Chapter-1

INTRODUCTION

1.1 Background

Stone has played a significant role in human endeavors since earliest recorded history and its use has evolved since ancient times. The quarrying and working of stone, already practiced in ancient times by the Egyptians and the Greeks, is greatly developed in Italy under the Romans. However towards the end of the 18th century, economic activity in the stone sector developed for the first time with the invention of gunpowder and the use of mechanical cutting. Dimensional stones were produced in more than 42 countries of the world while 12 of these producers were dominant in the international market i.e. 6 European countries and 3 each from Asia and Africa. Technological advances in the last seventy years had increased the world production and consumption of dimensional stones to 150 million tons while, consumption came to about 8.8 billion square feet (820 million square meters), generating overall turnover of $40 billion. The majority of world consumption comes from material that is quarried in different countries than those where it is eventually installed. The leading producers China, India, Italy, Spain and Portugal account for 53% of world quarrying production. The driving force in the sector is international trade, which is just under 29.6 million tons and equal to about 4.8 billion square feet (450 million equivalent square meters) and had reached US$ 8.6 billion mark in 2004 with an annual average increase of 13% while China had shown the largest increase in its export value i.e. almost 28% annually over 4 years. Italy, China and Spain were the major players in the international market and exported more than 55% of the dimensional stone's products (blocks and processed) by value. Other major exporters included Brazil, Spain, India, Turkey and Portugal. Marble and Granite is the sixth largest mineral extracted, the others being coal, rock salt, lime stone and china clay. Since 1990 mining & quarrying had consistently contributed 0.5% to the GDP. According to the industry estimates 1.37 million tons of marble and granite were produced while 97% of it is consumed locally. Little efforts were made in the past to identify and estimate marble and granite reserves in the country. Some of the reserves of marble and granite were however calculated with the efforts made by development projects and concerned departments. Known reserves of Marble in Pakistan were 160 million tons while actual reserves could be manifold. These reserves were mostly concentrated in NWFP and Baluchistan. Estimated reserves of

Granite in Pakistan were 2 billion M.T. out of which 1.15 Billion M.T. were in Thar - Sindh.**[1]** Major mining areas can be identified as Chitral, Buner, Swat, Lasbela, Swabi, Khuzdar, Mohmand Agency, Mardan, Nowshehra, Kashmir and Mansehra. Mine in Mianwali had also started meager operations.**[2]** Extraction of marble in Pakistan has increased 155 fold from 3000 tons in 1959-60 to 520,000 tons in 2003-04.Details of extraction of marble in last few years are given in Table 1-1**[3]**

Table 1.1: Record of Extraction of Marble in Pakistan

Year	Quantity (tons)
1989-90	267,000
1990-91	281,000
1991-92	321,000
1992-93	388,000
1993-94	460,000
1994-95	467,000
1995-96	458,000
1996-97	360,000
1997-98	380,000
1999-00	390,000
2000-01	450,000
2001-02	470,000
2002-03	485,000
2003-04	520,000

Marble and Granite is the sixth largest mineral extracted, the others being coal, rock salt, limestone and china clay. Since 1990 mining & quarrying had consistently contributed 0.5% to the GDP. According to the industry estimates 1.37 million tons of marble and granite were produced while 97% of it is consumed locally.**[1]**

1.2 Marble

The word Marble is derived from Greek word "Mamaros" which means shining stone. Marble is a non-foliated, Granular Metamorphic Rock which is formed by the Metamorphism of Limestone and Dolostone. Its chemical nomenclature is calcium Carbonate ($CaCO_3$). The term marble is also applied to serpentine rocks that can be polished to high shine. The Marble is a carbonate rock which means it has carbonate (CO_3) in chemistry. It is any limestone that is hard enough to take polish. It is used as construction material for buildings and interiors, and for manufacture of handicrafts. The finest marble is white and all varieties are composed of crystals of mineral calcite or dolomite, which are perfectly white when pure. Black, grey, pink, red, green, and various other kinds of marble is used in buildings and monuments.

Marble, Onyx and Granite belong to the category of building stones widely known as Dimension Stone, These are natural stones which can be shaped in form of blocks, slabs, tiles, etc and are mostly used for monumental and decorative purposes since antiquity, various civilizations have used dimension stone in many ancient buildings and monuments that have survived to the present day. Although numerous varieties of igneous, metamorphic and sedimentary rocks are used as dimension stone, the principal rock types used are granite, limestone, marble, sandstone and slate.

Ancient peoples made their finest buildings with either granite or marble. For instance the Egyptians worked chiefly with granite and Greeks with marble. Romans and Mughals also used marble with great skill.

1.2.1 Chemical Composition of Marble

Calcite & Dolomite Carbonate of calcium

(Hardness 3-sp.grav.2.72)

Carbonate of calcium & Magnesium (Hardness 3.5/4-Sp.Grave.2.9)

1.2.2 Marble Formula

($CaCO_3$), 1- Calcium, 1-Carbon, 3Oxygen

Pakistan has enormous wealth of marble, re-crystallized lime stone, fossil-ferrous limestone, dolomite and granite.

1.2.3 Marble Reserves

Not specifically measured, however Marble& Onyx more than 300 billion tons of reserves are estimated.**[2]**

1.2.4 Major Colors

White, Black, Green, Pink, Grey, Brown and Yellow colors.

Common forms of marble are discussed below:

1.2.5 Onyx

It is a fine-grained variety of quartz and the name is derived from the Greek word which means 'fingernail' to indicate the sharply contrasting bands of color in the stone. Onyx is strong and takes a high polish. The color of onyx marble varies from white to green, red and brown. Much of this soft onyx marble is cut into gemstones, colored and set into inexpensive jewelry. It is also used as a decorative stone in which form it has its major market in Pakistan.

1.2.6 Major Colors

Dark Green with layers of Light Green, Green with streaks of white & yellow and White with layers of Light Grey.

1.2.7 Location

Onyx occurs mainly in Chaghai District, Baluchistan. Baluchistan Onyx is favorite in the world markets and is used for facing, flooring and decorative items.

1.2.8 Granite

It is a hard crystalline rock made up chiefly of mineral crystals such as quartz and feldspar, and a few dark colored minerals. Granite is light colored and its crystals are large enough to be seen with the naked eye, like polished surfaces of granite blocks used in monuments and buildings. Granite is used in the construction of buildings and bridges due to the valuable support that it offers where great strength is needed, as it can withstand a pressure of 15,000-20,000 pounds per square inch. It is used for monuments as it can be polished and is hard enough not to be easily damaged. Carvings and inscriptions on granite withstand weather impacts for centuries.

1.2.9 Reserves

Not specifically measured, however more than 1000 billion tons of granite reserves are generally estimated.**[2]**

1.2.10 Major Colors

Black, Pink, Grey, Green, Gold & Yellow and Red

1.2.11 Location

Gilgit, Dir, Chital, Swabi, Kohistan, Nagarparker, Chagai, Mansehra, Malakand& Swat. Nagarparkar (Sindh) and Mansehra (Khyber Pukhtoonkhwa) are only known sources of workable Granite in the country. Geology evidence shows Gilgit Region holds great promise of the superior quality deposits.

1.3 Problem Statement

Nature has gifted Pakistan with large deposits of high quality marble and granite. World Stone production reached the peak of some 75 million tons net of quarry waste.**[4]** The official production figures of Pakistan are remarkable about 5,20,000 tons back in 2004; yet, the real production is considerably higher than the level indicated by the official statistics and it has also increased over the past 8 years. Extraction of marble in Pakistan involves boring of holes in the bedrock that are filled with explosives to blast the rock. The raw stone obtained is brought to marble cutting units and is cut as demanded either into tiles or slabs of various thicknesses (usually 25mm), using a gang saw. Water is showered on blades while stone blocks are cut into sheets of varying thickness to cool the blades and absorbs the dust produced during the cutting operation. The amount of wastewater from this operation is very large. It is not recycled as the water so highly alkaline that, if re-used, it can dim the slabs to be polished. In large factories, where the blocks are cut into slabs, the cooling water is stored in pits until the suspended particles settle (sedimentation tanks), then the slurry is collected in trucks and disposed of on the ground and left to dry. This water carries large amounts of stone powder. Owing to poor regulatory enforcement, the situation of industrial waste management in Pakistan is worsening. The industries are generating liquid as well solid waste and are disposing it openly on land or in rivers. There is no restriction over the improper disposal of waste in Pakistan that is resulting in number of serious problems like water reserves contamination, damage to aquatic life, diseases and etc.

The marble slurry as well as irregular pieces generated is generally disposed off in open lots, streams, roadside etc. that is not only resulting in to land degradation but also contaminating our waterways. Similarly water containing marble slurry is disposed off in a nearby river or streams which results in rivers contamination and damage the aquatic life. There is no proper method of disposal of solid wastes as well as contaminated water being generated by marble industry in Pakistan.

Thus due to lack of capability to enforce National Environmental Quality Standards (NEQS), this whole process is resulting in to loss of water reserves, land degradation and aquatic life. The enforcement process is slow due to influential industrialists in Pakistan who do not want to invest over proper disposal of wastes.

1.4 Waste Quantification

Actual figures about the quantity of waste produced in Pakistan from the marble and granite industry are inaccessible since it is not calculated or monitored by the government or any other party. Most references estimate that 20 to 25% of the marble/granite produced results in powder in the form of slurry, as for each marble or granite slab of 20mm produced; 5 mm is crushed into powder during the cutting process.**[5],[6]**

This powder flows along with the water forming marble slurry. Based on the lowest estimates of waste percentage, it can be estimated that about 1,30,000 ton of waste was produced in Pakistan back in 2004.

1.5 Marble Processing Wastes

1.5.1 Solid Waste

During the process of extraction and processing of raw marble in the marble processing units two types of waste is generated:

1. Crushed stone of irregular size produced in the quarry site.
2. Marble slurry dust produced during cutting and finishing of marble stone in marble processing units. It is carried away by the water used for cooling the blades of cutter and is deposited in the water channels.
3. Furthermore the stone of irregular size is transported to the nearby crusher machines to produce aggregate of different sizes and stone dust is produced as a byproduct. This

stone dust contains large amount of fines passing #200 sieve almost 15 to 20% by weight.

1.5.2 Liquid Waste

Another waste is the water itself which contains small amount of suspended marble slurry. The water utilized during the processing of marble is wasted without recycling due to its alkaline nature which may dim the polished surface of marble. Wastewater is being disposed off to nearby streams or rivers resulting in to contamination of ground water reserves and damage to aquatic life. On the other hand Pakistan is running shortage of water reserves and this deficiency can overcame by considering the recycling options for wastewater in industries.

1.6 Adverse Impacts of Marble Powder

Waste marble powder is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The amount of waste marble powder generated is very substantial as discussed earlier. The marble cutting plants are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of vast area of land especially after the powder dries up. This also may leads to contamination of the underground water reserves. **[5],[6]**

Traditionally, WMP products are disposed of as soil conditioners or land fill. However, there might be reusing or recycling alternatives that should be investigated and eventually implemented. Thanks to Civil Engineering research, numerous uses of waste marble powder have been introduced, including use in tiles manufacturing, concrete mixes, sub grade fill, and modified binder. **[7], [8],[9],[10]**Of our particular interest is the use of marble powder and stone dust in the concrete.

While marble blocks are cut by gang saws, water is used as a coolant. The blade thickness of the saws is about 5 mm and normally the blocks are cut in 20mm thick sheets. Therefore, out of every 25mm thickness of marble block, 5mm are converted into powder while cutting. This powder flows along with the water as marble powder. Thus nearly 20% of the total weight of the marble processed result into WMP. The produced WMP has nearly 35%-45%

water content. The total waste generation from mining to finished product is about 50% of mineral mined.

1.6.1 Health Problems

Processing of marble results in the formation of marble dust, which is suspended in the air and may then, is inhaled by the workers. Epidemiological studies indicates that workers exposed to marble dust stand an increased risk of suffering from asthma symptoms, chronic bronchitis, nasal inflammation and impairment of lung function.**[12],[13]** The affected workers were having body problems like headache, backache and stressed due to under-payment. Individuals having Papilloma have faced problem at work like noise, dust or fumes and poor maintenance of equipment.**[14]** The Dutch Expert Committee for Occupational Standards (DECOS) has recommended a health- based limit of 0.2 mg/m3 to prevent irritation of eyes and of the respiratory tract, as well as to minimize the risk of occupational asthma and nasal allergies. It was noticed that the highest exposures have generally observed during sawing machine for cutting and emery machine for polishing and glossing the surface. The rising threats to the health of the workers and inhabitants residing near the marble quarries in Pakistan, and the workers and residents living in adjacent areas are prone to a disease called silicosis, whereby inhaled marble dust damages the cells of the respiratory system.**[11]**

1.6.2 Environmental Problems

Cutting the stones produces heat, slurry, rock fragments, and dust. The wastes are dumped on the road sand the adjacent land and the dust is airborne by the wind and scrap is scattered. The marble slurry could lead in the long run to water clogging of the soil, to increasing soil alkalinity, and to disruption of photosynthesis and transpiration. **[15]** The net effect is a reduction of soil fertility and plant productivity. The marble powder also compromise the aesthetic appeal of the adjacent area by blanketing plants and surfaces. The WMP imposes serious threats to ecosystem, physical, chemical and biological components of environment. Problems encountered are:

1. It adversely affects the productivity of land due to decreased porosity, water absorption, water percolation etc.

2. When dried, it becomes air borne and cause severe air pollution. Introduces occupational health problems, it also affects machinery and instruments installed in industrial areas.
3. Affecting quality of water during rainy season, and reducing storage capacities and damaging aquatic life.
4. The heaps of slurry remain scattered all around the industrial estates are an eye sore and spoil aesthetics of entire region.
5. Due to long deposition on land, the finer particles block flow regime of aquifers thus seriously effecting underground availability.
6. Similarly extraction and processing of marble results in 35 % marble pieces of irregular sizes, which are of no use and are dumped on to barren land, which is resulting in land degradation.

From above discussion it is evident that marble waste is a problem and requires special attention. Hence is dire need to study various options for marble waste management and Special attention is required to establish treatment and recycling scheme for minimizing the threats to environment.

1.7 Scope

Keeping in view the above problems which are prevailing in our country we will address the situation in District Nowshehra in general and Barabanda industrial area in particular. Our activities will be limited to District Nowshehra. Raw materials including marble slurry and stone dust were collected from Barabanda Industrial area and concrete samples were prepared with following ratios as shown in table 1.7.The tests which were performed are Compressive strength test (ASTM-C39), Splitting tensile strength test (ASTM-C496), flexural strength test (ASTM C78/C78M), permeability test of concrete, XRF test of stone dust and marble powder, modulus of elasticity test of concrete and slump test (ASTM-C143).

Table 1.2 Percentage of MP and Crushed Stone

S/No	Batch No	%age of Marble Powder	% of Stone Dust
1	B-1	0%	0%
2	B-2	10%	0%
3	B-3	20%	0%

4	B-4	0%	25%
5	B-5	0%	50%
6	B-6	10%	25%
7	B7	20%	25%
8	B-8	10%	50%
9	B-9	20%	50%

While addressing the marble industry in general we kept our focus on the industries in the local area of Barabanda, Nowshehra and surroundings. The raw materials were collected from the Barabanda industrial area and all the tests were conducted in MCE labs for the above percentages of concrete. The samples were casted, cured and tested in lab environment to check the various perimeters of concrete.

1.8 Objectives

The objectives of proposed study are:

1. Investigating the engineering feasibility of crushed stone as a replacement material for sand and marble powder slurry waste as a filler material in construction industry, by performing various lab analysis.
2. To evaluate the cost effectiveness of construction by replacing sand with crushed stone.

1.9 Summary

In this chapter the basic definition of marble and its uses has been explained. The locations of marble reserves have been told. The problem statement is explained and the types of marble wastes are clarified. Light has been thrown on adverse effects of marble waste on environment. In the end scope and objectives are elaborated.

Chapter-2

LITERATURE REVIEW

2.1. General

Marble and crushed stone industry has grown significantly in the last decades with the privatization trends in early 1990's. Crushed stone is highly polluting waste and its alkaline nature, manufacturing and processing techniques imposes a health threat to the surroundings. Waste marble powder is generated as a by-product during cutting of marble; this waste is approximately in the range of 20% of the total marble handled. The marble cutting plants are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental hazards and dust pollution occupy vast area of land especially after the powder dries up. This also may leads to contamination of the underground water reserves. **[16]** Waste products are disposed of as soil conditioners or land fill. However, there might be reusing or recycling alternatives that should be investigated and eventually implemented. As a result of Civil Engineering research, numerous uses of waste marble powder has been introduced, which includes use in tiles manufacturing, concrete mixes, sub grade fill, and modified binder. **[17]**

2.2. Industry of Marble in Pakistan

Pakistan is blessed with immense natural mineral resources. Nature has gifted Pakistan with enormous wealth of marble, recrystallized lime stone, fossil ferrous limestone, dolomite and granite.

