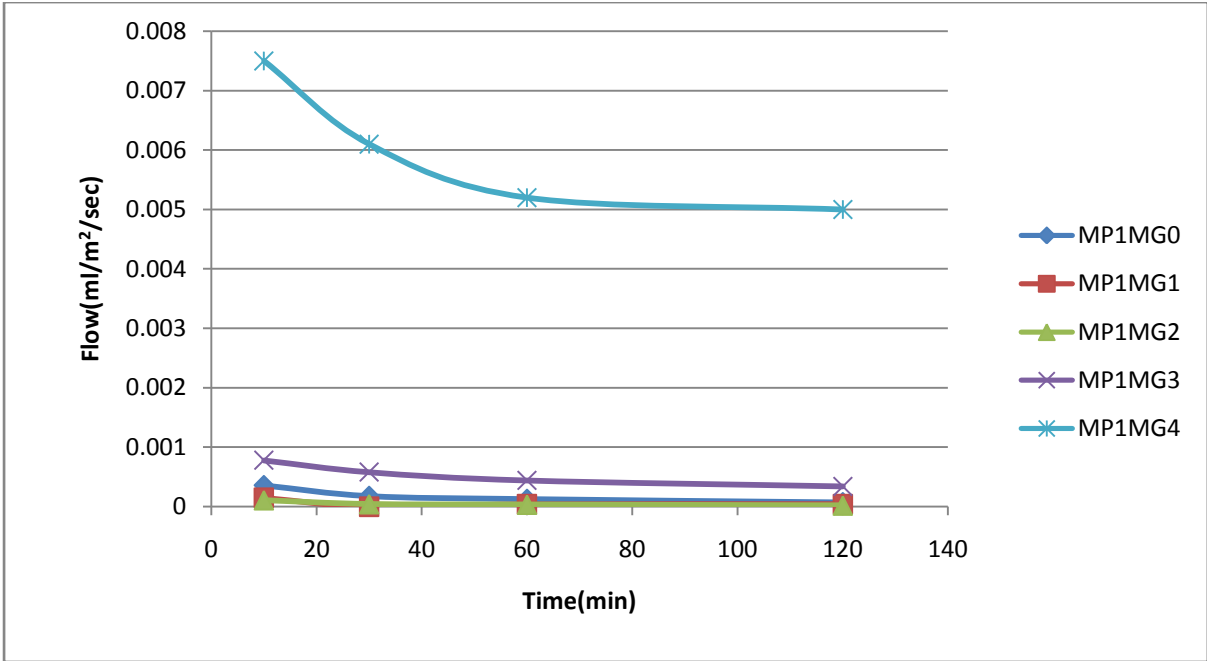


Fig 7.27 Effect of change of different percentage of glass on initial water surface absorption on concrete with 20% plastic.

