

# Analysis Of Pervious Concrete With Waste Marble Powder Blended Cement And Recycled Pet Fibers As A Sustainable Construction Material

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**Abstract-** *Pervious* The rapid pace of urbanization has significantly increased impermeable surface areas, leading to severe storm water runoff and depleting groundwater reserves. Pervious concrete offers a viable solution for sustainable storm water management; however, its widespread structural application is often hindered by inherently low tensile strength and brittleness. This study investigates a cleaner production approach by evaluating the mechanical and hydrological performance of eco-friendly pervious concrete incorporating two distinct industrial and municipal waste streams: Waste Marble Powder (WMP) and Recycled Polyethylene Terephthalate (PET) fibers. In this investigation, WMP was used as a partial replacement for Ordinary Portland Cement (OPC) at varying percentages, while recycled PET bottles were processed into fibers and introduced as discrete reinforcement. A comprehensive laboratory program was executed to analyze the fresh and hardened properties of the modified mixes. The hydrological performance was assessed through total porosity and falling-head permeability tests, while the mechanical behavior was evaluated via compressive strength, split tensile strength, and flexural strength testing. The results indicate that while PET fibers bridge micro-cracks and substantially enhance the tensile and flexural capacity of the porous matrix, the extreme fineness of WMP acts as a micro-filler, densifying the interfacial transition zone around the smooth plastic fibers. This synergistic interaction helps mitigate the typical strength loss associated with plastic inclusions without significantly compromising the required hydraulic conductivity. The findings demonstrate that optimizing WMP and PET fiber content yields a highly sustainable construction material suitable for low-volume traffic pavements, pedestrian walkways, and parking lots.

**Keywords:** WMP, WBF, SLUMP, Compressive strength test, pervious concrete

## I. INTRODUCTION

### A. GENERAL

Concrete is composite material which consists of cement, coarse aggregate, fine aggregate and water in required proportions. Concrete is a material which used for the purpose of construction in now a days. Due to its composite nature concrete is weak in tension but strong in compression. Basic Principle involved in the increase in strength of concrete is heat of Hydration. The desired physical properties of the finished material can be achieved by including additives and reinforcements in the mixture. A fluid mass that is easily moulded into shape can be formed by mixing these ingredients together in certain proportions. Over the time, a hard matrix formed by cement binds the rest of the ingredients together into a stone-like durable material with many uses such as Famous concrete structures like the Hoover Dam, the Panama Canal and the Roman Pantheon. The concrete technology was used earlier on large-scale by the ancient Romans, and the concrete was highly used in the Roman Empire. The Colosseum was built largely of concrete in rome, and the concrete dome of the patheon is the World's largest unreinforced concrete. After the collapse of Roman Empire in the mid-18th century the technology was re-pioneered as the use of concrete has become rare. Today, the widely used man made material is concrete.

### B. PERVIOUS CONCRETE

The use of no-fines concrete as a pavement material has been extremely limited and has only recently been developed for this particular application. However, no-fines concrete has been used extensively as a structural building material in Europe, and the Middle East for over 70 years. The use of no-fines concrete became considerably more widespread during the material shortages after World War II, for cast-in place load bearing walls of single and multi-storey buildings. No-fines concrete has been used in south-eastern America for the past 20 years in pavement applications.

Pervious concrete is also a unique and effective means to address important environmental issues and sustainable growth. When it rains, pervious concrete automatically acts as a drainage system, thereby putting water

back where it belongs. Pervious concrete is rough textured, and has a honeycombed surface, with moderate amount of surface raveling which occurs on heavily travelled roadways (Concrete network, 2009). Carefully controlled amount of water and cementitious materials are used to create a paste (Dan, 2003). The paste then forms a thick coating around aggregate particles, to prevent the flowing off of the paste during mixing and placing. Using enough paste to coat the particles maintain a system of interconnected voids which allow water and air to pass through. The lack of sand in pervious concrete results in a very harsh mix that negatively affects mixing, delivery and placement. Also, due to the high void content, pervious concrete is light in weight (about 1600 to 1900kg/m<sup>3</sup>).