Years of neglect on the part of the successive governments, outdated extraction methods and lack of modern manufacturing facilities have taken their toll on the marble sector which, despite being accorded the status of industry over a decade ago, has not only failed to develop on organized lines, but is also facing a technical crisis at present.

Though the extraction of marble has increased 155-fold, from 3,000 tons in 1959-60 to 467,000 tons in 1994-95. Extraction and export in the last few years show a declining trend for the industry which contributed a negligible 0.13 per cent to the overall exports in 1995-1996.

Furthermore, the lack of quality control has resulted in wide variation in export prices — 12,719 metric tons of marble and stone exports fetched $2.285 million in 1993-94 while over seven-fold increase in the quantity in 1994-95 depicted only a 50 per cent increase in the value in 1994-95. **[3]**

While onyx is only found in Baluchistan, marble is found in the northern North West Frontier Province, Sindh and Baluchistan. Onyx is primarily used in the manufacture of handicrafts while the comparatively harder marble and granite are mostly used in the construction industry.

While the price of marble, granite and onyx is largely governed by the color, pattern, texture, hardness and resistance to environmental change, the size of the rock also results in added value.

While internationally the quarrying machinery consists of drilling, wedging and splitting equipment, use of outdated extraction methods here in Pakistan results in considerable waste. Extraction in Pakistan comprises boring of holes in the bed rock which are filled with explosives to blast the rock. This results not only in a high, 35 per cent, wastage, but also in smaller stone size which substantially reduces the price which is directly proportional to size. In addition, this also limits the scope of value addition in certain high priced products as table tops, flower vases, table lamps, etc. As the raw stone is sold by weight to the processing companies, whose product size is consequently smaller, it deprives the miners of a substantial amount of money. The extraction method used in Pakistan is totally opposite to the modern method, which consists of drilling holes around the optimal block size and the use of hydraulic jacks and splitting equipment to pries the block out of the bed rock. The block size and shape of the rock are thus more controlled and the wastage is minimized to less than seven per cent. **[3]**

2.3. Threat to life due to Marble Slurry

Marble slurry is generated as a by-product during cutting of marble. The waste is approximately in the range of 20 % of the total marble handled.

Figure: 2.1 Marble Slurry as Waste Material

The marble cutting industries are dumping the marble slurry in any nearby pit or vacant spaces like forms and fields or rivers. This leads to serious environmental and health pollution and occupation of valuable agricultural. Air borne dried slurry is a breath inhibitor. The marble powder waste imposes serious threats to ecosystem, physical, chemical and biological components of environment. Problems encountered are:

1. It adversely affects the productivity of land due to decreased porosity, water absorption, water percolation etc.

2. When dried, it becomes air borne and cause severe air pollution. Introduces occupational health problems, it also affects machinery and instruments installed in industrial areas. **[18]**

3. Affecting quality of water during rainy season, and reducing storage capacities and damaging aquatic life.

4. It adversely affect social and industrial activities of people since the heaps of powder remain scattered all round the country are an eye sore and spoil aesthetics of entire region.**[19]**

2.3.1 Marble Slurry

The amount of the marble slurry generated is very substantial being in the range of 5-6 million tons per annum. The heaps of this waste material acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region and have affected the tourism and industrial potential of the state. **[20]**While marble blocks are cut by gang saw, water is used as a coolant. The blade thickness of the saws is about 5 mm and normally the blocks are cut in 20 mm thickness sheet. Therefore out of every 25 mm thickness of marble block, 5 mm are converted in to powder while cutting. This powder flows along with the water as marble slurry. Therefore nearly 20% of the total weight of the marble processed results into marble slurry. The marble slurry has nearly 35 % to 45 % water content. The total waste generation from mining to finished product is about 50 % of mineral mined.

Figure: 2.2 Gang saw for cutting small marble rocks

2.3.2 Quantitative Analysis of Marble Slurry

XRF test are conducted at NUST (H – 12 Campus) for measuring the composition of elements present in marble slurry. Results are shown in table below:

Figure: 2.3 XRF testing

Table: 2.1 Quantitative result of marble powder with oxides

Ser no	Elements	%age
1	MgO	2.1805
2	SiO2	0.6116
3	SO3	0.1309
4	CaO	96.5773
5	Fe2O3	0.3578
6	GeO2	0.0417
7	BrO	0.0216
8	SrO	0.0605

Table:2.2 Qualitative analysis of marble slurry

Ser no	Elements	%age
1	Mg	1.2177
2	Si	0.3347
3	S	0.0769
4	Ca	97.7820
5	Fe	0.4093
6	Sr	0.0824
7	Pb	0.0970

Marble slurry collected from different local industrial areas was analyzed physically before using it as an additive with concrete. Physical properties like specific gravity and bulk density were calculated by using formulas.

Table: 2.3 Properties of marble slurry

Property	Result
Bulk density (gm/cc)	1.3-1.5
Specific gravity	2.83-2.87

Table 2.4: Particle Size Distribution of Marble Slurry [16]

Particle size (mm)	% finer by Volume
363.1	100
193-205.8	90
130-140	80
81-94.7	70
54.5-62.51	60
37.5-43.1	50
23.9-28.1	40
14.24-15.2	30
5.9-7.15	20
1.23-1.69	10
0.321	0.00

Figure: 2.4 Sieve Analysis

Table: 2.5 Physio-Chemical Characteristics of Marble Slurry [16]

Property	Results
Density	1.96 g/cu.cm
Moisture content	0.2 - 0.40%
Modulus of rupture	21 -26 Mpa
Tensile strength	23 - 25 Mpa
Compressive Strength	77 - 96 Mpa
Water absorption# 2 hours	0.15 - 0.40%
Fire retarding tendency	Self-extinguishing
Exposure to boiling water	No change in dimensions
Chemical action	Appears chemically inactive

2.3.4. Hazards due to Marble Slurry

The marble slurry imposes serious threats to eco-system, physical, chemical and biological components of environment.

Problems encountered are:

1. When dumped on upper land, it adversely affects the productivity of land due to decreased porosity, water absorption, water percolation etc.
2. Slurry dumped areas cannot support any vegetation and remain degraded.
3. When dried, the fine particle become air born and cause severe air pollution. Apart from occupational health problems, it also affects machinery and instruments installed in the industrial area.
4. During rainy season, the slurry is carried away to rivers, drains roads and water bodies effecting quality of water, reducing storage capacities and damaging aquatic life.
5. Due to long deposition on land the finer particle block flow regime of aquifers thus seriously effecting underground availability.

6. The heaps of slurry remain scattered all around the industrial estates are an eye sore and spoil aesthetics of entire region. Subsequently tourism and industrial potential of the state is adversely affected.

These generated wastes cause environmental, health and economical drawbacks. Few of which are described below:

a. Environmental Problems

When stone slurry is disposed in landfills, its water content is drastically reduced and the stone dust resulting from this, presents several environmental impacts in dry season the stone powder dangles in the air, flies and deposits on vegetation and crop. All these significantly affect the environment and local systems. In some cases, stone dust disposed in the river bank and around the production facilities cause reduction in porosity and permeability of the topsoil and results in water logging. Moreover, fine particles result in poor fertility of the soil due to increase in alkalinity. **[21]** Runoff from the scrap mounds can cause erosion problems, and fines introduced into natural waterways can suffocate local eco systems.

Figure 2.5: Waste marble slurry left unattended

b. Health Problems

Marble waste and scrap can impart undesirable visual impact on workers if not stacked properly. Airborne dust from uncovered stockpiles or poorly functioning filtration equipment can cause respiratory, ocular or dermal irritation for employees and local community. If waste contain silica it can even cause lung cancer. **[22]**

c. Economic Problems

Large amount of Crushed stone generated in manufacturing industry has to be transported to landfills bares a vast sum of money. Besides, the accumulation of waste in landfills is also pressing problem for many businesses, from economic prospective. Therefore it is extremely important to incorporate this kind of waste in other industrial activities.

2.4. Types of Wastes

Marble extraction methods used in Pakistan result in a smaller size of extracted stone and as high as 35% wastage of marble rocks, which as a result reduces the price. These marble blocks are then brought to cutting units for final cutting and processing phase. The size of marble is directly proportional to its price.

Water is used as a coolant during marble cutting process. Out of every 25 mm thickness of marble block, 5 mm are converted in to powder while cutting. This powder flows along with the water as marble slurry. Thus, nearly 20% of the total weight of the marble processed results into marble slurry. The marble slurry has nearly 35 % to 45 % water content. The total waste generation from mining to finished product is about 55 % of mineral mined.

The water required per plate is 10 to 12 liters per minute and therefore a gang saw requires about 43000 liters water per hour.**[22]**

Thus the whole process results in two types of wastes:

1. Marble pieces of varying sizes generated during extraction and cutting process and marble slurry
2. Marble wastewater

The size of marble waste produced during the processing is shown in Table 2.5:

Table 2.6: Size Distribution of Marble Remains

Maximum	5-6 Inch
Minimum	2-3 Inch
Average	3-4 Inch

In the present study efforts have been done to find the environmentally and financially feasible solution of marble industry wastes management.

2.4.1 Crushed Stone

Natural and artificial stone industry generates large volume of crushed stone. It is classified to various forms such as powder or fines, aggregates, larger stone pieces and cobbles, damaged blocks or slabs and stone slurry. These generated wastes cause environmental, health and economic problems.

Figure 2.6: Crushed Stone at crush plant

2.4.2 Physical Properties of Stone Dust

Physical properties of stone dust are examined before replacing with sand in concrete mix. Standard methods are used to calculate grain size distribution, fineness modulus.

Stone dust fineness modulus = 2.4

Table 2.7: Sieve Analysis

SIEVE NO.	% BY WEIGHT (gm)
4	1
8	116
16	242
30	264
50	197
100	297
200	62
Pan	60

Table 2.8 : Qualitative analysis of crushed stone by XRF

Ser no	Elements	%age
1	Mg	0.7595
2	Al	1.0889
3	Si	2.6902
4	K	06567
5	Ca	91.4143
6	Cr	0.2263
7	Mn	0.0886
8	Fe	2.5019

2.4.3 Crushed Stone Applications

A lot of researches have been done all around the world in utilization of natural and artificial crushed stones in different types of industries, in particular, construction materials. The continued depletion of natural resources in construction industry throws new light on the potential use of some industrial wastes like crushed stone in its different materials.

Table 2.9: Reuse of Crushed stone Material

Crushed stone Forms	**Different Applications for Crushed stone Reusing**					
Fines	Asphalt and concrete	Brick manufacturing	Construction fill	Media for bio filtration systems	Mineral content for soil	Synthetic aggregate production
Aggregate	Construction fill	Construction mixture ingredient	Landscaping &decorative uses	Media for bio filtration system	Residential driveway	Road bed construction material
Larger stone cobbles	Fill for gabion retaining walls	Jetty rock	Landscaping & decorative uses	Rip rap	-	-
Damaged blocks or slabs	Aggregate	Cut stone tiles	Stone pavers	Veneer	-	

2.5. Solid Waste

2.5.1 Recognition of Stone Dust and Marble Waste

Crush plants and Marble industries were visited in Mardan and Nowshehra in order to develop the understanding of processing technology. Visual inspection, literature review and discussions with employees of industries helped in developing the understanding of processing and types of wastes generated during the process.

2.5.2 Current Waste Management Practices

In 2004, 520,000 tons of marble were extracted in Pakistan. Poor extraction methods resulted in 104,000 tons of marble slurry and 182,000 tons of marble stone of irregular size that was of no use. **[3]**The marble cutting industries are dumping the marble slurry and marble stones in any nearby pit or vacant spaces like land or rivers. This leads to serious environmental and dust pollution and loss of vast area of land especially after the slurry dries up. Fine slurry particles percolate into the topsoil along with rainwater thus making is less fertile. Over a long stretch of time, this would also contaminate the underground water reserves. The other option being observed for the marble solid waste is disposal in to waterways. This is resulting in to contamination of water reservoirs, which is harmful for aquatic life. Pakistan is already running shortage of water reservoirs which can be used for the desired purpose and when these sources get polluted it becomes costly to treat water for the required purpose. This is also resulting in the decreased capacity of water reservoirs.

2.5.3 Waste Management Options

Following are the some options for the waste management of marble industries:

There are two options, which can be considered for the disposal of marble solid wastes.

1. Recycling and/or reuse options
2. Disposal in to landfill site.

The present study for the waste management of marble slurry is conducted for considering the reuse option of the marble slurry. For the desired purpose concrete blocks were prepared using marble slurry in various ratios in order to consider reuse option for the waste management of marble industry. The details of concrete block casting and testing are mentioned below.

2.6 Summary

In this chapter the terminology used and concept of the paper has been explained. The main definition of marble slurry, the threat it poses to life and its basic physical properties have been explained. Furthermore the types of waste, their properties and utilization have been discussed along with waste management options.

Chapter-3

MATERIALS AND METHODS

3.1 Methodology

Marble slurry is collected from various industries in Barabanda industrial area which was used as an additive in concrete mix and stone dust from crush plants used as replacement material for sand with different composition (%ages) and samples were casted, cured and tested. After laboratory testing of the casted samples, the feasibility of marble slurry as well as crushed stone in construction industry is evaluated. At the end cost analysis of sand replacement by crushed stone is carried out for comparison with standard concrete.

3.2 Stone Dust

Sand is being replaced by stone dust in different percentages. Samples were casted with measured percentage of all constituents. Stone dust used as replacement material for sand is available in abundance at crush plant sites at Nowshehra, Risalpur, Peshawar, and Swat. The idea of replacement also leads us to the concept of green concrete which uses bye products (crushed stone) in place of natural materials (sand). The economy is achieved by using crushed stone in place of sand due to its local availability. The results obtained are quite satisfactory.

3.3 Slurry Formation

A standard mix design by absolute volume method was made which was kept constant throughout the experiments. The slurry was collected from the nearest sites of Risalpur from Barabanda industrial area. The slurry brought was first dried in open air and then oven dried to remove the water content. The slurry was dried in oven for 24 hrs. After that it was crushed so that it could attain a uniform texture free from lumps and could easily mix with the cement and concrete to give a uniform composition throughout the mix.

Fig 3.1: Drying Marble Slurry

Fig 3.2: Removing Lumps from Slurry

3.4. Concrete Sampling

For these tests concrete samples were made with definite percentages of stone dust and marble slurry as additive. Cement content was kept constant throughout the sampling. In this project studies were focused to find a suitable composition of stone dust and marble slurry which can be safely used in concrete without any hazards. For this purpose the samples were prepared with following percentages of materials. The batches were given numbers as follows.

Table 3.1: Batch Description

S/No	Batch No	%age of Marble Powder	% of Stone Dust
2	B-2	10%	0%
8	B-8	10%	25%
10	B-10	10%	50%

3.5. Concrete Casting and Testing Protocols

Table 3.2Analytical Techniques

TESTS	ASTM #	REMARKS
Splitting tensile strength	C496 / C496M	Cylinders
Compressive strength	C39 / C39M	Cylinders
Slump	C143 / C143M	Cone
Flexural strength test	ASTM C78 / C78M	Prism
Permeability test		Cylinders
Modulus of elasticity	C469/C469M	Cylinders
XRF		Pallet

Concrete is an important building unit used in the construction field. Normally concrete blocks are prepared from coarse aggregate, fine aggregate, cement and water. The strength of the concrete blocks depends upon the type of materials used. The better the materials the better will be the strength and quality of concrete blocks.

3.6 Components of a Basic Concrete Mix

There are four basic ingredients in the concrete mix:

1. Portland Cement
2. Sand
3. Aggregates
4. Water

Portland cement - The cement and water form a paste that coats the aggregate and sand in the mix. The paste hardens and binds the aggregates and sand together.

Table 3.3 Cement Properties (ASTM C-150)

Properties	Values
Initial setting time	40 min (Min 30min)
Final setting time	282 min (Max 600min)
Compressive strength of cement	18 N/mm2 in 3days and 25.3 N/mm2 in 7 days

Water- Water is needed to chemically react with the cement (hydration) and to provide workability with the concrete. The amount of water in the mix in kilograms compared with the amount of cement is called the water/cement ratio. The lower the w/c ratio, the stronger the concrete. (Higher strength, less permeability).