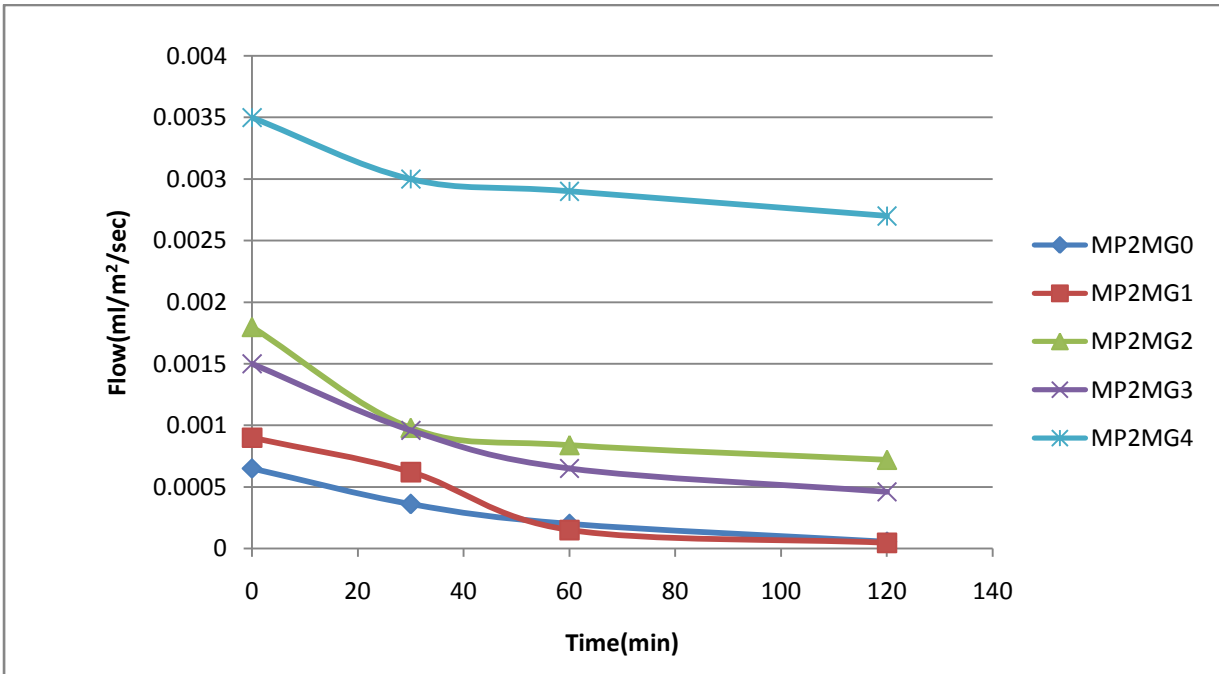


Fig 7.28: Effect of change of different percentage of glass on initial water surface absorption on concrete with 30% plastic.

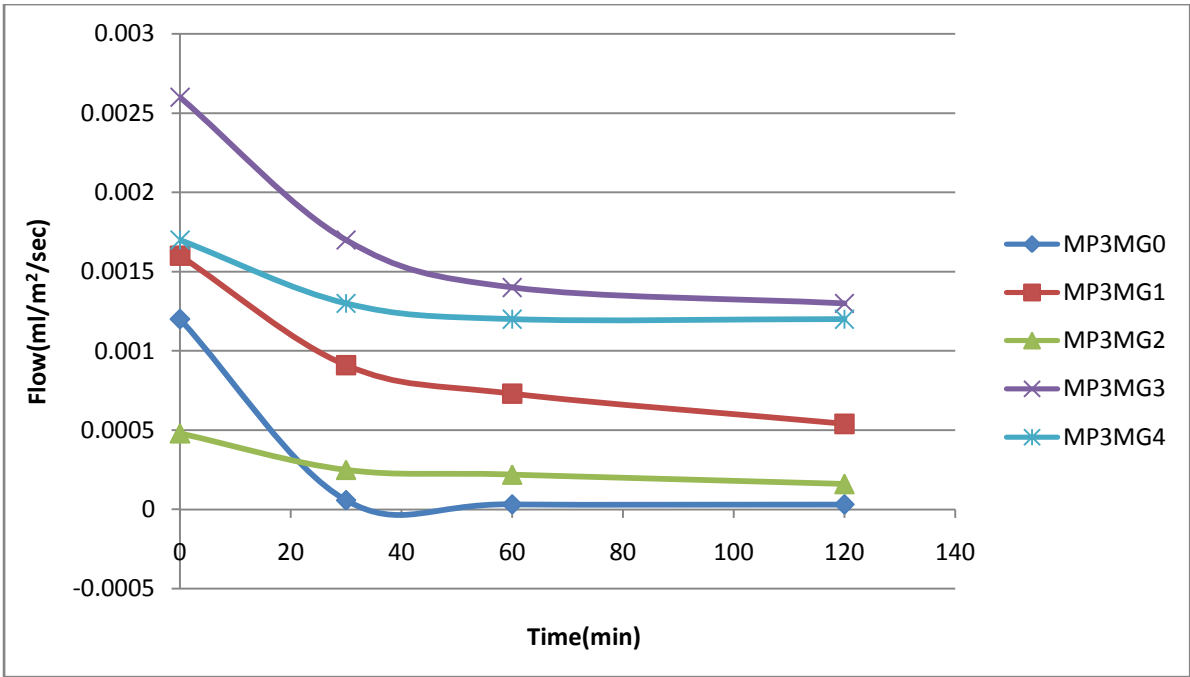


Fig 7.29: Effect of change of different percentage of glass on initial water surface absorption on concrete with 40% plastic.