Pervious concrete void structure provides pollutant captures which also add significant structural strength as well. It also results in a very high permeable concrete that drains quickly. It can be used in a wide range of applications, although its primary use is in pavements which are in: residential roads, alleys and driveways, low volume pavements, low water crossings, sidewalks and pathways, parking areas, tennis courts, slope stabilisation, sub-base for conventional concrete pavements etc.

### C. BENEFITS OF PERVIOUS CONCRETE

#### Environmental benefits

- Helps in saving precious water which otherwise goes to drains.
- Helps in keeping earth below wetter, greener and cooler.
- Recharging ground water level.

#### Other benefits

- Eliminates the need of costly water drainage systems.
- Rough texture thus avoiding skidding of vehicles.
- Low maintenance cost.
- Stronger and durable for light traffic loads.
- Use of local building material.
- Use local semi-skilled mason or labor.-

### D. Objectives

Pervious concrete has been predominantly used in non pavements applications with only a limited use in pavement applications. The purpose of this project is to assess the suitability of pervious concrete to be used for the construction of road pavements.

The main objectives of this study as follows

- To investigate the properties of pervious concrete with fibers.
- To conduct the necessary tests to assess the strength.
- To analyze the results obtained and conclude the effectiveness of no fines concrete as a pavement material.

## II. REVIEW OF LITERATURE

Portland cement pervious concrete (PCPC) has great potential to reduce roadway noise, improve splash and spray, and improve friction as a surface wearing course. A pervious concrete mix design for a surface wearing course must meet the criteria of adequate strength and durability under site-specific loading and environmental conditions. To date, two key issues that have impeded the use of pervious concrete in the United States are that strengths of pervious concrete have been lower than necessary for required applications and the freeze-thaw durability of pervious concrete has been suspect. This research is supported with the related reading material previous research about the no fines concrete which had been done as the references to describe more and explain the characteristic and application of pervious concrete.

The literature search included reviews of published and unpublished literature, field Performance reports, and other published and unpublished documents.

A research project on the freeze-thaw durability of pervious concrete mix designs at Iowa State University (ISU) has completed (Schaefer et al. 2006). The results of this study have shown that a strong, durable pervious concrete mix design that will withstand wet, hard- freeze environments is possible. The strength is achieved through the use of a small amount of fine aggregate (i.e., concrete sand) and/or latex admixture to enhance the particle-to-particle bond in the mix. The preliminary results were reported in Kevern et al. (2005). The recent work has been limited to laboratory testing and to only a few mixes using two sources of aggregates. Preliminary laboratory testing has shown the importance of compaction energy on the properties and performance of the mixes, an issue that has direct bearing on the construction technique used to place the materials in the field. Additional laboratory and field testing is necessary to establish minimum mix design properties and determine optimum construction techniques.

**B.FERGUSON(2008)** Eight years of research have recently concluded with the first comprehensive review of porous pavement technology and applications resulting in the book, *Porous Pavement*, authored by Bruce Ferguson. It defines nine

families of porous paving material each of which has distinctive costs, maintenance requirements, advantages and disadvantages for different applications, installation methods, sources of standard specifications, and performance levels.

**R. C.MEININGER(2011)** Results of a laboratory study of no-fines pervious concrete for paving are presented. Conclusions are drawn regarding the percentage of air voids needed for adequate permeability, the optimum water-cement ratio range, and the amounts of compaction and curing required. Recommendations are made regarding appropriate uses for this type of concrete.

**M.A.PINDADO,A. AGUADO AND A.JOSA (1999)** Highly permeable materials provide drainage and noise-absorption properties that are useful in pavement top layers. In such porous concretes, the voids reduce the mechanical integrity, which may have to be compensated for with the incorporation of non-conventional components, such as polymers. A basic property needed for the design of pavements is the fatigue behavior of the material, which has not been studied thoroughly for polymer-modified porous concretes.