Table 3.4Composition of Water Used

Properties	Value	Remarks
Color, haze units	5	Colorimeter
Turbidity NTU	0.6	Visual method, candle turbid meter
Ph value	6.7	-
Sulphates	152 mg/L	Turbidimetric method
Chlorides	78.4 mg/L	Argentometric method
Total dissolved solids	500 ppm	-

Aggregates- Sand is the fine aggregate. Gravel or crushed stone is the coarse aggregate. Water absorption is 0.625% of the coarse aggregate which we have used in concrete mix and its specific gravity is 2.7.

Table:3.5 Size of Aggregates (sieve analysis) (ASTM C-33)

Size	Percentage by aggregate
¾ inch	20
½ inch	60
3/8 inch	20

Sand

Sand is a natural material extracted from quarry sites and river beds, being used in concrete to fill in the voids in aggregate which makes the structure more composite and strengthen it.

Figure 3.3 Aggregate

Figure 3.4 Components Of Concrete

3.7 Concrete Properties

1. The concrete mix is workable. It can be placed and consolidated properly by you.

2. Desired qualities of the hardened concrete are met**;** for example, resistance to freezing and thawing and deicing chemicals, water tightness (low permeability), wear resistance, and strength.

3. Economy; since the quality depends mainly on the water to cement ratio, the water requirement should be minimized to reduce the cement requirement (and thus reduce the cost).

4. Stone dust; as replacement of sand

These steps are taken to reduce the water and cement requirements:

1. Use the stiffest mix possible
2. Use the largest size aggregate practical for the job.
3. Use the optimum ratio of fine to coarse aggregate.

3.8 Concrete Admixtures

Admixtures are additions to the mix used to achieve certain goals.

Here are the main admixtures and what they aim to achieve.

3.8.1 Accelerating Admixtures

Accelerators are added to concrete to reduce setting time of the concrete and to accelerate early strength. The amount of reduction in setting time varies depending on the amount of accelerator used. Calcium chloride is a low cost accelerator, but specifications often call for a non-chloride accelerator to prevent corrosion of reinforcing steel.

3.8.2 Retarding Admixtures

These are often used in hot weather conditions to delay setting time. They are also used to delay setting time of more difficult jobs or for special finishing operations like exposing aggregate. Many retarders also act as a water reducer.

3.8.3 Fly Ash

Fly ash is a byproduct of coal burning plants. Fly ash can replace 15%-30% of the cement in the mix. Cement and fly ash together in the same mix make up the total cementious material.

1. Fly ash improves workability
2. Fly ash is easier to finish
3. Fly ash reduces the heat generated by the concrete
4. Fly ash costs to the amount of the cement it replaces

3.8.4 Air Entraining Admixtures

Must be used whenever concrete is exposed to freezing and thawing, and to deicing salts. Air entraining agents entrains microscopic air bubbles in the concrete: when the hardened concrete freezes, the frozen water inside the concrete expands into these air bubbles instead of damaging the concrete.

1. Air entrainment improves concrete workability
2. Air entrainment improves durability
3. Air entrainment produces a more workable mix

Water reducing admixtures-reduces the amount of water needed in the concrete mix. The water cement ratio will be lower and the strength will be greater. Most low range water reducers reduce the water needed in the mix by 5%-10%. High range water reducers reduce the mix water needed by 12% to 30% but are very expensive and rarely used in residential work.

3.9 Making and Curing Of Concrete Samples

3.9.1 Apparatus

Following items form the apparatus for making and curing of concrete.

3.9.1.1 Moulds

It is specified that moulds shall hold their shape and dimensions under all conditions of use. A suitable sealant such as heavy grease shall be used where necessary to prevent leakage through joints, and positive ways should be used to hold the base plates to the moulds. Moulds used in our project are cylinders.

3.9.1.2 Tamping Rods

3.9.1.3 Vibrators

External vibrators are used in our project which is of table type.

3.9.1.4 Other Tools

1. Shovels
2. Pails
3. Trowels
4. Scoops
5. Rulers
6. Rubber Gloves
7. Mixing Bowls

3.9.1.5 Mixing Pan

The size should be such that it can receive the whole batch of concrete and allow remixing in it by trowel or shovel.

3.9.1.6 Concrete Mixer

A power driven concrete mixer shall be a revolving drum capable of thoroughly mixing batches of the prescribed sizes.

3.9.2 Specimens

Cylindrical specimens selected should have a length twice that of the diameter.

3.9.3 Preparation of Materials

Before the start of mixing the concrete, the materials are brought to room temperature. Cement is placed in a dry place, as for aggregates these are placed in separate individual size fractions and are than recombined for each batch to produce the desired grading.

3.9.4 Procedure

3.9.4.1 Mixing Concrete

Concrete is mixed in a mixer as specified, machine mixing procedure of drum type are used and it is made compulsory that mixing sequence and procedure should not vary from batch to batch.

Before the start of mixer coarse aggregate is added with some water, and then the mixer is started. After that the fine aggregate, cement, and water is added with the mixer running. The concrete is mixed after all ingredients are in the mixer for 3 minutes , followed by 3 minutes rest, and then 2 minutes of final mixing or till concrete is mixed properly. After the concrete is mixed it is deposited in a pan and to prevent segregation the mixed concrete is deposited in a clean, damp mixing pan and is then remixed by shovel until it appears uniform. Water is added incrementally during mixing to adjust the desired slump. To recover all the concrete from the mixer a tech is used called buttering, in its prior to mixing a test batch the mixer is buttered by mixing a batch proportioned to simulate closely to the test batch the mortar adhering to the mixer is considered to compensate for the loss of mortar in the test sample.

Figure 3.5 Mixing Concrete

3.9.4.2 Making Specimens

The molds are placed as close to the place where they are to be placed for first 24 hours, these are placed on a rigid surface free of vibration and other disturbances. Jarring, striking, tiling, or scarring of the surface of the specimen should be avoided.

The concrete is placed in the mounds using a scoop. Each scoop selected should be such that it should be a uniform representative of the whole batch. The concrete should be mixed with a shovel to prevent segregation during molding of the samples. The concrete is distributed by the use of tamping rod prior to the start of consolidation. The final layer should be such that it should exactly fill the mold after the process of compaction.

According to ASTM the number of layers in which concrete should be added to the mould is dependent on the diameter of the cylinders, as the diameter of our mould is 6 inch the number of layers employed are 3.

Figure 3.6: Placing Concrete in Cylinders

3.9.4.3 Consolidation

The method used for the process of consolidation is by vibration table, by vibration table a uniform duration of vibration is maintained for the concrete and specimen mold involved, the duration of vibration is dependent on the workability of concrete and effectiveness of the vibrator. It is usually taken as sufficient vibration when the surface of the concrete becomes relatively smooth and large air bubbles cease to break through the top surface, over vibration is to be avoided as it causes segregation. The moulds are filled and vibrated in the required number of approximately equal layers. Place all the concrete of each layer in the mould before starting vibration of the layer. While placing the final layer it is avoided to overfill by not more than .25 of inch.

3.9.5 Finishing

After consolidation is done the top surface of the mould is finished by striking them off with the tamping rod where the consistency of the concrete permits, after that the top surface of the freshly made cylinder is capped with a thin layer of stiff Portland cement paste which is permitted to harden and cure with the specimen or the use of plaster of Paris after the concrete is hardened.

Figure 3.7: Finishing of Samples

3.9.6 Curing

3.9.6.1 Initial Curing

The specimens should be stored immediately after finishing until the removal of the moulds to prevent the loss of moisture from the specimen; a method should be adopted with appropriate procedures so that to prevent moisture loss and it should be non-absorptive and non-reactive with the concrete.

3.9.6.2 Removal from Moulds

The specimens are to be removed from the moulds after 24+_ 8 hours from casting of samples.

Figure 3.8: Demolding

3.9.6.3 Final Curing

The final curing of the specimen shall be done in a moist environment at 23 degree Celsius from the time of molding the time of test, this storage should be free from vibration, after the demolding of the specimens moist curing is applied which means that the test specimen shall have free water maintained on the entire surface at all times. So this type of condition is achieved by using water storage tanks.

Figure 3.9: Samples Being Cured

3.10 Testing Protocols

The tests being carried out in this project are compressive strength test, splitting tensile strength test, slump test and density. These are discussed below:

3.10.1 Compression Test, Its Protocols and Procedure

The compression test shows the compressive strength of hardened concrete. These tests are done in concrete lab of MCE Risalpur. The strength is measured in (Psi) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it.

3.10.1.1 Apparatus

1. Cylinders (100 mm diameter x 200 mm high or 150 mm diameter x 300 mm high)
2. Small scoop

3. Bullet-nosed rod (600 mm x 16 mm) or vibration table
4. Steel float
5. Steel plate

3.10.1.2 Procedure

1. Clean the cylinder mould and coat the inside lightly with form oil, then place on a clean, level and firm surface, i.e. the steel plate.
2. Collect a sample.
3. Fill the volume of the mould with concrete then compact by rodding 25 times or vibrating table and specified layers. Cylinders may also be compacted by vibrating using a vibrating table.
4. Fill the mould to overflowing and rod 25 times or by help of vibrating table into the top of the first layer, then top up the mould till overflowing.
5. Level off the top with the steel float and clean any concrete from around the mould.
6. Cap, clearly tag the cylinder and put it in a cool dry place to set for at least 24 hours.
7. After the mould is removed the cylinder is taken to the laboratory where it is cured and crushed to test compressive strength.

3.10.2 Slump Test

The slump test is done to make sure a concrete mix is workable. The measured slump must be within a set range, or tolerance, from the target slump**.**

3.10.2.1 Apparatus

1. Standard slump cone (100 mm top diameter x 200 mm bottom diameter x 300 mm high)
2. Small scoop
3. Bullet-nosed rod
4. (600 mm long x 16 mm diameter)
5. Rule
6. Slump plate (500 mm x 500 mm)

3.10.2.2 Procedure

1. Clean the cone. Dampen with water and place on the slump plate. The slump plate should be clean, firm, level and non-absorbent.
2. Collect a sample.
3. Stand firmly on the foot pieces and fill 1/3 the volume of the cone with the sample. Compact the concrete by 'rodding' 25 times.
4. Rodding means to push a steel rod in and out of the concrete to compact it into the cylinder, or slump cone. Always rod in a definite pattern, working from outside into the middle.
5. Now fill to 2/3 and again rod 25 times, just into the top of the first layer.
6. Fill to overflowing, rodding again this time just into the top of the second layer. Top up the cone till it overflows.
7. Level off the surface with the steel rod using a rolling action. Clean any concrete from around the base and top of the cone, push down on the handles and step off.
8. Carefully lift the cone straight up making sure not to move the sample.
9. Turn the cone upside down and place the rod across the up-turned cone.
10. Take several measurements and report the average distance to the top of the sample.
11. If the sample fails by being outside the tolerance (i.e. the slump is too high or too low), another must be taken. If this also fails the remainder of the batch should be rejected.

Figure 3.10: Slump Calculation

3.10.3 Splitting Tensile Strength of Concrete Specimens

This test method measures the splitting tensile strength of concrete by the application of a diametric compressive force on a cylindrical concrete specimen placed with its axis horizontal between the platens of a testing machine.

3.10.3.1 Apparatus

a) Testing Machine

Shall conform to the requirements of Test Method may be of any type of sufficient capacity that will provide the rate of loading prescribed.

b) Supplementary Bearing Bar Or Plate

If the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested, a supplementary bearing bar or plate of machined steel shall be used. These bars shall have a width of at least 51 mm (2 in.), and a thickness not less than the distance from the edge of the spherical or rectangular bearing block to the end of the cylinder. The bar or plate shall be used in such manner that the load will be applied over the entire length of the specimen.

c) Bearing strips

Two bearing strips of nominal 3.2 mm (1/8 in.) thick plywood, free of imperfections, approximately 25 mm (1 in.) wide, and of a length equal to or slightly longer than, that of the specimen shall be provided for each specimen. Bearing strips shall be placed between the specimen and both the upper and lower bearing blocks of the testing machine or between the specimen and supplemental bars or plates, if used. Bearing strips shall not be reused.

3.10.3.2 Procedure

Draw diametrical lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane. Determine the diameter of the test specimen to the nearest 0.25 mm (0.01 in.) by averaging three diameters measured near the ends and the middle of the specimen and lying in the plane containing the lines marked on the two ends. Determine the length of the specimen to the nearest 2.5 mm (0.1 in.) by averaging at least two length measurements taken in the plane containing the lines marked on the two ends. Position the bearing strips, test cylinder, and supplementary bearing bar such that the center of the specimen are directly beneath the center of thrust of the spherical bearing block. Apply the load continuously and without shock, at a constant rate until failure of the specimen.

Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and the appearance of the concrete.

3.10.3.3 Calculation

Calculate the splitting tensile strength of the specimen as follows:

T=2P/πld

$$T = 2P/\pi l d$$

Where:

♦ T = splitting tensile strength, kPa (psi)

♦ P = maximum applied load indicated by the testing machine, kN (lbf)

♦ l = length, m (in.)

♦ d = diameter, m (in.)

Figure 3.11: Splitting Tensile Test

Figure 3.12: Failure of Sample

3.10.4 Permeability of concrete

3.10.4.1 Apparatus

a) Cock for rapid filling
b) Rapid connection to cell holes
c) Air cock for compensation chamber
d) Pump switch
e) Pressure regulator
f) Filter
g) Compensation chamber

Figure 3.13: Permeability testing machine

3.10.4.2 Procedure

The equipment consists of a strong metallic frame holding four cells containing the specimen to be tested. Every cell is provided with a manometer controlling the internal pressure. Are chargeable compensation chamber grants a constant pressure all test long. The pressure value is adjustable (from 0 – 30 bar) and is given by an automatic pump of variable supply, allowing it to achieve the most suitable installation for the specimen under test.

The specimen are subjected to hydrostatic stress for a pre set period of time. The water permeated through the specimen is directly collected and measured into a graduated cylinder. Therefore it is possible to get the permeability coefficient in cm/sec by the following formula

K = cc x h / A x t x P

Where :

cc = permeated water in cm^3

h = specimen height (cm)

A = specimen area surface (square cm)

t = time to permeate (sec)

P = hydrostatic pressure in cm of water column

3.10.5 Flexural strength of concrete

3.10.5.1 Apparatus

a) Concrete mixer
b) Vibrating table
c) 4” x 4” x 20” prism moulds
d) Flexural testing machine
e) Two point loading arrangement
f) Concrete making material

3.10.5.2 Procedure

Weigh the concrete making material according to the mix design and mix them in a concrete mixture. Prepare the required number of mould and fill the concrete mix into the mould in two layers. After each layer compact the mould with the help of vibrating table and place the mould under standard condition. De mould the specimen after 20 hours and cure them for 28 days in curing tank. After 28 days take out the specimen from the curing tank and wipe off surface with a cloth. Mark the load points and supports on the specimen. Place the specimen in the testing machine on the side as cast. Apply the load at third point with the help of loading assembly @ 2.9 psi /sec. load should be applied slowly till the specimen fail, note the reading on the testing machine.

Flexural strength is calculated as modulus of rupture. If it occurs within the middle third of the span, the modulus of rupture is calculated from the formula

Fr = PL/ bd^2

If failure occurs outside the middle third say at a distance ' a' from the near support then .

Where ;

Fr = modulus of rupture in psi

P = Maximum load on beam

L = Span length in inches

b = Average width of beam in inches = 4"

d = Average depth of the beam in inches = 4"

Figure 3.14: Testing flexural strength of concrete beam

3.10.6 Modulus of elasticity

Determining chord modulus of elasticity of concrete

3.10.6.1 Apparatus

a) compression testing machine (capacity 200 tons)
b) compressive extensive motor
c) material cylinders (6” x 12”)

Figure 3.15. : Setting Concrete Cylinder for Testing Modulus of Elasticity

3.10.6.2 Procedure

Prepare six specimens of 6” x 12” cylinders and pour the prepared concrete mix into the moulds. Demold the specimen after 24 hours. After that cure the specimen for 28 days in curing tank and after 28 days take out all the cylinders from curing tank and cap them. Out of six, three cylinders are for testing compressive strength of concrete and remaining three are used for testing modulus of elasticity. Clamp the metal ring of compressive meter an a specimen such that equal distance are left below and above two rings attach the dial gauge with the least count of least 0.0001 inch. Place the specimen with the strain measuring equipment and attach the lower plate of test machine.