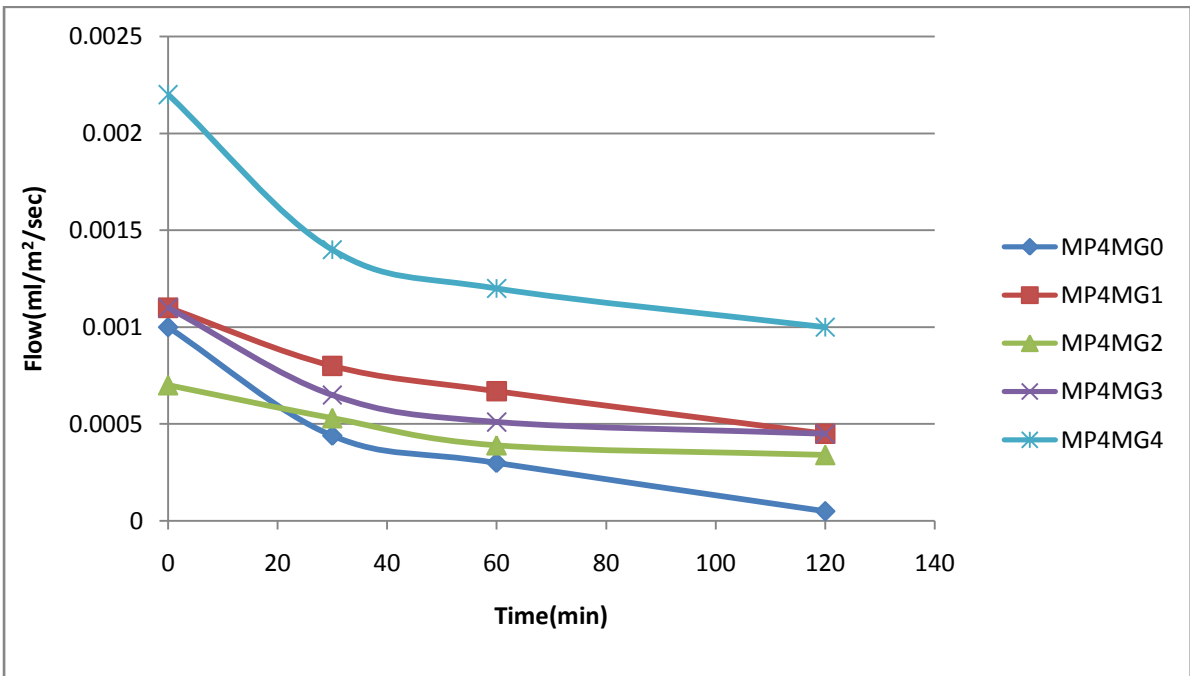


Fig 7.30: Effect of change of different percentage of glass on initial water surface absorption on concrete with 50% plastic.

7.5.2 Effect of plastic on absorption of water on concrete

Figs. 7.31-7.35 shows initial water surface absorption results as the percentage of plastic as a coarse aggregate in concrete is increased from 0% to 50% and percentage of glass is fixed at certain level. As it can be seen from the Fig 7.31-7.34 addition of plastic in concrete decreases the water absorption to the barest minimum value. It is due to double benefit of plastics, firstly the plastics are hydrophobic so they do not allow the entry of water into concrete, secondly plastic do not absorb water itself. This dual advantage reduces the flow of water into concrete to the minimum value and hence increases the corrosion resistance and durability of system. Out of all the mixes the least flow is observed in the mix containing 20% glass as replacement of cement and 20% replacement of plastic as a coarse aggregate.