**L.M.HASELBACH AND R.M.FREEMAN(2005)** Pervious concrete is an alternative pavement material which may help reduce nonpoint source pollution problems. The porosity of pervious concrete is an important parameter used for both pavement and environmental design and is dependent on field placement techniques. It is recommended that porosity be tested on field-placed specimens. It has been noted that some of the concrete is knocked out while coring from field-placed samples which may affect the porosity. This paper researches a methodology for estimating the in-situ porosity of pervious concrete from the porosities of cores taken from the field based on aggregate size, core size and porosity.

**N.NEITHALATH, J.WEISS AND J.LEK (2006)** This paper presents a unique non-destructive method to determine the permeability of pervious concrete from electrical conductivity measurements. Combining the normalized electrical conductivity of pervious concrete determined using either alternating or direct currents with the porosity of the material, and applying it in a modified version of Kozeny-Carman equation, a new parameter called hydraulic connectivity factor is introduced. Using this factor, and the porosity, the hydraulic conductivity or permeability of pervious concrete is determined.

**L.M.HASELBACH,S. VALAVALA AND F.MONTES(2006)** Pervious concrete is an alternative paving surface that can be used to reduce the nonpoint source pollution effects of storm water runoff from paved surfaces

such as roadways and parking lots by allowing some of the rainfall to permeate into the ground below. This infiltration rate may be adversely affected by clogging of the system, particularly clogging or covering by sand in coastal areas.

**C.WOLFERSBERGER (2008)** Some critics claim that Pervious gets clogged with oil and debris. It can if not given minimum attention. Some common sense procedures will keep it performing indefinitely. All pavements require some maintenance depending on traffic and location. Pervious concrete usually requires much less.

**AMMAR YAHIA** have studied the effects of aggregate size and gradation as well as the paste volume on unit weight, compressive and tensile strength, porosity, and permeability of pervious concrete (PC). Three different coarse aggregate (CA) types with nominal maximum size of 2.5/10 mm (CA-10), 5/14 mm (CA-14), and 10/20 mm (CA-20) were used. Binary combinations of these aggregate were optimized to provide a wide range of uniformity coefficients ( $U_c$ ) and packing density values. All PC mixtures were proportioned with a fixed water-to-cement ratio (w/c) of 0.30. For each aggregate gradation, the inter-particle void index was determined and used as a design parameter.

### III. MATERIALS USED

#### MATERIALS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. WMP
5. Waste Bottle Fibres

#### CEMENT

Cement is a commonly used binding material in the construction. The cement is obtained by burning a mixture of calcareous (calcium) and argillaceous (clay) material at a very high temperature and then grinding the clinker so produced to a fine powder. It was first produced by a mason Joseph Aspdin in England in 1924. He patented it as portland cement.

**Table No-1** Physical Properties of Cement

Sl. No.	Properties	Values
1	Specific Gravity	3.54
2.	Standard consistency	31%

3.	Initial setting time in min.	35
4.	Final setting time in min	290

## COARSE AGGREGATE

Since approximately three-quarters of the volume of concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only may the aggregate limit the strength of concrete but the aggregate properties greatly affect the durability and structural performance of concrete.

Aggregate was originally viewed as an inert, inexpensive material dispersed throughout the cement paste so as to produce large volume of concrete. In fact, aggregate is not truly inert because its physical, thermal and sometimes, chemical properties influence the performance of concrete. For example, by improving its volume stability and durability over that of the cement paste. From the economic view point, it is advantageous to use a mix with as much aggregate and as little cement as possible, but the cost benefit has to be balanced against the desired properties of concrete in its fresh and hardened state. Material which retained on 4.75 mm size classified as a coarse aggregate. For most works, 20 mm aggregate is suitable. The locally available aggregate having nominal size of 20mm was used.

**Table-2** Properties of Coarse Aggregate

Sl. No.	Properties	Values
1	Specific Gravity	2.69
2.	Fineness modulus	5.01
3.	Water absorption	0.4%
4.	Aggregate Impact Value	21
5.	Aggregate Crushing Value	17.5%
6.	Los Angeles value	27%

## WASTE MARBLE POWDER

The use of Waste Marble Powder (WMP) in concrete, particularly in pervious concrete, is a significant area of research aimed at improving structural performance while promoting sustainable waste management. Marble powder is a fine byproduct generated during the sawing and shaping of marble blocks.