Align the axis of specimen with the center of thrust of upper plate. Note the dial reading and gently obtain the uniform setting of upper plate apply the load at the rate of 35 psi/min. load and unload the specimen twice and do not record any data. Loading is done to obtain 40 % of compressive strength of concrete. Load the specimen twice about 40 % of its strength and record data each time. Determine the modulus of elasticity of concrete before this, work out any strain and stress from above data and plot the stress, strain curve. Modulus of elasticity is determined by shape of straight line, originating at point on the curve corresponding to a strain of 50 micro inches and stress of 40 % of ultimate stress.

3.11 Summary

In this chapter the main emphasis is on methodology. Concrete sampling, properties, admixture and basic component of concrete mix have been elaborated. Furthermore the procedure for making concrete sample and the apparatus required have been explained. The different tests for which the concrete samples are tested are discussed and there apparatus and procedure are stated.

Chapter-4

RESULTS AND DISCUSSIONS

4.1 Test Results

4.1.1. Compressive Strength Test

The compressive strength test was carried out on cylinders at 7 days, 14 days and 28 days respectively. The test results are shown in the tables below and figures. The sample without marble powder and crushed stone is taken as standard. Then the effect of marble powder was studied as an additive and in the next two batches 10% marble powder by weight of cement was added. An increase in strength was observed during this phase. Next the sand was replaced by crushed stone by 25% and 50%,. An increase in strength was observed during this stage also. The combination of crushed stone with marble powder was also investigated. Firstly 25% sand was replaced with crushed stone and then 10% and 20%of marble powder was added. The same procedure was repeated for 50% crushed stone.

Now discussing figure **4.1,2,3** which shows the effect of the marble powder on compressive strength of concrete at 7 days, 14 days and 28 days respectively. The compressive strength has increased by addition of marble powder.

Table 4.1 Effect of marble powder on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 7 days
B-1	0%	00%	2175
B-2	10%	00%	2450
B-3	20%	00%	2345

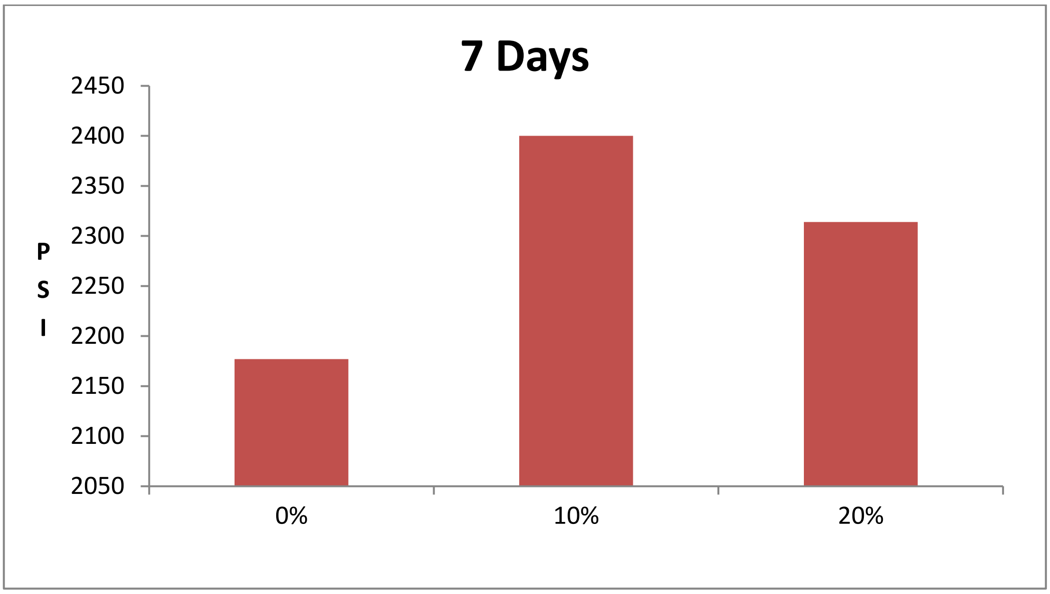


Figure: 4.1 Effect of marble powder on strength of concrete at 7 days

Table: 4.2 Effect of marble powder on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 14 days
B-1	00%	00%	2527
B-2	10%	00%	2585
B-3	20%	00%	2625

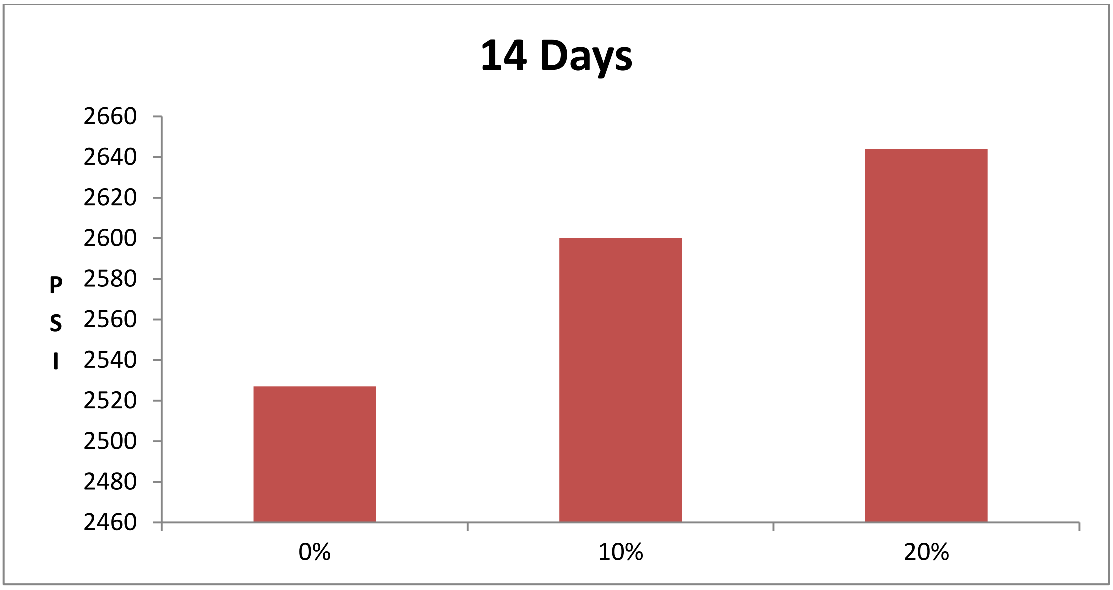


Figure: 4.2 Effect of marble powder on strength of concrete at 14 days

Table: 4.3 Effect of marble powder on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 14 days
B-1	00%	00%	3072
B-2	10%	00%	3282
B-3	20%	00%	3181

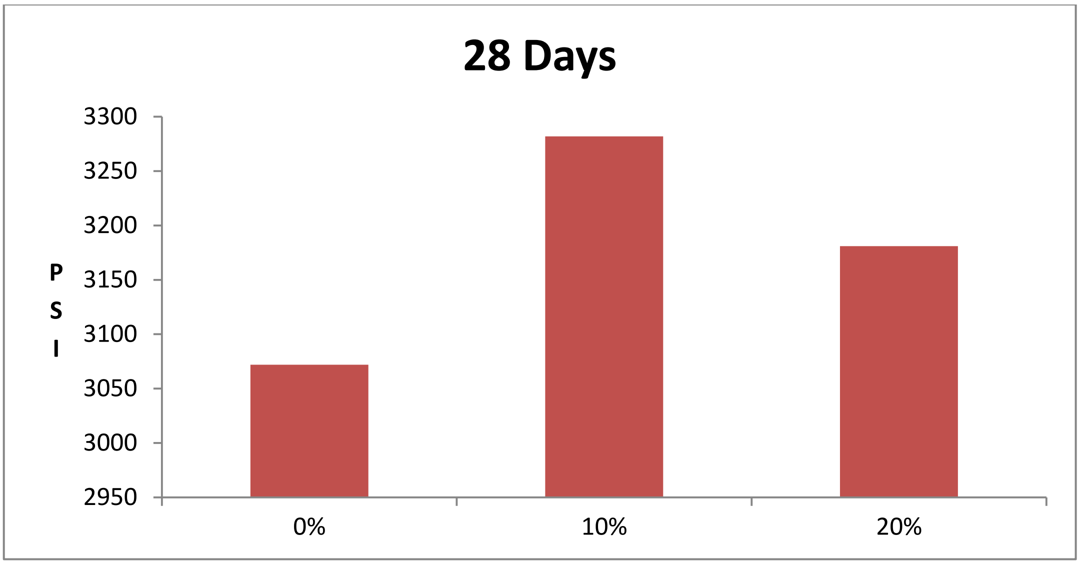


Figure: 4.3 Effect of marble powder on strength of concrete at 28 days

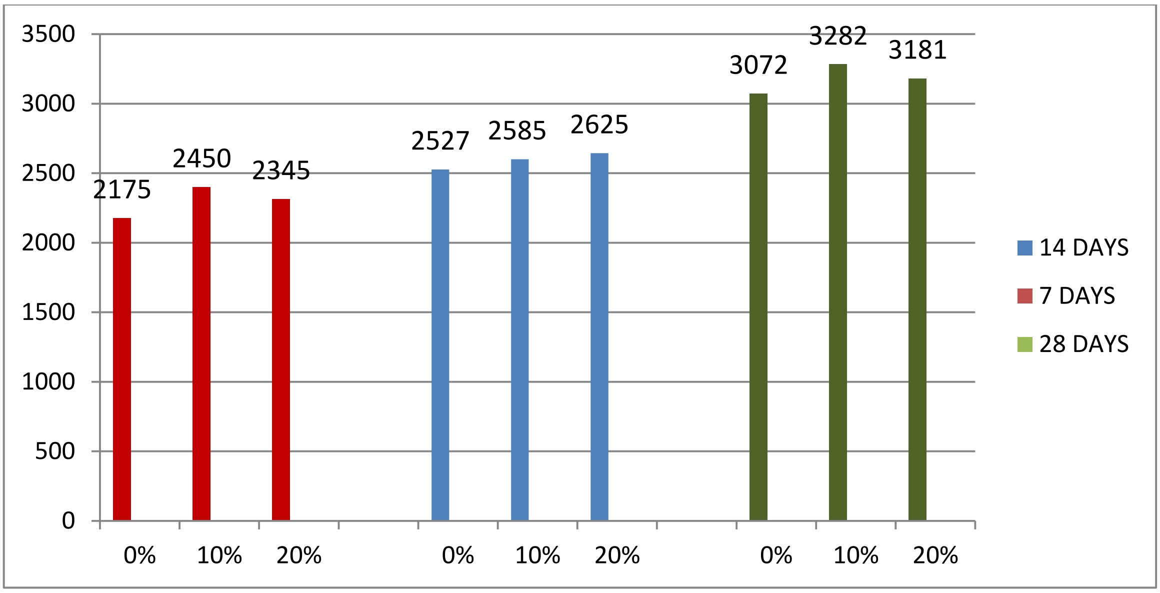


Figure: 4.4 Effect of marble powder on compressive strength of concrete

In figure **4.4,5,6**shows the effect of crushed stone on the strength of concrete. Batch-1 without marble powder and crushed stone is taken as standard. In this phase 25% and 50%, sand was replaced with crushed stone. The compressive strength as observed shows an increase in strength. The compressive strength results at 7 days shows a decrease in strength for 25% and 50% replacement of sand. At 14 days an rapid increase in strength was observed in all the batches as shown in the figure. The 28 days testing shows that the strength is more in each case as shown in figures below.

Table: 4.4 Effect of crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 7 days
B-1	00%	00%	2175
B-4	00%	25%	2127
B-5	00%	50%	1975

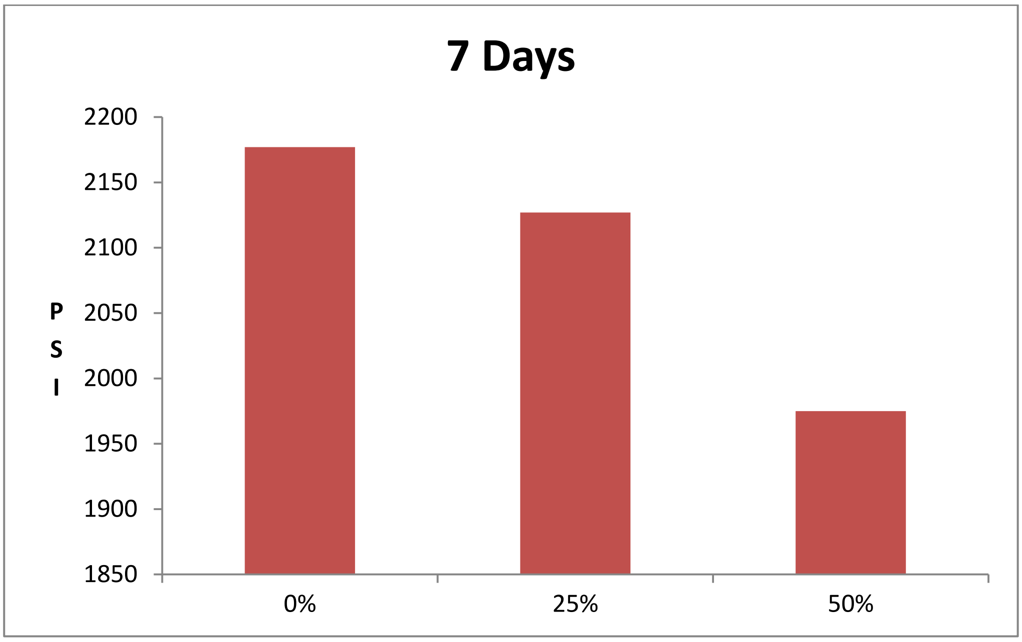


Figure: 4.5 Effect of crushed stone on strength of concrete

Table: 4.5 Effect of crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 14 days
B-1	00%	00%	2527
B-4	00%	25%	2683
B-5	00%	50%	2722

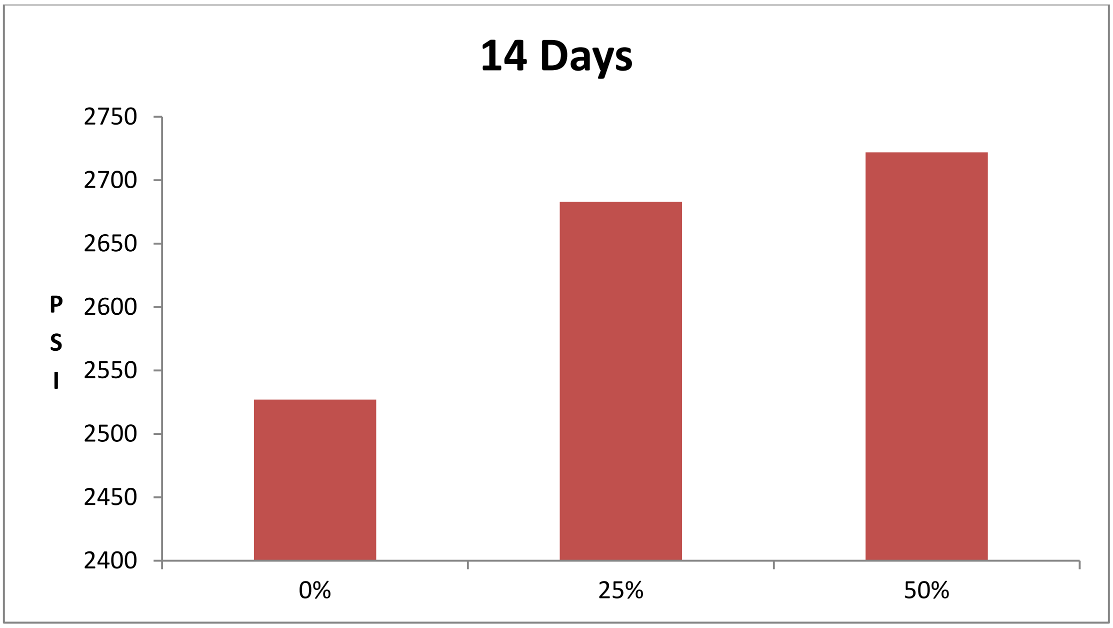


Figure: 4.6 Effect of crushed stone on strength of concrete

Table: 4.6 Effect of crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 28 days
B-1	00%	00%	3072
B-4	00%	25%	3103
B-5	00%	50%	3134