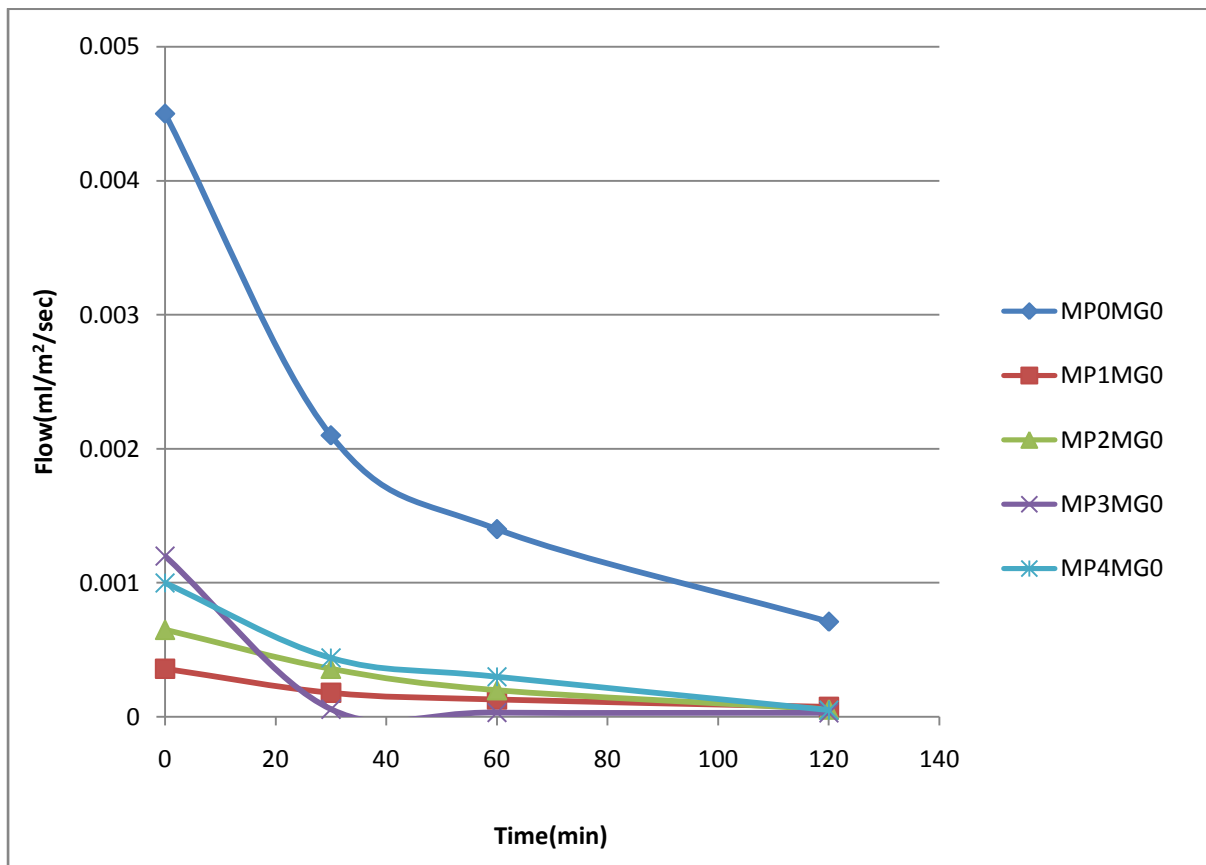


Fig. 7.31: Effect of change of different percentage of plastic on initial water surface absorption on concrete.