Waste Marble Powder (WMP) is a fine-grained industrial byproduct primarily composed of calcium carbonate, typically exhibiting a particle size of less than 75  $\mu\text{m}$  and a specific gravity ranging from 2.60 to 2.85. Its

morphological structure is generally angular to sub-angular, which, when combined with its high fineness, allows it to function effectively as a mineral filler that densifies the cementitious matrix by filling micro-voids and strengthening the Interfacial Transition Zone (ITZ) between coarse aggregates and the cement paste. Unlike pozzolanic materials, WMP acts primarily through a physical filler effect rather than chemical bonding, and while its addition can improve the workability and slump of concrete mixtures by reducing internal friction, it must be used in controlled proportions—typically 5% to 15%—to avoid excessive water demand or the potential for paste segregation that could compromise the interconnected pore system required for effective permeability in pervious concrete.

### 3.1 WASTE BOTTLE FIBRES

The Waste bottle which can easily be obtained from the environment with almost no cost. Waste plastic bottles are major cause of solid waste disposal. Polyethylene Terephthalate (PET, PETE or polyester) is commonly used for carbonated beverage and water bottles. This is an environmental issue as waste plastic bottles are difficult to biodegrade and involves processes either to recycle or reuse. The fibers have been obtained by simply cutting the bottles.

Waste Bottle Fibers (WBF) (2 mm wide and 75 mm long) are cut into discrete fibres and used in the project

## IV METHODOLOGY

In the present work, various proportioning for concrete mix was carried out and the proportions of cement to the aggregate ratios are 1:4, 1:6, and 1:8 and designated as M1, M2, M3 respectively. WMP is added to the cement with the percentage of 0%, 5%, 10% & 20% as a partial replacement in addition to 0%, 0.5%, 1%, 1.5% of Waste Bottle fibre.

DESIG NATION	MIX PROPORTION (CEMENT:AGGR EGATE)
M1	1:4
M2	1:6
M3	1:8

## 4.1 LABORATORY EXPERIMENTATION

In the present experimental investigation WMP has been used as partial replacement of cement in concrete mixes. On replacing cement with different weight percentage of WMP the Slump and compressive strength is studied at different ages of concrete cured in water and further studied effect of Waste Bottle fibers on WMP blended concrete.

## 4.2 LIST OF TESTS CONDUCTED

The following tests were conducted as per IS codes of practice.

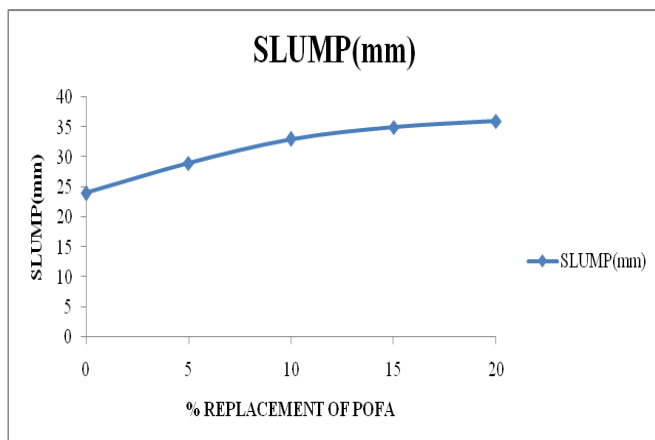
- Specific gravity
- Fineness
- Normal Consistency
- Water absorption test
- Sieve Analysis
- Slump test
- Compressive strength test