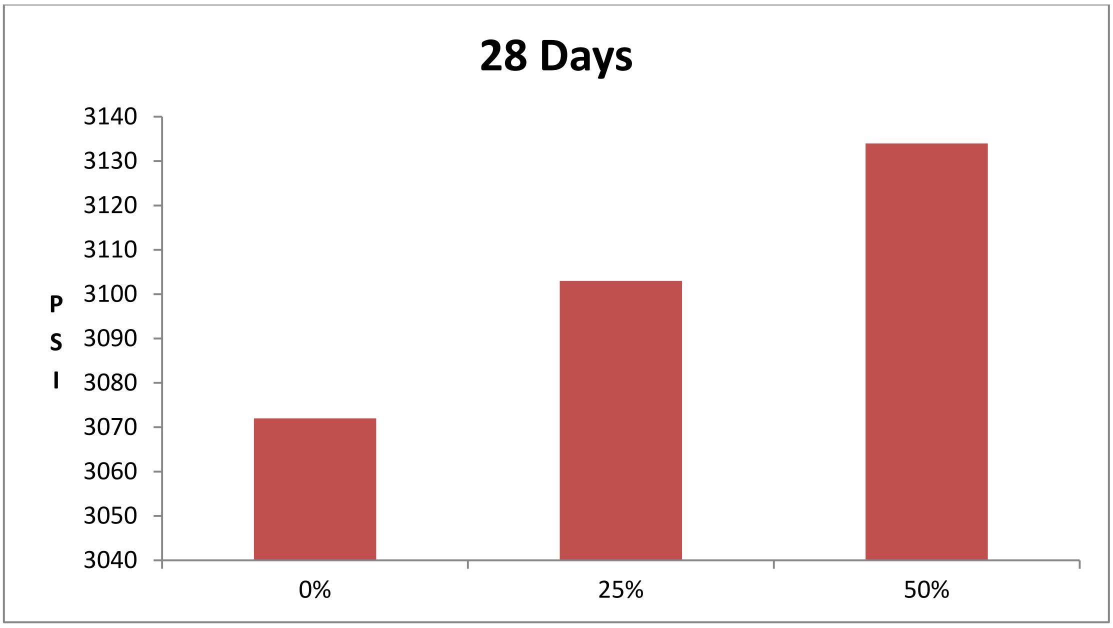


Figure: 4.7 Effect of crushed stone on strength of concrete

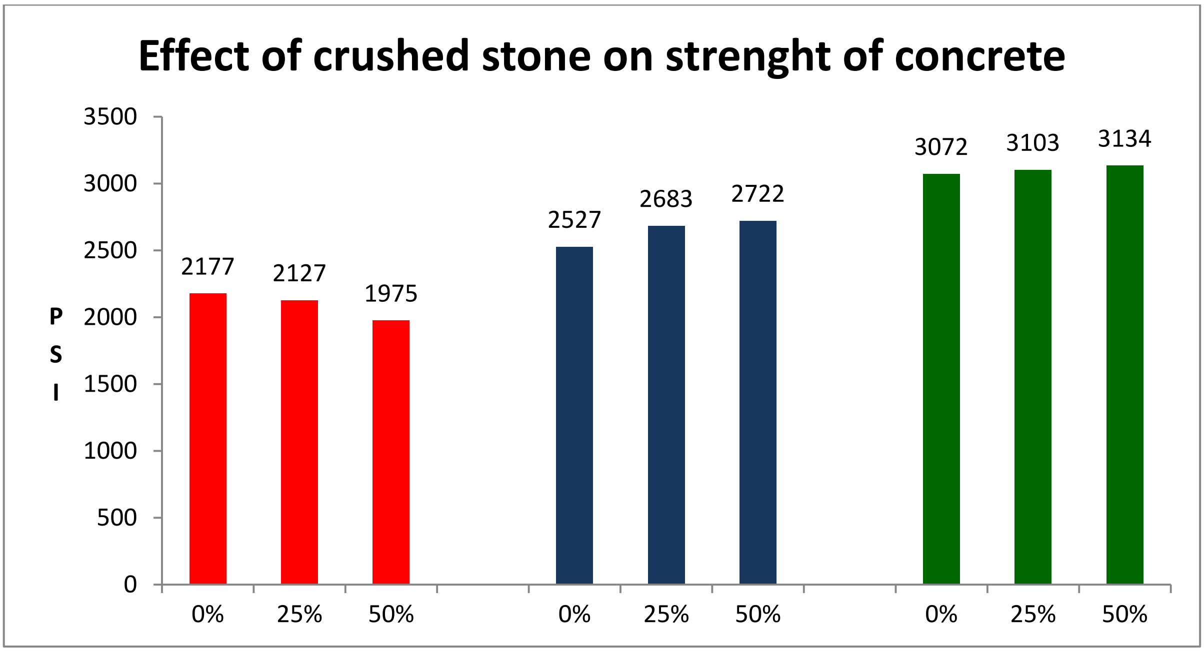


Figure: 4.8 Effect of crushed stone on compressive strength of concrete

The third step was to combine both the marble powder and crushed stone to view the combined effect of the combination of the two on concrete. For this purpose 25% sand was replaced with crushed stone and 10% and 20% marble powder was added as an additive in batch-8 and batch-9 respectively. Then the crushed stone was changed to 50% and again 10% and 20% of marble powder was added as an additive in batch-10 and batch-11 respectively.

The compressive strength results show an increase in strength by 10 to 20% in with different percentages. The results are shown in the figures **4.7,8,9** at 7, 14 and 28 days respectively.

Table: 4.7 Effect of marble powder & crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 7 days
B-1	00%	00%	2175
B-6	10%	25%	2567
B-7	20%	25%	2613

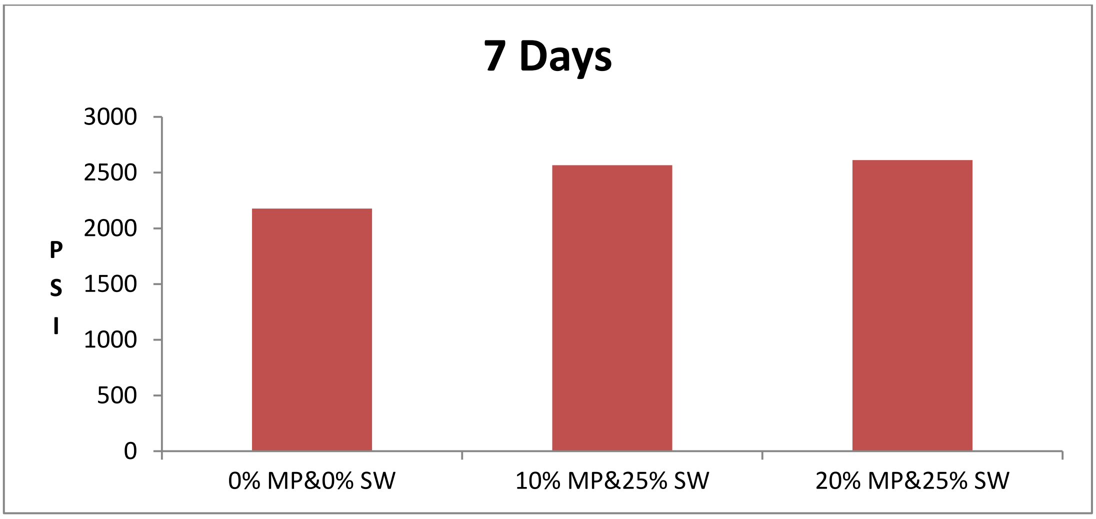


Figure: 4.9 Effect of marble powder & crushed stone on strength of concrete

Table: 4.8 Effect of marble powder & crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 14 days
B-1	00%	00%	2527
B-6	10%	25%	2644
B-7	20%	25%	3150

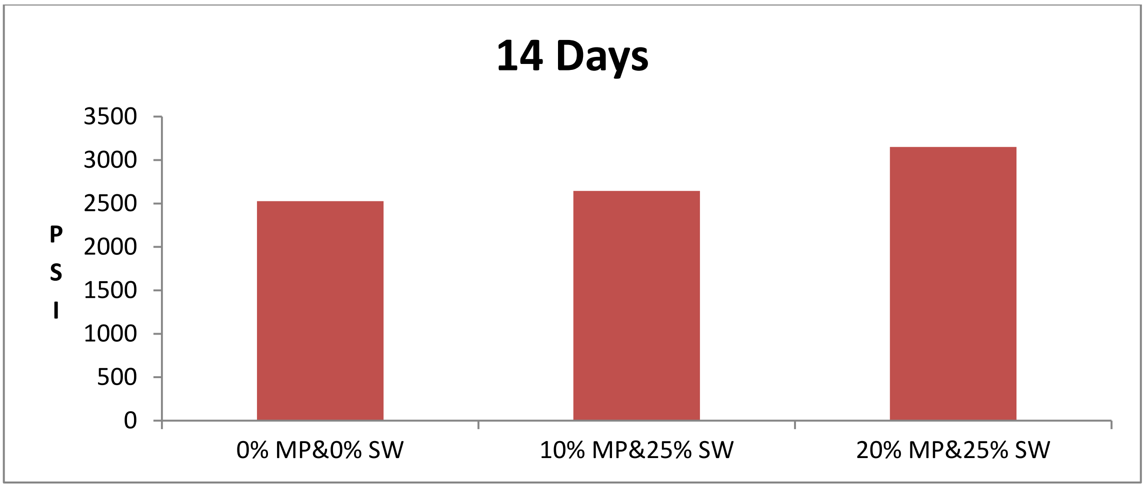


Figure : 4.10 Effect of marble powder & crushed stone on strength of concrete

Table: 4.9 Effect of marble powder & crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 28 days
B-1	00%	00%	3072
B-6	10%	25%	3461
B-7	20%	25%	3267

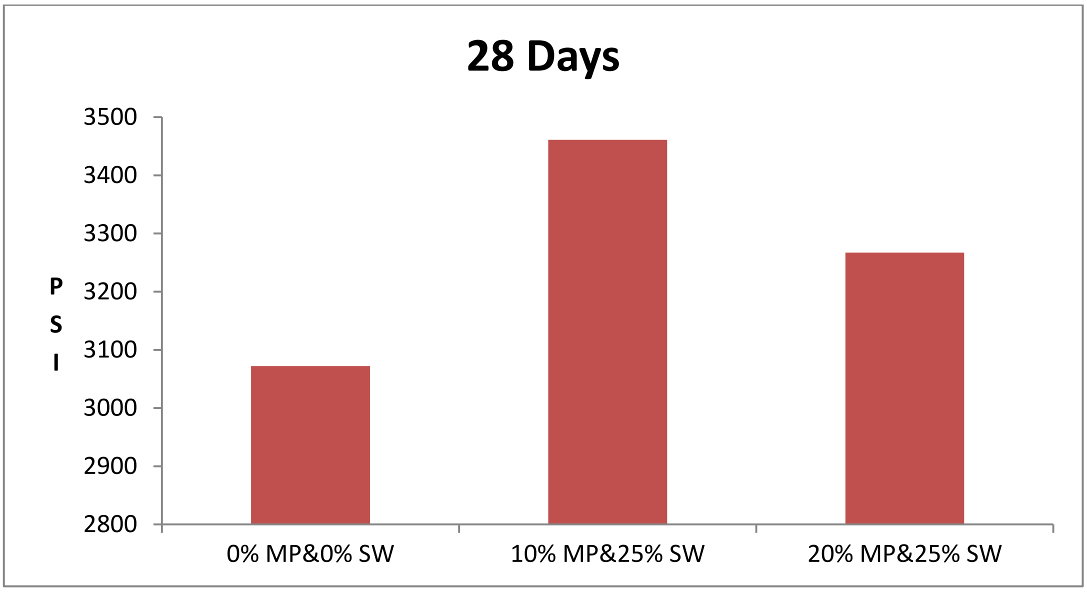


Figure : 4.11 Effect of marble powder & crushed stone on strength of concrete

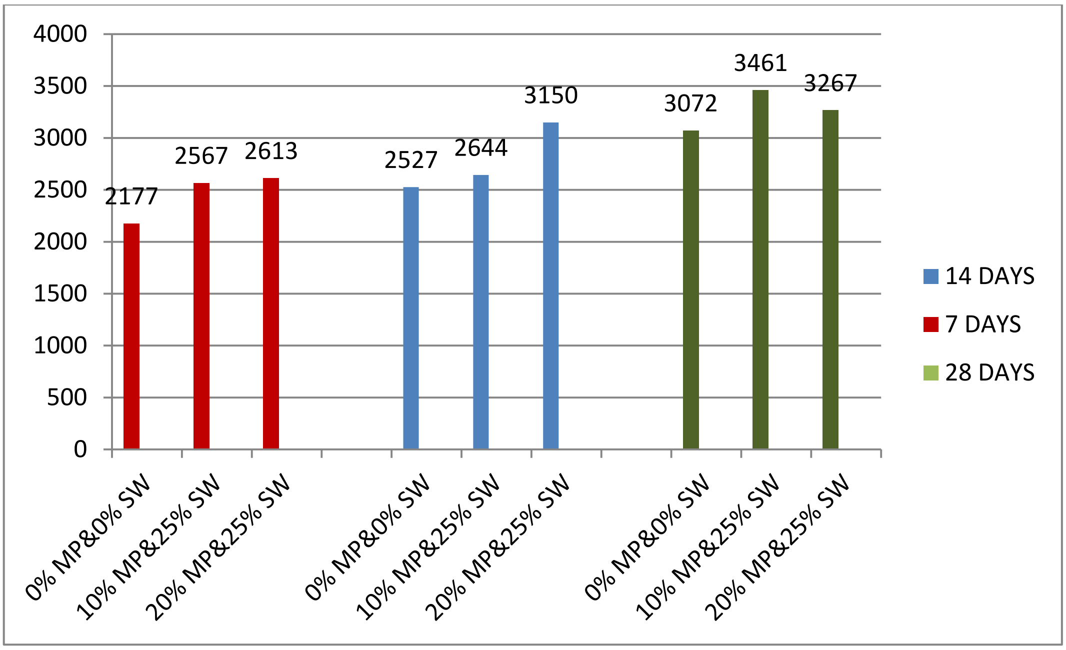


Figure : 4.12 Effect of marble powder & crushed stone on strength of concrete

Table: 4.10 Effect of marble powder & crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 7 days
B-1	00%	00%	2175
B-8	10%	50%	2800
B-9	20%	50%	2664

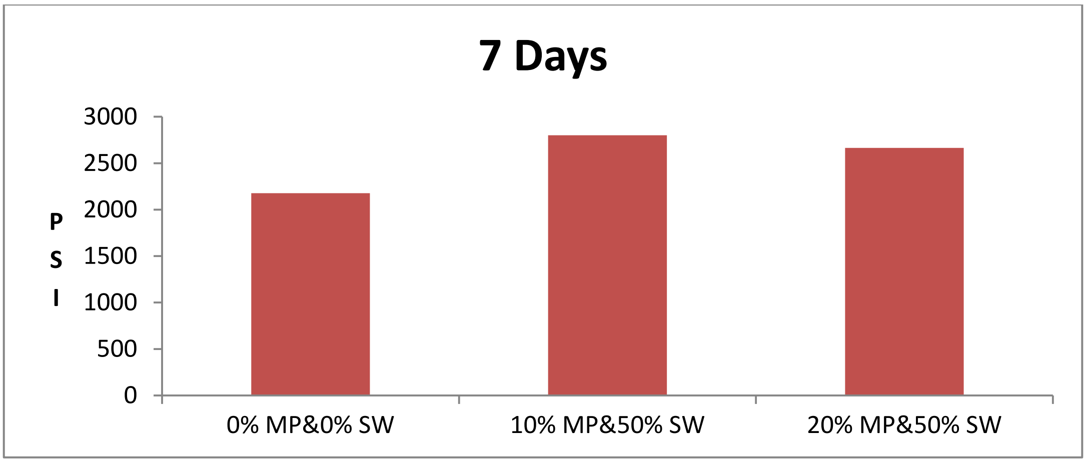


Figure : 4.13 Effect of marble powder & crushed stone on strength of concrete

Table: 4.11 Effect of marble powder & crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 14 days
B-1	00%	00%	2527
B-8	10%	50%	3383
B-9	20%	50%	2761