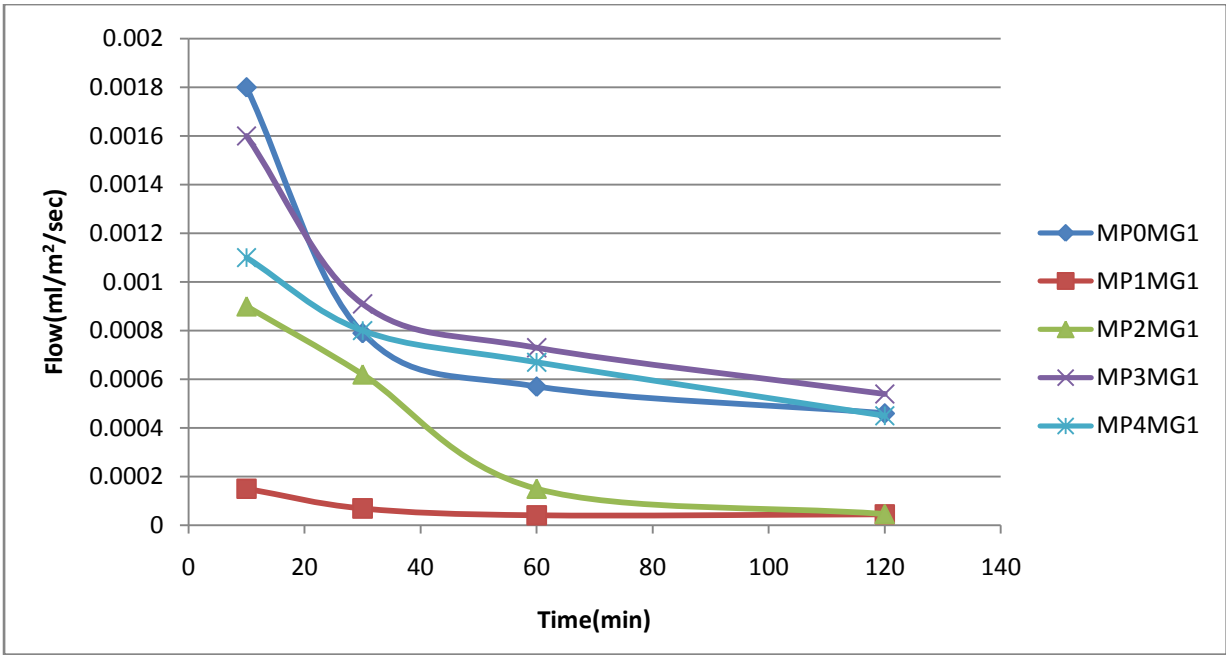


Fig. 7.32 Effect of change of different percentage of plastic on initial water surface absorption on concrete with 20% glass.

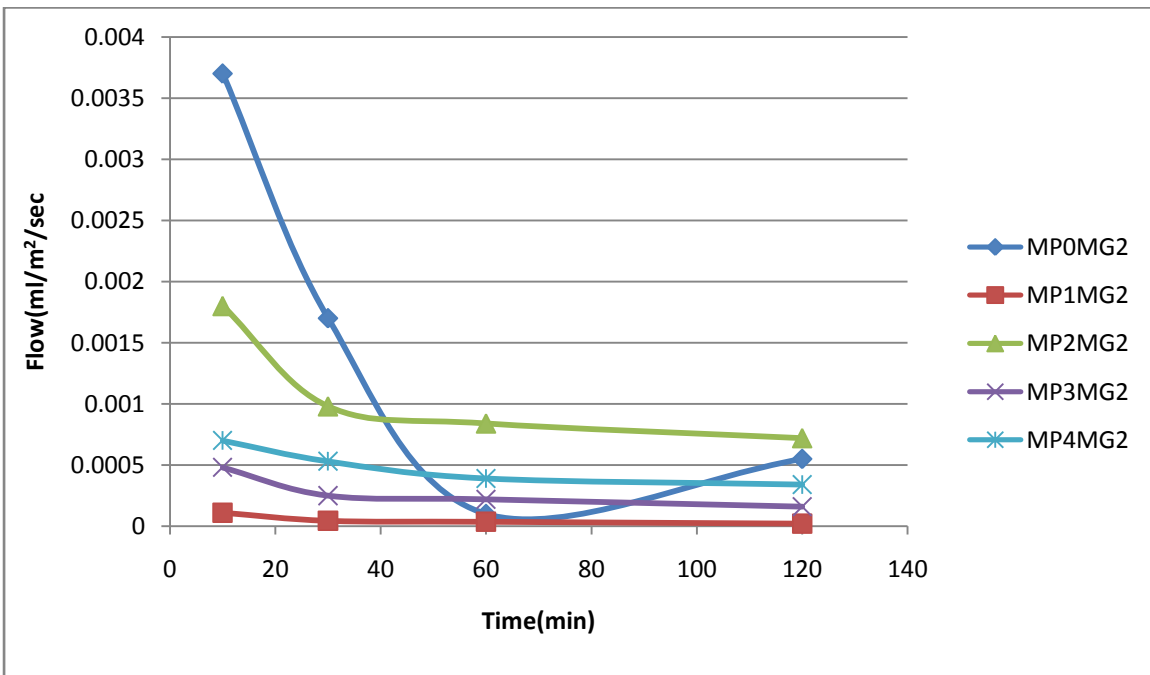


Fig 7.33 Effect of change of different percentage of plastic on initial water surface absorption on concrete with 40% glass.