**V. RESULTS AND DISCUSSIONS**

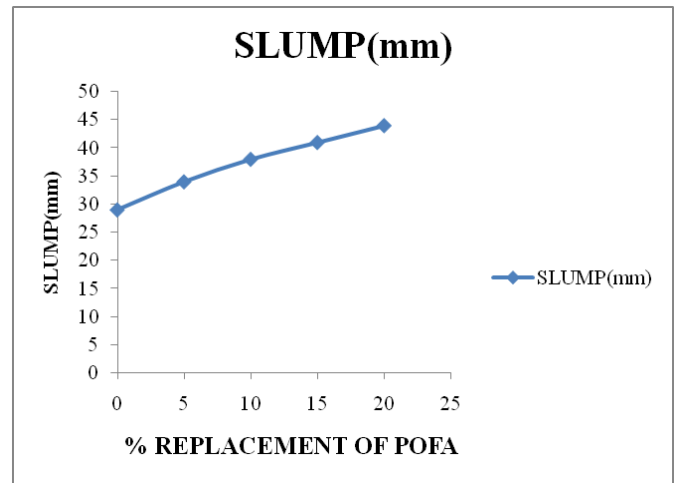
The result of the experimental investigation on WMP Blended Waste Bottle fibre reinforced concrete where WMP has been used as partial replacement of cement in concrete mixes designated as M1, M2, and M3. On replacing cement with different percentage of WMP the workability, compressive strength is studied after cubes cured in normal water and further discrete Waste Bottle Fibre reinforcement is provided and different tests are conducted and the test results are given below.

**Table 5.1: Variation of slump for different percentages of WMP For Different Mixes**

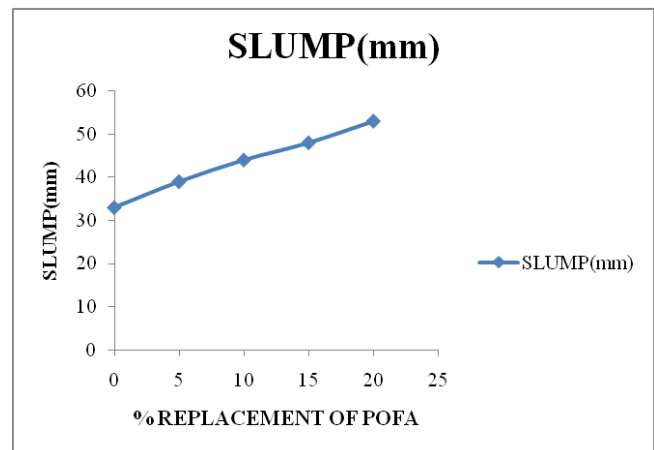
WMP(%)	SLUMP(mm) M1	SLUMP(mm) M2	SLUMP(mm) M3
0	24	29	33
5	29	34	39
10	33	38	44
15	35	41	48
20	36	44	53



**Fig: 5.1 shows the Variation of slump for different percentages of WMP For Mix M1**



**Fig: 5.2 shows the Variation of slump for different percentages of WMP for Mix M2**



**Fig: 5.3 shows the Variation of slump for different percentages of WMP For Mix M3**

**Table 5.2: Variation of Compressive strength for different percentages of WMP For Mix M1**

WMP(%)	7 Days	14 Days	28 Days
0	12.6	19.5	23.7
5	13.8	20.1	25.3
10	16.4	21.6	27.1
15	18.5	22.7	28.4
20	17.3	20.4	25.6

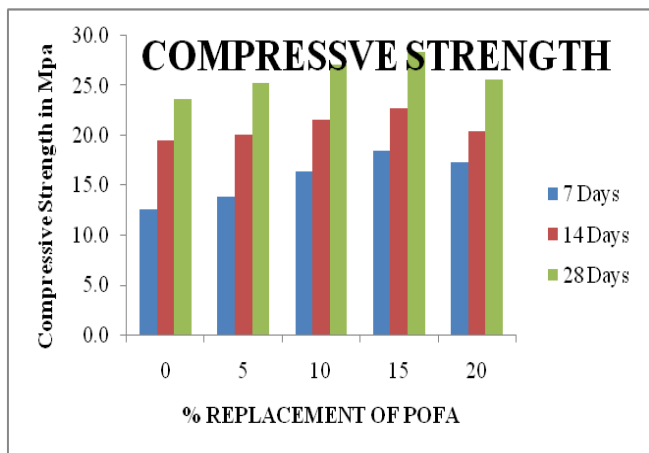


Fig: 5.4 shows the Variation of Compressive Strength for different percentages of WMP for Mix M1