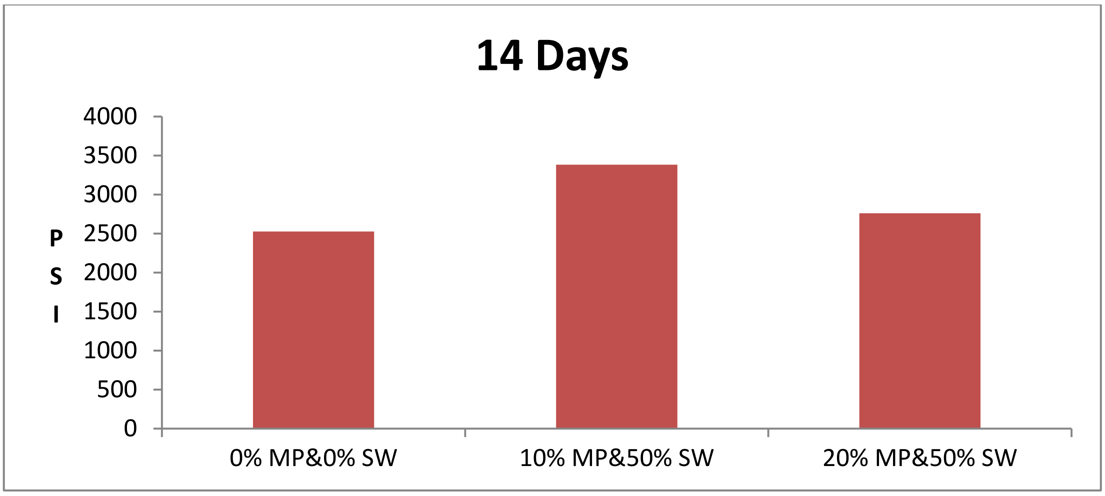


Figure : 4.14 Effect of marble powder & crushed stone on strength of concrete

Table: 4.12 Effect of marble powder & crushed stone on strength of concrete

Batch no	% of marble powder	% of crushed stone	Compressive strength (psi) at 28 days
B-1	00%	00%	3072
B-8	10%	50%	3772
B-9	20%	50%	3150

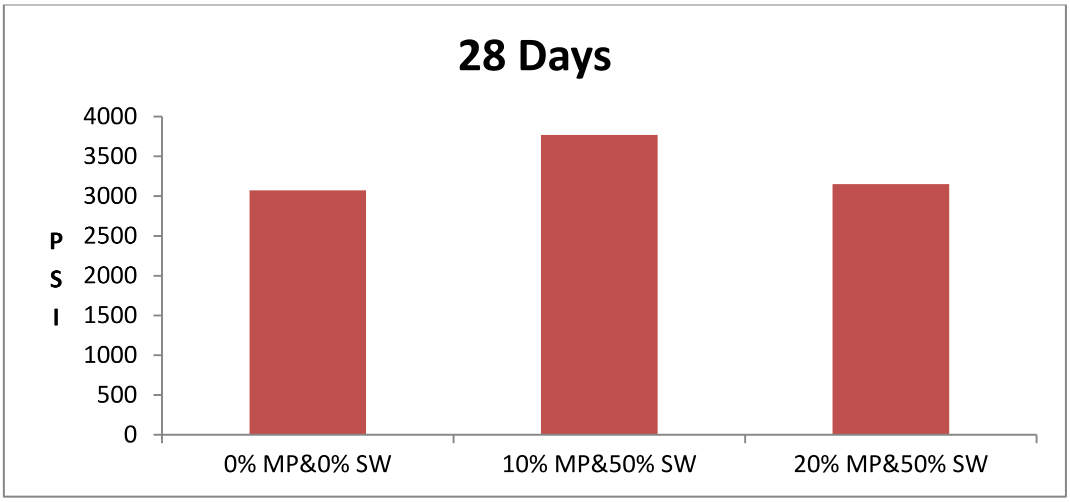


Figure : 4.15 Effect of marble powder & crushed stone on strength of concrete

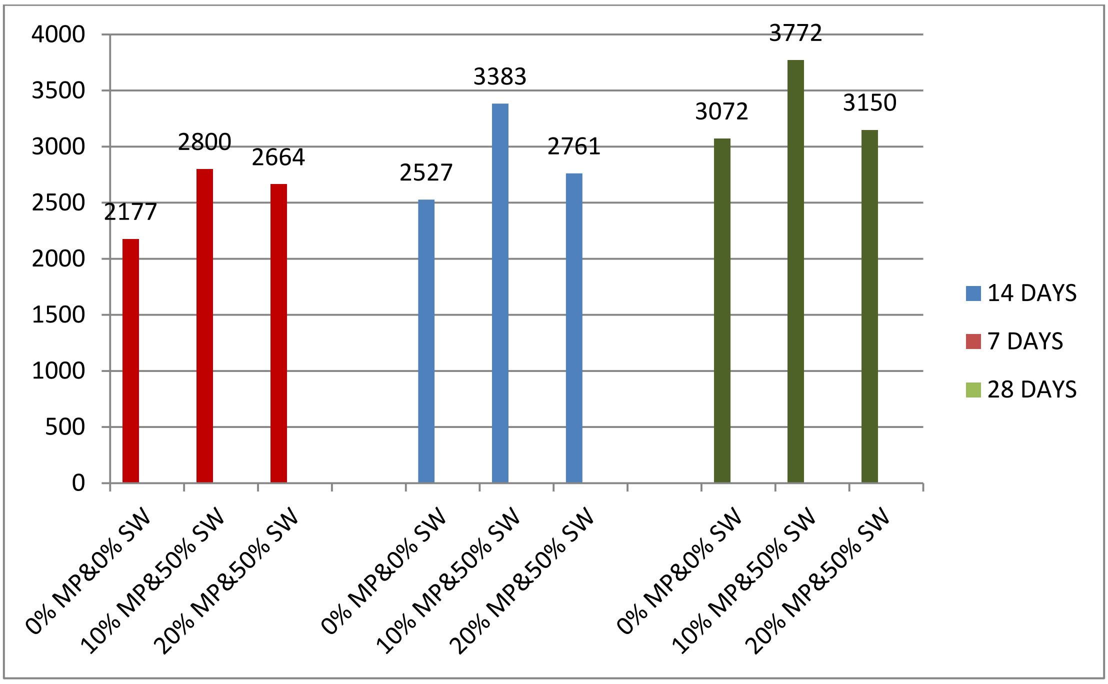


Figure : 4.16 Effect of marble powder & crushed stone on strength of concrete

Table 4.13 Compressive Strength Values after 7 Days Curing

Batch No	% of Marble Powder (slurry)	% of Crushed Stone	7 days 1st sample (tons)	7days 2nd sample (tons)	7days 3rd sample (tons)	Avg	Avg value in PSI
B-1	0%	0%	29	28	27	28	2175
B-2	10%	0%	32.5	33.4	30.2	32.033	2282
B-3	20%	0%	28.2	30	31	29.733	2181
B-4	0%	25%	26	27.1	29	27.366	2127
B-5	0%	50%	23.8	25.4	27	25.4	2975
B-6	10%	25%	34	33.5	31.5	33	2567
B-7	20%	25%	34.8	32	34	33.6	2613
B-8	10%	50%	36	39.4	32.7	36	2800
B-9	20%	50%	31.4	35.5	36	34.3	2664

Table 4.14 Compressive Strength Values after 14 Days Curing

Batch No	% of Marble Powder (slurry)	% of Crushed Stone	14 days 1st sample (tons)	14 days 2nd sample (tons)	14 days 3rd sample (tons)	Avg	Avg value in PSI
B-1	0%	0%	32	33	32.5	32.5	2527
B-2	10%	0%	32.5	35	33	33.5	2585
B-3	20%	0%	34	36	32	34	2625
B-4	0%	25%	35	32	36.5	34.5	2683
B-5	0%	50%	35	32	38	35	2722
B-6	10%	25%	30	35	37	34	2644
B-7	20%	25%	37	42.2	42.3	40.5	3150
B-8	10%	50%	45.8	47.3	37.4	43.5	3383
B-9	20%	50%	36.2	37.4	32.9	35.5	2761

Table 4.15 Compressive Strength Values after 28 Days Curing

Batch No	% of Marble Powder (slurry)	% of Crushed Stone	28 days 1st sample (tons)	28 days 2nd sample (tons)	28 days 3rd sample (tons)	Avg	Avg value in PSI
B-1	0%	0%	38.5	42	38	39.5	3072
B-2	10%	0%	42.2	46	38.4	42.2	3282
B-3	20%	0%	39.7	36.4	46.6	40.9	3181
B-4	0%	25%	37.6	40	42.1	39.9	3103
B-5	0%	50%	39	41	40.9	40.3	3134
B-6	10%	25%	44	45.4	44.1	44.5	3461
B-7	20%	25%	40	44	42	42	3267
B-8	10%	50%	49	47.7	48.8	48.5	3772
B-9	20%	50%	39.4	41.2	40.9	40.5	3150

4.1.2 Concrete Slump Test

Figure 4.1.16 shows the results of slump tests which were carried out for the concrete batches B-1 to B-11 having different ratios of marble powder and crushed stone. It is observed that the concrete slump decreases by addition of marble powder and the batch in which 50% sand was replaced with crushed stone shows a slump of 3.5 inches. The table below gives the value of slump for all the concrete samples.

Table 4.16 Value of Slump Test for All Samples

Batch No	% of Marble slurry	% of crushed stone	Value of Slump (inches)
1	0%	0%	2.5
2	10%	0%	2.5
3	20%	0%	2
4	0%	25%	2.5
5	0%	50%	3.5
6	10%	25%	2
7	20%	25%	1.75
8	10%	50%	1.75
9	20%	50%	1.5

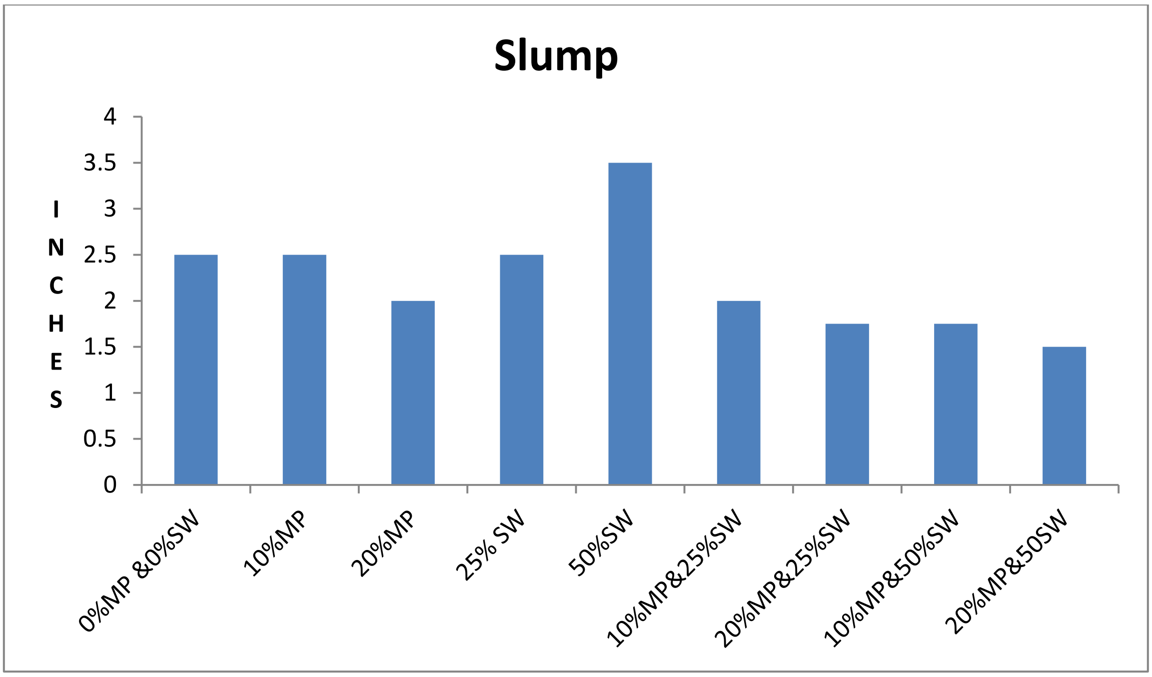


Figure 4.17 Value of Slump Test for All Samples

4.1.3 Concrete Splitting Tensile Strength Test

Figures4.17,18,19 show the values of splitting tensile tests which were carried out on concrete cylinders. The concrete cylinder without any marble powder and crushed stone is taken as standard. The tensile test is carried out at 28 days for three cylinders each from every batch and average is taken. In the first figure the effect of marble powder is shown on the tensile strength. The subsequent two figures show the effect of crushed stone and combined effect of marble powder and crushed stone on the splitting tensile test. The results as displayed show an increase in splitting tensile strength due to addition of marble powder and crushed stone as well as the two combined.

Table 4.17 Effect of marble powder on splitting tensile strength

Batch No	% of marble powder	% of crushed stone	Splitting tensile test (psi)
B-1	0%	0%	840
B-2	10%	0%	911
B-3	20%	0%	874

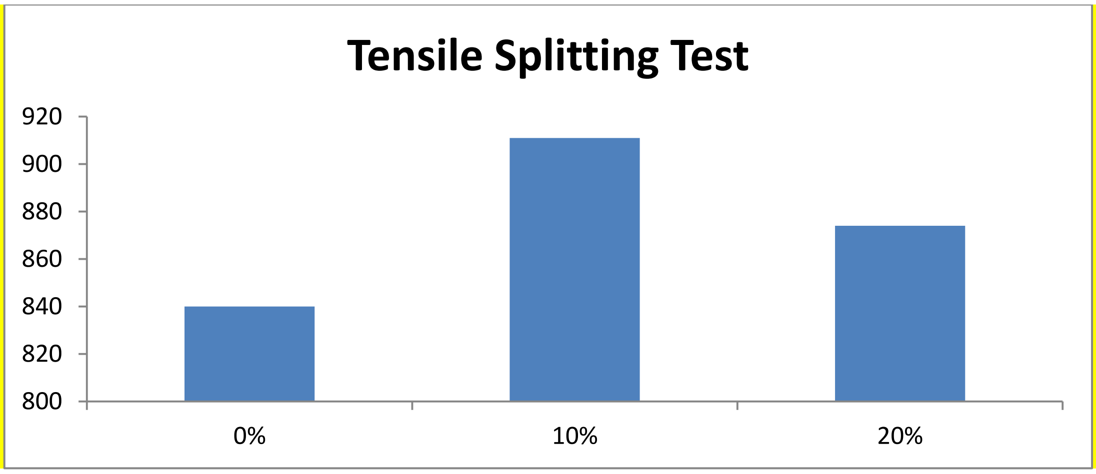


Figure 4.18 Effect Of Marble Powder On Tensile Strength Of Concrete

Table 4.18 Effect of marble powder on splitting tensile strength

Batch No	% of marble powder	% of crushed stone	Splitting tensile test (psi)
B-1	0%	0%	840
B-4	0%	25%	843
B-5	0%	50%	918

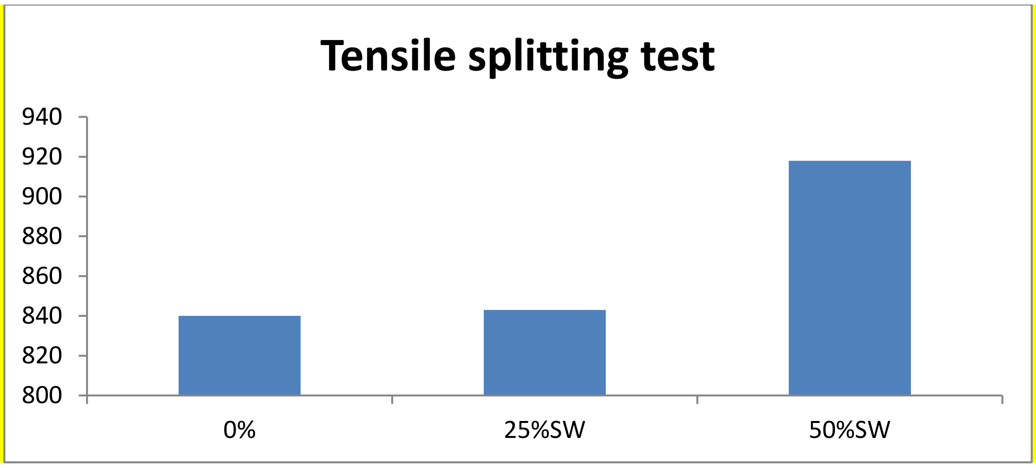


Figure: 4.19 Effect Of crushed Stone On Tensile Strength Of Concrete

Table: 4.19 Combined Effects Of Crushed stone and MP On Tensile Strength Of Concrete

Batch No	% of marble powder	% of crushed stone	Splitting tensile test (psi)
B-1	0%	0%	840
B-6	10%	25%	939
B-7	20%	25%	778