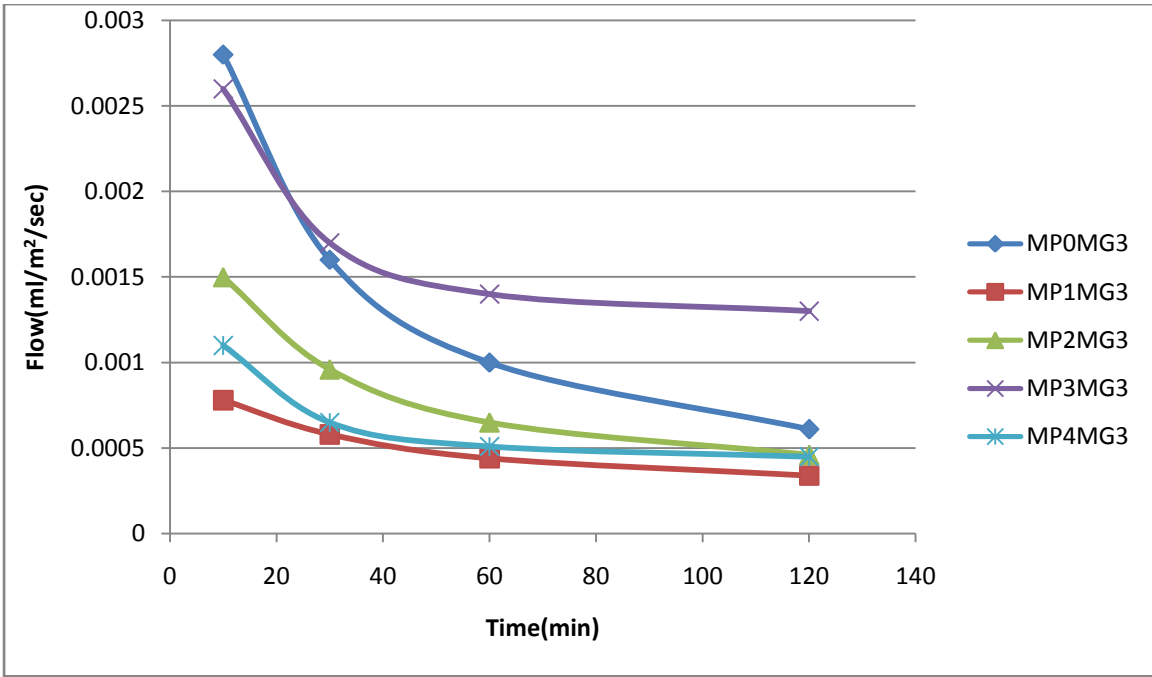


Fig 7.34: Effect of change of different percentage of plastic on initial water surface absorption on concrete with 60% glass.