Table 5.3: Variation of Compressive strength for different percentages of WMP For Mix M2

WMP(%)	7 Days	14 Days	28 Days
0	9.2	14.8	18.7
5	11.1	17.3	20.6
10	13.7	18.6	21.9
15	15.5	20.4	23.4
20	14.6	18.2	20.0

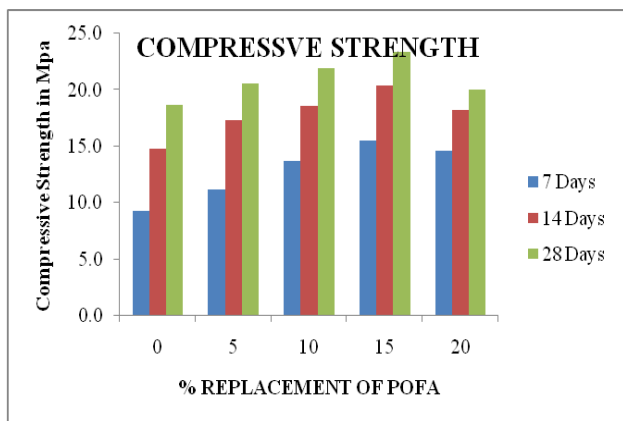


Fig: 5.5 shows the Variation of Compressive Strength for different percentages of WMP for Mix M2

Table 5.4: Variation of Compressive strength for different percentages of WMP For Mix M2

WMP(%)	7 Days	14 Days	28 Days
0	6.5	10.3	13.6
5	9.8	12.1	14.8
10	12.0	13.3	16.1
15	14.1	15.7	17.3
20	12.4	13.5	15.7

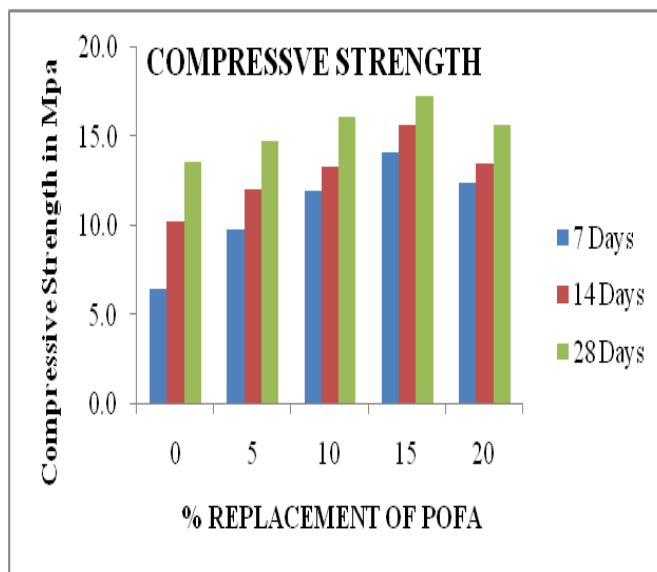


Fig: 5.6 shows the Variation of Compressive Strength for different percentages of WMP for Mix M3

Table 5.5: Variation of slump for different percentages of WBF for Different Mixes

WBF (%)	SLUMP(mm) M1	SLUMP(mm) M2	SLUMP(mm) M3
0	35	41	48
0.5	31	38	42
1	28	36	38
1.5	26	33	35
2	25	31	32

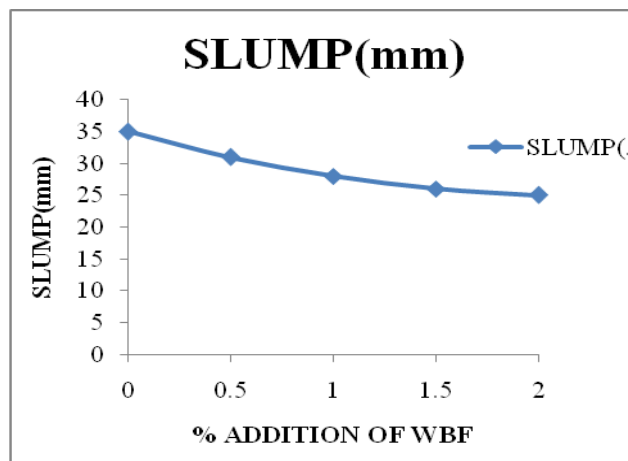


Fig: 5.7 shows the Variation of slump for different percentages of WBF For Mix M1