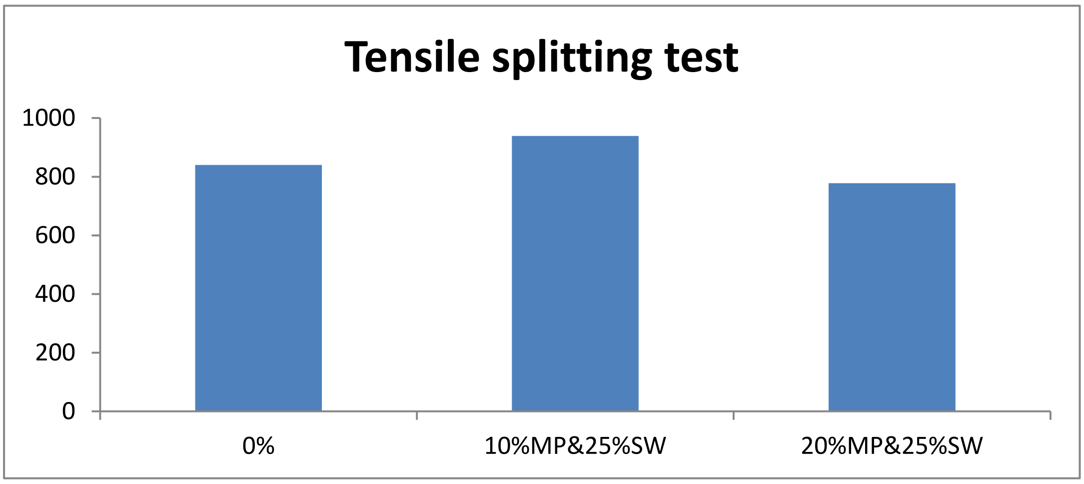


Figure 4.20 Combined Effects Of Crushed stone and MP On Tensile Strength Of Concrete

Table 4.20 Effect of marble powder on splitting tensile strength

Batch No	% of marble powder	% of crushed stone	Splitting tensile test (psi)
B-1	0%	0%	840
B-8	10%	50%	984
B-9	20%	50%	1065

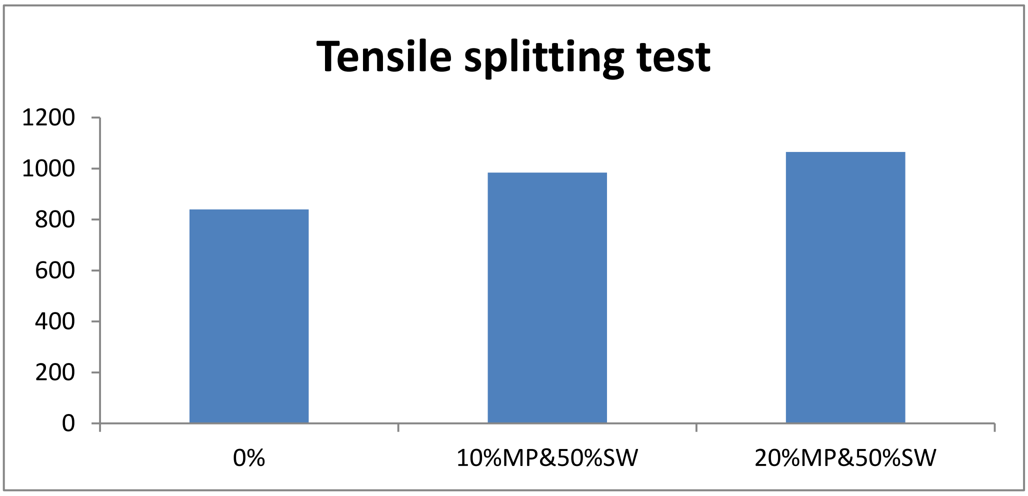


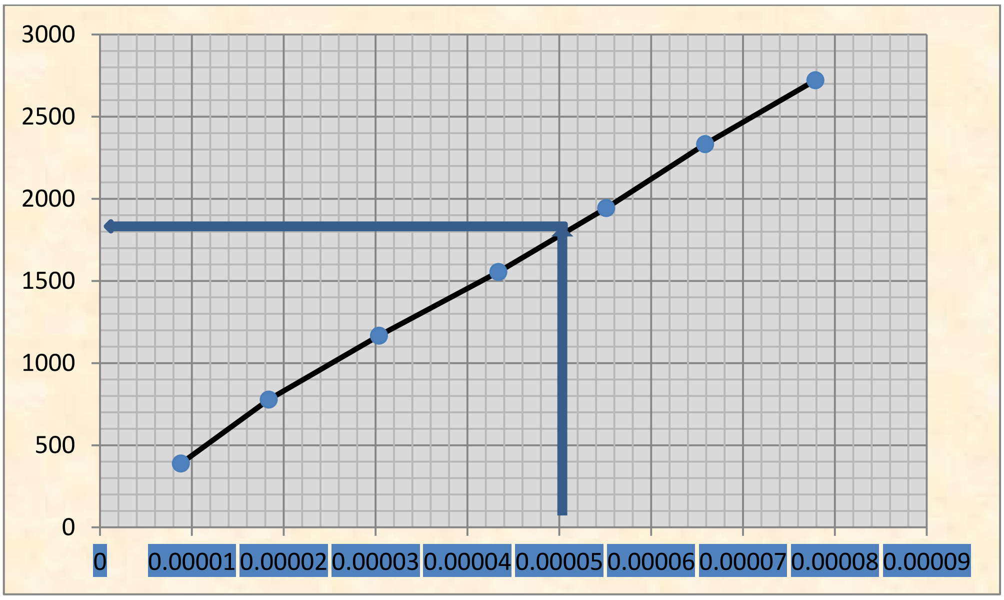
Figure 4.21 Combined Effect Of Crushed stone and MP On Tensile Strength Of Concrete

Table 4.21 Splitting Tensile Values for All Samples

Batch No	% of marble powder slurry	% of crushed stone	1st sample (tons)	2nd sample (tons)	3rd sample (tons)	Avg (tons)	Psi
B-1	0%	0%	17.9	18.8	18.35	18.35	840
B- 2	10%	0%	18.9	19.9	20.9	19.9	911
B-3	20%	0%	18.1	19.1	20.1	19.1	874
B-4	0%	25%	17.9	18.9	18.4	18.4	843
B-5	0%	50%	20.4	19.7	20.05	20.05	918
B-6	10%	25%	20.2	20.8	20.5	20.5	939
B-7	20%	25%	16	17.5	17.5	17	778
B-8	10%	50%	24.5	21.3	18.7	21.5	984
B-9	20%	50%	23.7	23	23.4	23.3	1065

4.1.4 Modulus of Elasticity Test

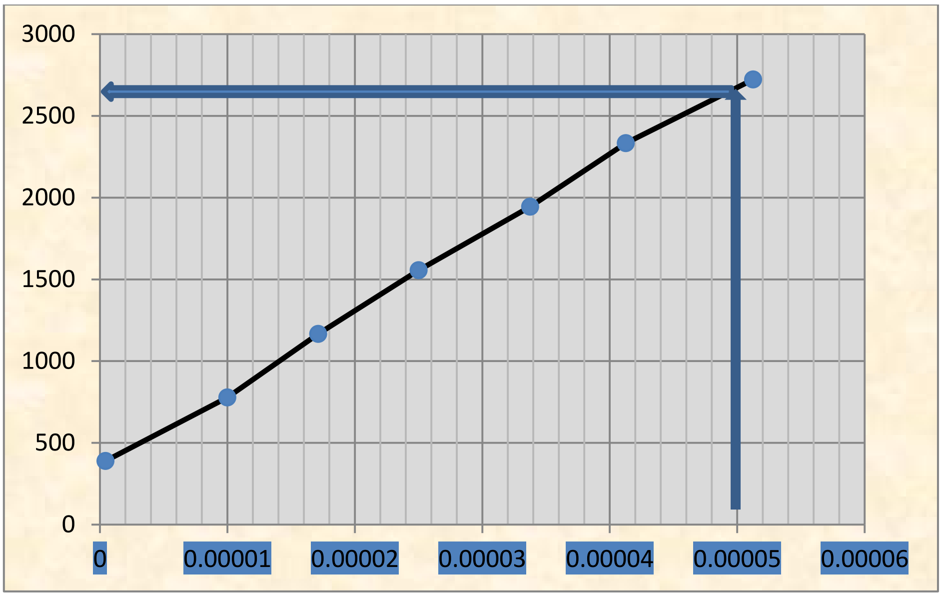
Figures 4.(22,23&244) shows the values of modulus of elasticity tests which were carried out on concrete cylinders. The concrete cylinder without any marble powder and crushed stone is taken as standard. This test is carried out at 28 days for three cylinders each from every batch and average is taken. In the first figure the effect of marble powder is shown on the modulus of elasticity. The subsequent two figures show the effect of crushed stone and combined effect of marble powder and crushed stone on the modulus of elasticity. It is obvious from the results of modulus of elasticity of concrete that it has increased by increasing the lime crushed stone with marble powder with same cement content. The limited gain of the modulus of elasticity were 6% for 10% marble powder and a decrease is observed in modulus of elasticity by 2% for 20% marble powder. Similarly 5% increase is observed in modulus of elasticity for 25% crushed stone. The results as displayed show an increase in modulus of elasticity due to addition of marble powder and crushed stone as well as the two combined.



Stress strain diagram

B-1

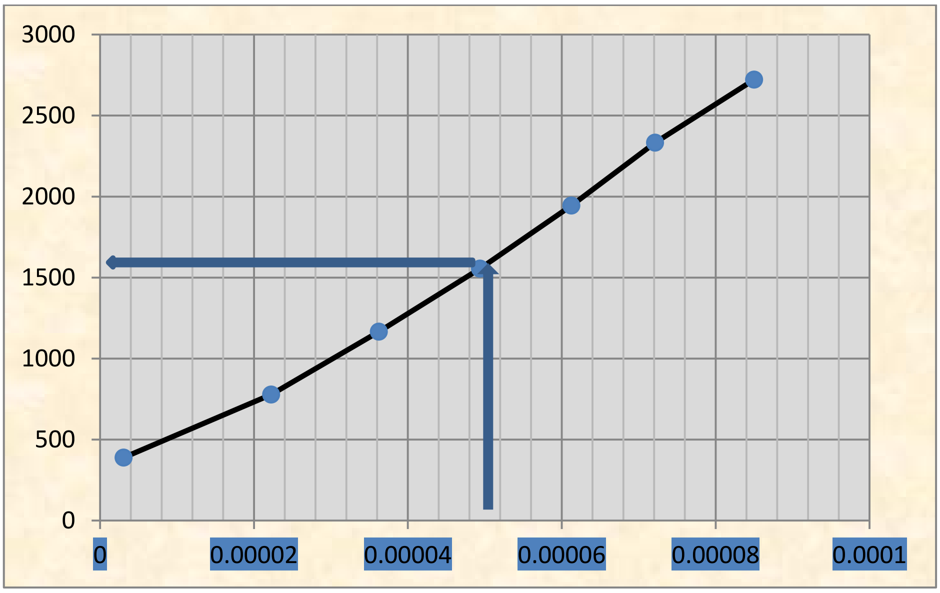
Figure 4.22 Modulus of Elasticity of 1:2:4 concrete



Stress strain diagram

B-2

Figure 4.23 Effect of 10% Marble Powder On Modulus of Elasticity



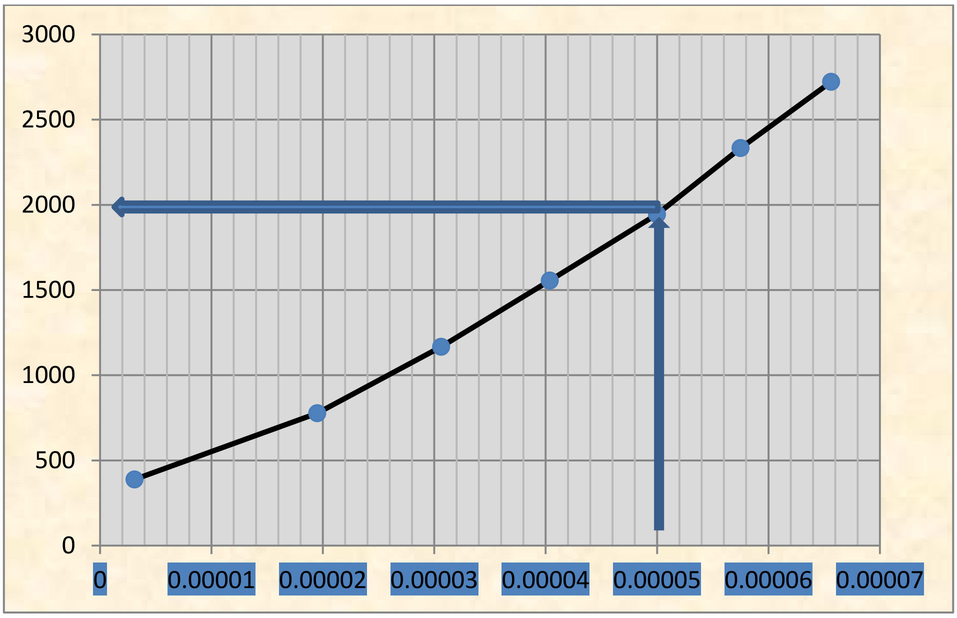
Stress strain diagram

B-3

Figure 4.24 Effect of 20% MP On Modulus of Elasticity

Table 4.22 Effect of Marble Powder On Modulus of Elasticity

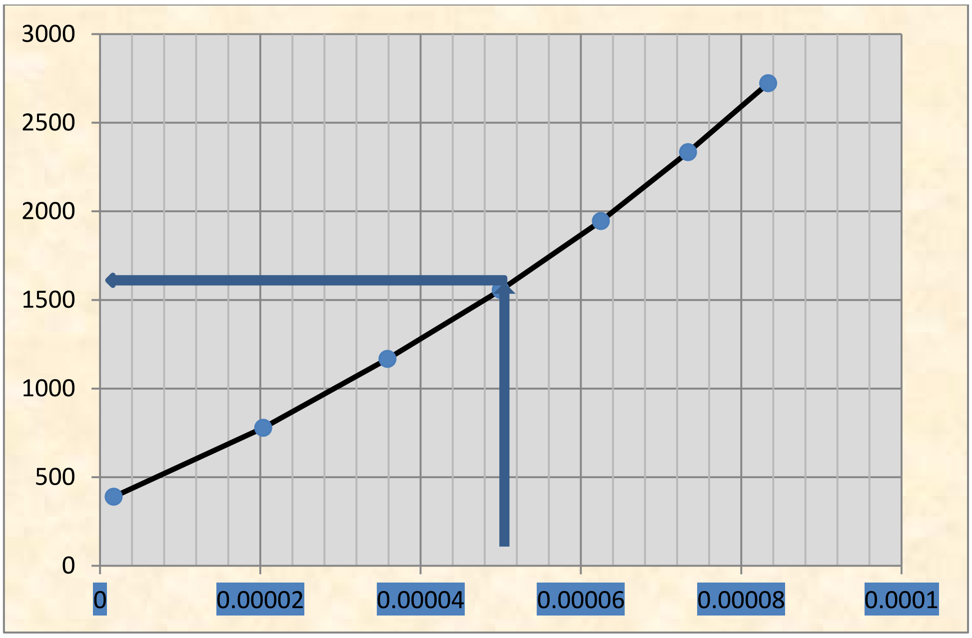
Batch No	% of marble powder	% of crushed stone	Modulus of elasticity (psi)x10^6
B-1	0%	0%	4.43
B-2	10%	0%	4.71
B-3	20%	0%	4.52