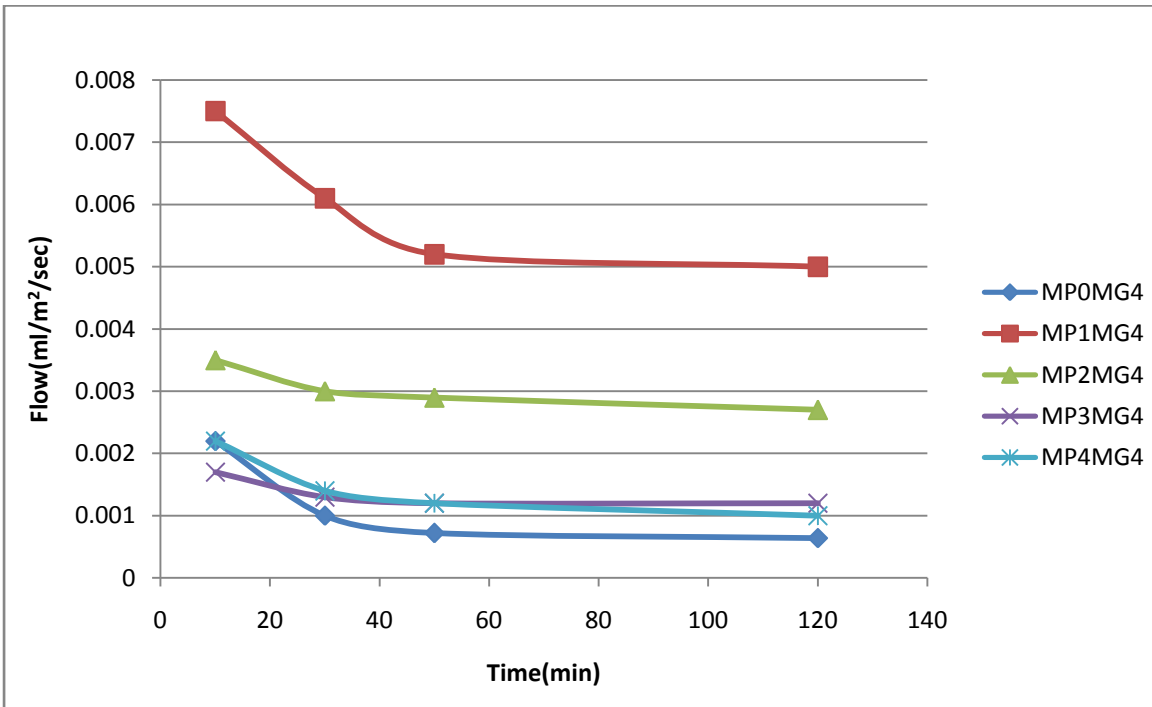


Fig 7.35: Effect of change of different percentage of plastic on initial water surface absorption on concrete with 80% glass.

7.6 Alkali silica reaction test

Study of expansion due to possible reaction between alkali in cement and silica in glass was done in accordance with ASTM C1260 length bar readings were taken till 16 days and the results are reported in Table 7.3. According to ASTM C1260 expansion at the end of 16 days after casting is classified as non detrimental. If it is below 0.10%, as potentially detrimental if it is between 0.10% and 0.20% and as detrimental if it is over 0.20%. Further according to ASTM C1260, the 14th day expansions are considered as final expansion for determining the ASR resistance. As illustrated in table all mixes with percentages of glass ranging from 20% to 80% have 14 day expansion when below 0.1%. It indicates that expansions are of all mixes are below detrimental. Therefore these mixes can be used for production of concrete.

Table 7.3: Length changes in % of the mortar bars prepared in compliance with ASTM C1260.

Mixes	% Expansion at 14 days
MP0MG0	0.072
MP0MG1	0.086
MP0MG2	0.080
MP0MG3	0.072
MP0MG4	0.064

Chapter 8

Conclusions

Following conclusions are drawn from present work.

- When glass is used as replacement of cement. The compression strength increases when the percentage of glass is increased upto some level, thereafter strength starts decreasing with further increase in percentage of glass. The optimum replacement level of cement by glass is nearly 20%.
- When plastics are used as replacement of coarse aggregate, the strength of mix is lower than control mix. However use of upto 20% plastic in mix at 0.5 w/c ratio makes the mix of compressive strength nearly 20MPa which can be used for construction purposes.
- The addition of optimum percentage of glass powder as replacement in cement lowers initial water surface absorption in concrete, hence as positive effect on durability of concrete. This optimum percentage is 20% which leads to nearly 60% lower water absorption than control mix.
- Addition of plastics in concrete decreases the water absorption to barest minimum value. Out of all mixes the least flow is observed in the mix containing 20% glass as replacement of cement and 20% replacement of plastic as a coarse aggregate.
- The alkali silica reaction of glass powder is found to be below detrimental limits.

REFERENCES

1. A. Remadnia, R.M. Dheilily, B. Laidoudi, M. Quéneudec Use of animal proteins as foaming agent in cementitious concrete composite manufactured with recycled PET aggregates *Construction and Building Materials* 23 (2009) 3118–3123.
2. A.R. Bagheri , M. Alibabaie, M. Babaie Department of Civil Engineering, Khaje Nasir Toosi University of Technology, No. 1346, Vali Asr Street, Mirdam Crossing, Tehran 19967-15433, Iran.
3. Al-Manaseer, A.A., T.R., Dalal.,1997. “Concrete containing plastic aggregates”, *Concrete International*, 47– 52.
4. Asokan P, Osmani Mohammad, Price ADF. Improvement of the mechanical properties of glass fibre reinforced Plastic waste powder filled concrete. *Construction Building Material* (2009), doi:10.1016/j.conbuildmat.2009.10.017.
5. Bayasi, Z, Zeng, J., 1993.” Properties of polypropylene fiber reinforced concrete”. *ACI Materials Journal* 90 (6), 605–610.
6. Byung-Wan Jo a,1, Seung-Kook Park b, Jong-Chil Park a,c Mechanical properties of polymer concrete made with recycled PET and recycled concrete aggregates *Construction and Building Materials* 22 (2008) 2281–2291.
7. Chi-Sun Poon , Dixon Chan Effects of contaminants on the properties of concrete paving blocks prepared with recycled concrete aggregates *Construction and Building Materials* 21 (2007) 164–175.
8. Choi, Y.W., Moon, D.J., Chung, J.S., Cho, S.K., 2005. “Effects of waste PET Bottles aggregate on properties of concrete”. *Cement and Concrete Research* 35, 776–781.
9. Dr EA Byars, Dr B Morales and HY Zhu Centre of Cement and Concrete University of Sheffield The Old Academy, 21 Horse Fair, Banbury, Oxon OX160AH March 2004 ISBN: 1-84405-116-1.