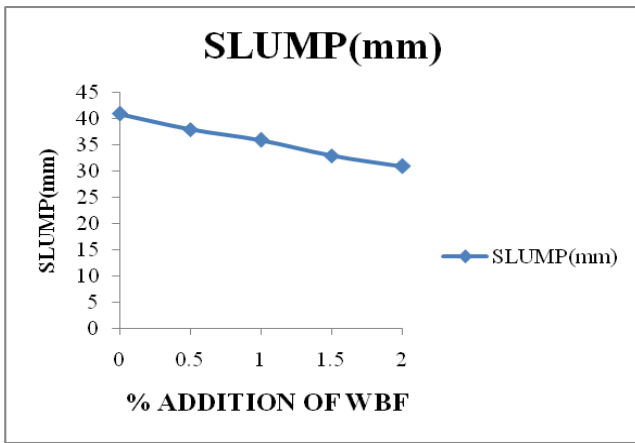


Fig: 5.8 shows the Variation of slump for different percentages of WBF for Mix M2

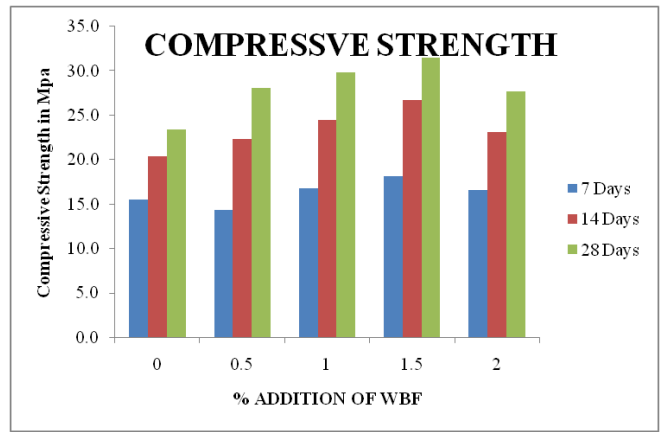


Fig: 5.11 shows the Variation of Compressive Strength for different percentages of WBF for Mix M1

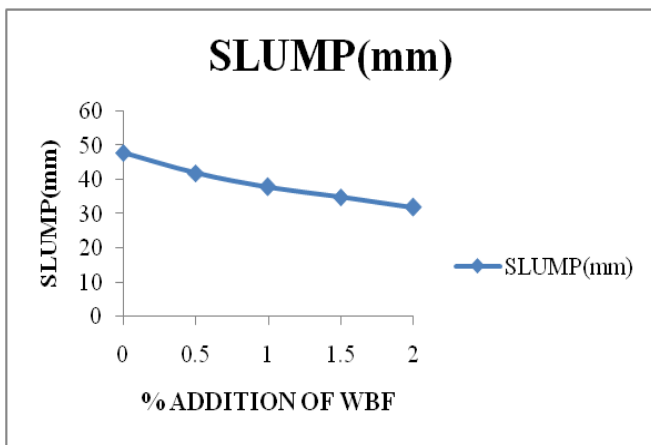


Fig: 5.9 shows the Variation of slump for different percentages of WBF for Mix M3

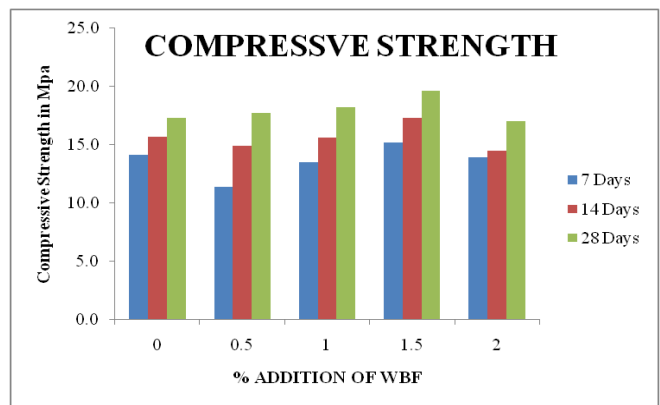


Fig: 5.12 shows the Variation of Compressive Strength for different percentages of WBF for Mix M3

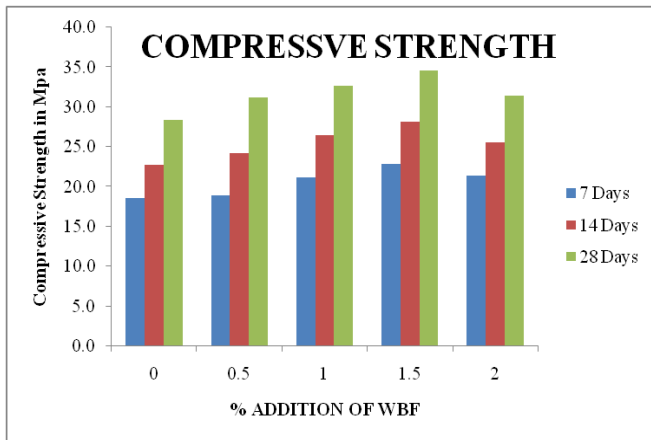


Fig: 5.10 shows the Variation of Compressive Strength for different percentages of WBF for Mix M1

It can be inferred from the graphs, that there is a gradual increase in Compressive strength with percentage replacement of WMP. From the above results the 15% replacement of Cement with WMP can be considered as optimum for all the mix proportions considered.

After taking the optimum percentage of WMP it is observed that Optimum Content of Waste Bottle Fibres (WBF) with an optimum 15% WMP as replacement in Cement at W/C ratio of 0.45. It can be inferred from the graphs, that there is a gradual increase in Properties of concrete with percentage replacement of WMP and percentage addition of Waste Bottle Fibre.

From the results it is concluded that 1.5% addition of Waste Bottle Fibre shows maximum compressive strength.

## VI. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

The following conclusions are made based on the laboratory experiments carried out. Based on the results and discussions, the conclusions regarding the use of waste marble powder (WMP) and waste bottle fibres (WBF) in concrete can be summarized as follows:

### 1. Effect of Waste Marble Powder (WMP)

- **Workability:** The slump value of the concrete mix increases as the percentage of WMP replacement increases, indicating that the addition of WMP reduces the water demand in the concrete.
- **Optimum Content:** Based on compressive and split tensile strength test results, a **15% replacement of cement with WMP** is considered the optimum content for all mix proportions (M1, M2, and M3).
- **Mix Performance:** Among the mixes tested (M1=1:4, M2=1:6, M3=1:8), the results were most pronounced for the M1 mix (1:4 ratio). Strength increases with the increase of WMP up to 15%, after which it begins to decrease.

### 2. Effect of Waste Bottle Fibres (WBF)

- **Workability:** Unlike WMP, the addition of WBF leads to a decrease in slump values, indicating a reduction in workability as fibre content increases.
- **Strength Enhancement:**
  - There is a gradual increase in both compressive and split tensile strength with the addition of WBF.
  - The percentage increase in strength continues as the fibre content increases.
- **Optimum Content:** The **1.5% addition of WBF** (combined with the previously determined 15% WMP replacement) is considered the optimum content for all considered mix proportions.

### 3. Summary

The experimental investigation demonstrates that waste materials can be effectively utilized to improve concrete properties. By replacing 15% of cement with waste marble powder and adding 1.5% of waste bottle fibres, the concrete achieves enhanced compressive and split tensile strength compared to conventional mixes, with the M1 (1:4) mix showing the most significant performance improvements.

Finally it can be summarized that the materials WMP and Waste Bottle Fibre inclusions had shown promising influence on the Mechanical Properties of concrete, thereby giving a two-fold advantage in solving a problem of waste disposal and ground water recharge.

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- [38] Concrete Technology, by M.S.Shetty.