10. Fragata A., Paiva H., Velosa A.L., Veiga M.R., Ferreira V.M. “Application of crushed glass residues in mortars”.(2007)
11. Flavie Moulinier, Simon Lane, Andrew Dunster BRE (Building Research Establishment) Project code: GLA0046 The Waste & Resources Action Programme (2006).
12. Iker Bekir Topc, Mehmet Canbaz Properties of concrete containing waste glass Cement and Concrete Research 34 (2004) 267–274.
13. Jo,B.W., Park, S.K., Park , J.C., 2007. “Mechanical properties of polymer concrete Made with recycled PET and recycled concrete aggregates”. Construction and Building Materials.
14. Khaled Sobhan, High Performance Construction Materials From C&D Waste Aggregate and Recycled Plastics *LACCEI International Latin American and Caribbean Conference for Engineering and Technology(LACCEI’2004)*“.
15. Oliveira L.A Pereira de, Gomes J.P. Castro & Santos P. “Optimization of pozzolanic reaction of ground waste glass incorporated in cement mortars”.
16. Park Seung-Bum, Lee Bong-Chun. “Studies on expansion properties in mortar Containing waste glass and fibers”. Cement and Concrete Research 34 (2004) 1145–1152.
17. Pike RG, Hubbard D, Newman ES. Binary silicate glasses in the study of Alkali aggregate reaction. High Res Board Bull 1960;275:39.
18. *Robert Malloy, Nirav Desai and Charles Wilson High Carbon Fly Ash / Mixed Thermoplastic Aggregate for Use in Lightweight Concrete*
19. S.C. Kou, C.S. Poon Properties of self-compacting concrete prepared with recycled glass aggregate Cement & Concrete Composites 31 (2009) 107–113.
20. Saradhi Babu D, Ganesh Babu K, Wee TH. Properties of lightweight expanded polystyrene aggregate concretes containing fly ash. Cem Concr Res 2005;35:1218–23
21. Saglik Aydin, Kocabeyler. “A study for preventing the risk of alkali-silica Reaction due to the aggregate planned to be Used in mass concrete of deriner dam and hepp Project”.

22. S.S. Verma The Indian Concrete Journal NOVEMBER 2008. 21. Shayan, Xu. "Value-added utilisation of waste glass in concrete". Cement and Concrete Research 34 (2004)81–89.
23. Shayan Ahmad, Xu Aimin. "Value-added utilisation of waste glass in concrete". Cement and Concrete Research 34 (2004) 81–89.
24. Shi Caijun, Wu Yanzhong, Riefler Chris & Wang Hugh. "Characteristics and pozzolanic reactivity of glass powders". Cement and Concrete Research 35 (2005) 987– 993.
25. Soroushian, P., Mirza, F., Alhozaimy, A., 1995. "Permeability characteristics of polypropylene fiber reinforced concrete". ACI Materials Journal 92 (3), 291–295.
26. Tim Boniface Instarmac Group plc WRAP Project code: GLA44-014. The Waste & Resources Action Programme Date (published) March 06.
27. Wan Jo Byung, Park Seung-Kook, Park Jong-Chil. "Mechanical properties of polymer concrete made with recycled PET and recycled concrete aggregates". Construction and Building Materials 22 (2008) 2281–2291.
28. www.cptechcenter.org/publications/imcp/
29. www.ehow.com/how_5577585_mix-recycled-glass-concrete.html.
30. www.greenstudentu.com/encyclopedia/recycling/plastic.
31. www.hinduonnet.com/2001/08/21/13210613.htm
32. www.indian-plastic-industry.com/types-of-plastic.htm
33. www.optaminerals.com/Abrasives/Greenblast.html
34. www.chemistrydaily.com/chemistry/Plastic
35. Zainab, Z. Ismail, E., Hashmi, A., 2007. "Use of waste plastic in concrete mixture as aggregate replacement" Waste Management.