Stress strain diagram

B-4

Figure 4.25 Effect of 25% Crushed stone On Modulus of Elasticity



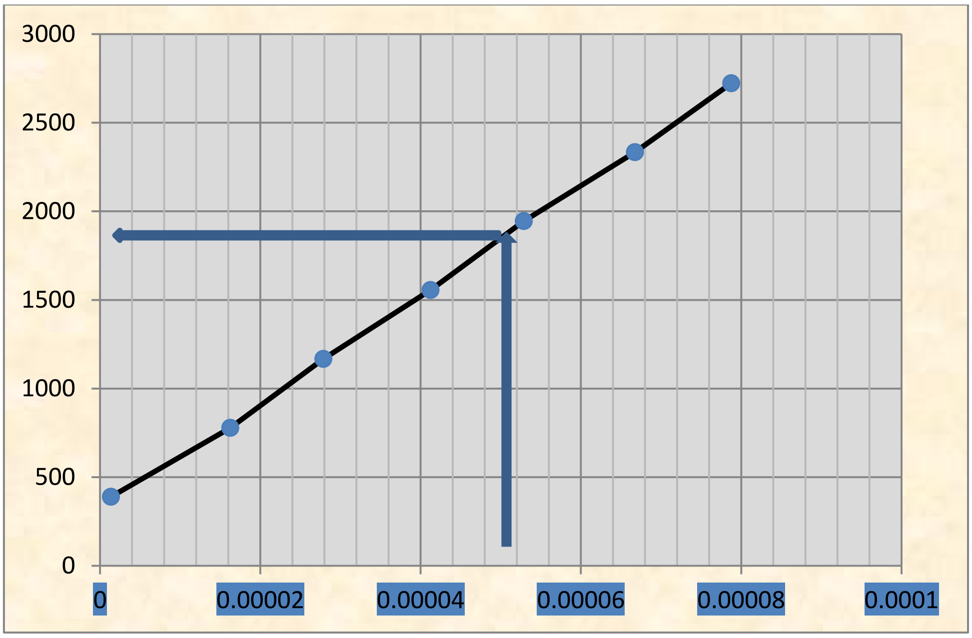
Stress strain diagram

B-5

Figure 4.26 Effect of 50% Crushed stone On Modulus of Elasticity

Table 4.23 Effect of Crushed stone On Modulus of Elasticity

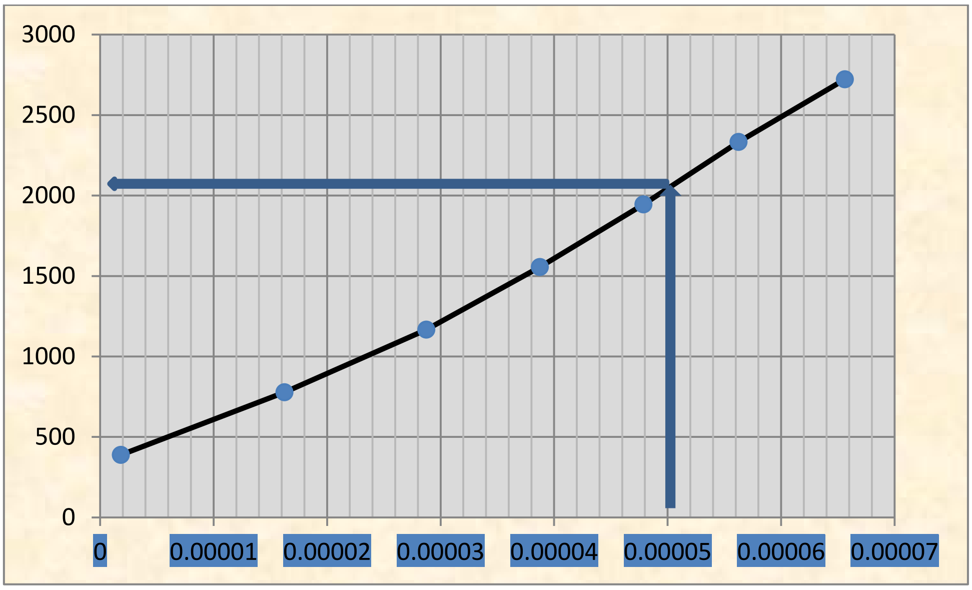
Batch No	% of marble powder	% of crushed stone	Modulus of elasticity (psi)x10^6
B-1	0%	0%	4.43
B-4	0%	25%	4.66
B-5	0%	50%	4.44



Stress strain diagram

B-6

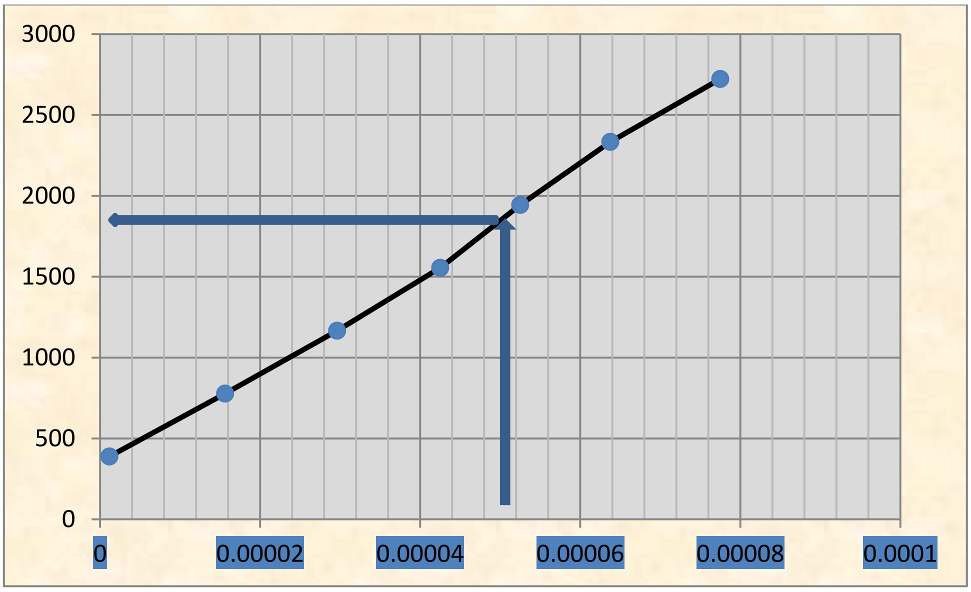
Figure 4.29 Effect of 10% Marble powder and 25% Crushed stone On Modulus of Elasticity



Stress strain diagram

B-7

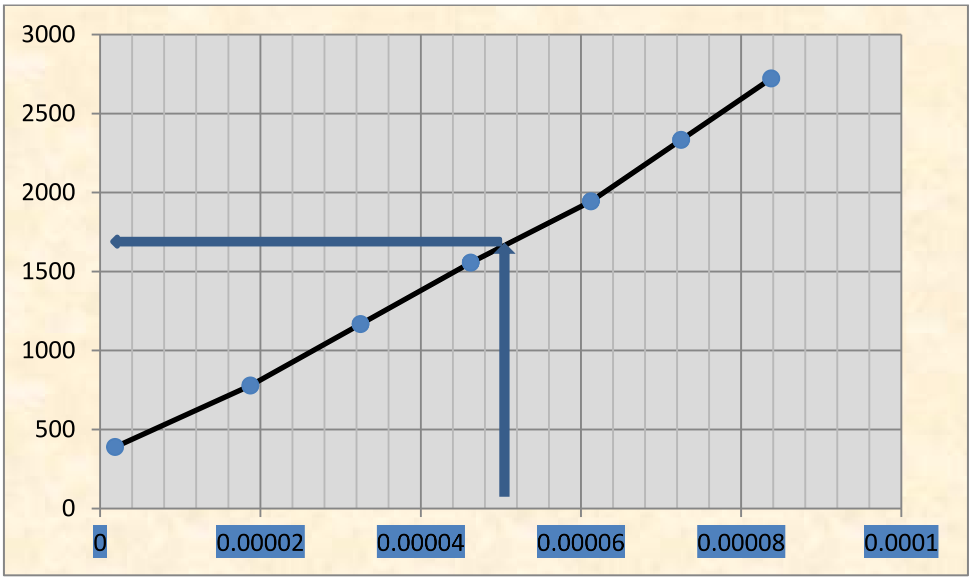
Figure 4.30 Effect of 20% Marble powder and 25% Crushed stone On Modulus of Elasticity



Stress strain diagram

B-8

Figure 4.31 Effect of 10% Marble powder and 50% Crushed stone On Modulus of Elasticity



Stress strain diagram

B-9

Figure 4.32 Effect of 20% Marble powder & 50% Crushed stone On Modulus of Elasticity

Table 4.24 Effect of Marble powder and Crushed stone On Modulus of Elasticity

Batch No	% of marble powder	% of crushed stone	Modulus of elasticity (psi)x10^6
B-1	0%	0%	4.43
B-6	10%	25%	3.51
B-7	20%	25%	4.57
B-8	10%	50%	4.61
B-9	20%	50%	4.57

Table 4.25 Effect on Modulus of Elasticity (summary)

Batch no	% of marble powder	% of crushed stone	Modulus of elasticity (psi)x10^6
B-1	0%	0%	4.43
B-2	10%	0%	4.71
B-3	20%	0%	4.52
B-4	0%	25%	4.66
B-5	0%	50%	4.44
B-6	10%	25%	3.51
B-7	20%	25%	4.57
B-8	10%	50%	4.61
B-9	20%	50%	4.57

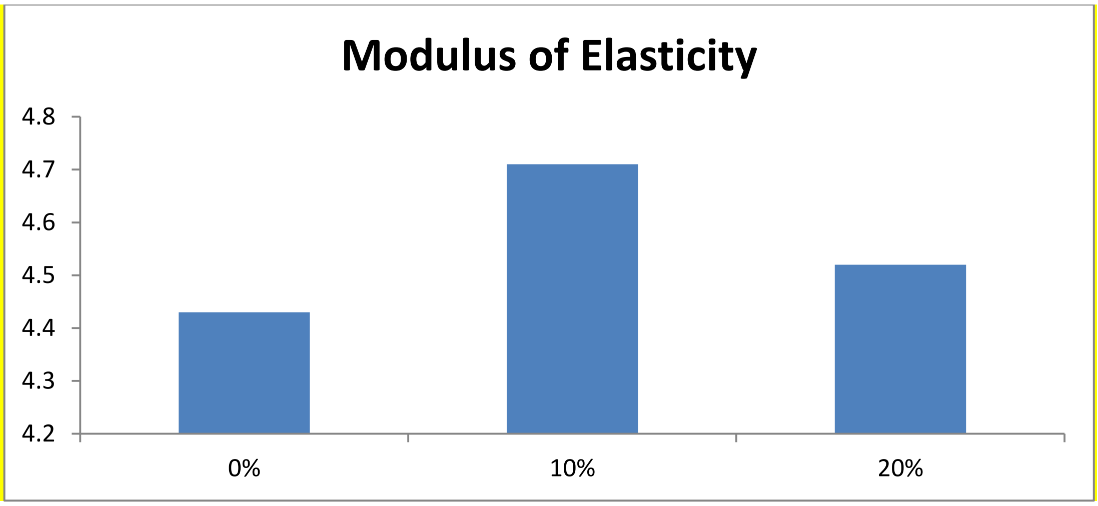


Figure 4.33 Effect Of MP On Modulus of Elasticity Of Concrete

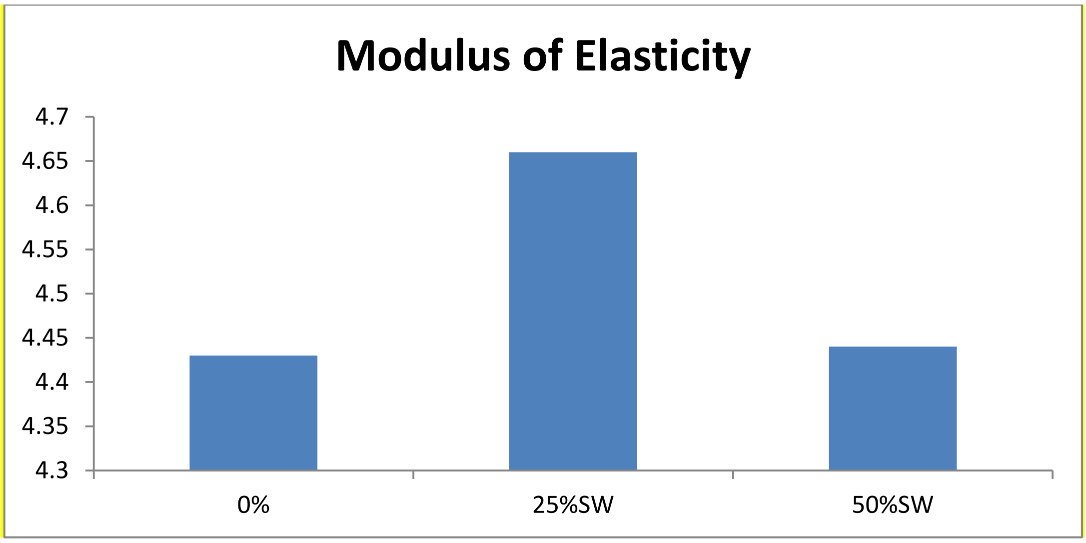


Figure 4.34 Effect Of crushed stone On Modulus of Elasticity Of Concrete

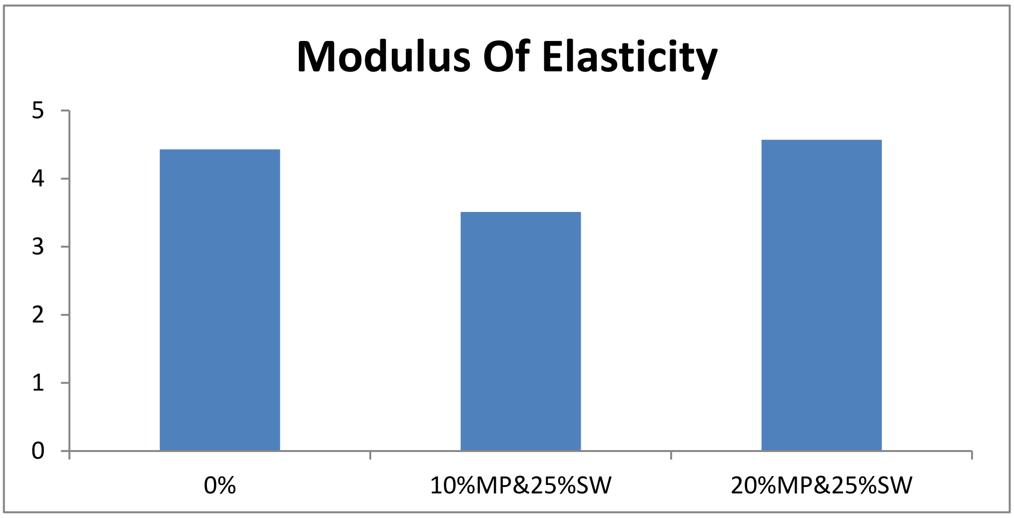


Figure 4.35 Effect Of SW and MP On Modulus of Elasticity Of Concrete

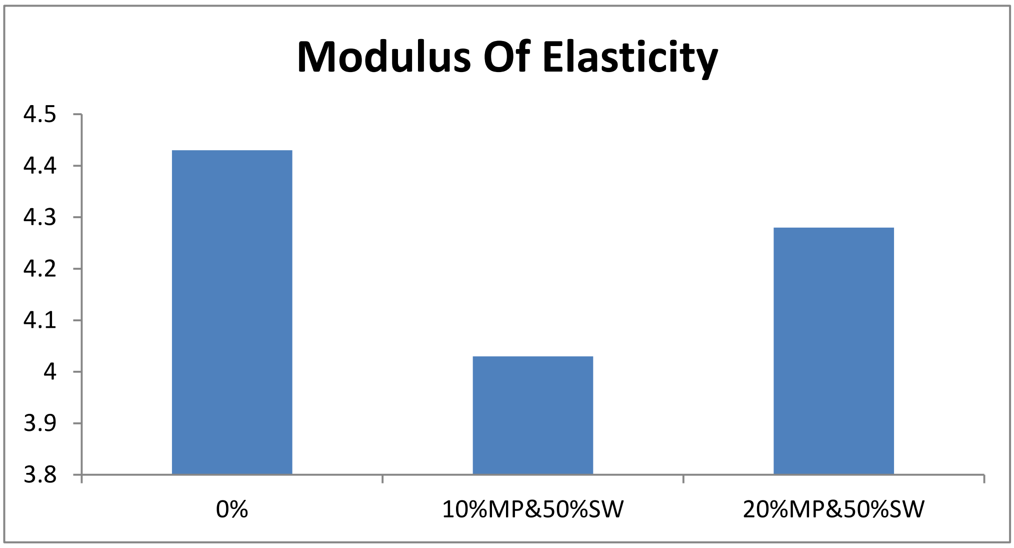


Figure 4.36 Effect Of SW and MP On Modulus of Elasticity Of Concrete

4.1.5 Permeability test

The permeability of concrete is affected by use of marble powder as well as crushed stone. Figure 4.37 shows the values of permeability of concrete. Only selected batches were subjected to permeability test and mould which was selected was of 6 inch height and 4 inch diameter. The standard concrete cylinder without any marble powder and crushed stone was taken as standard. The permeability coefficient is calculated for each sample in cm/sec. The results show the lowest permeability for 50% crushed stone with 10% marble powder almost

2.6 times less than the standard sample. The test was carried out at 7th day after the casting. The results are shown in the table below.

Table 4.26 Effect Of SW and MP On permeability Of Concrete

S/No	% of marble powder	% of crushed stone	Permeability coefficient (cm/sec)	Remarks
1	0%	0%	4.81157E-07	Standard
2	10%	0%	5.11869E-07	
3	20%	0%	1.13561E-06	
4	0%	25%	6.14243E-07	
5	0%	50%	4.7092E-07	
6	10%	25%	5.11869E-07	
7	20%	25%	3.89021E-07	
8	10%	50%	1.84273E-07	2.61 times less

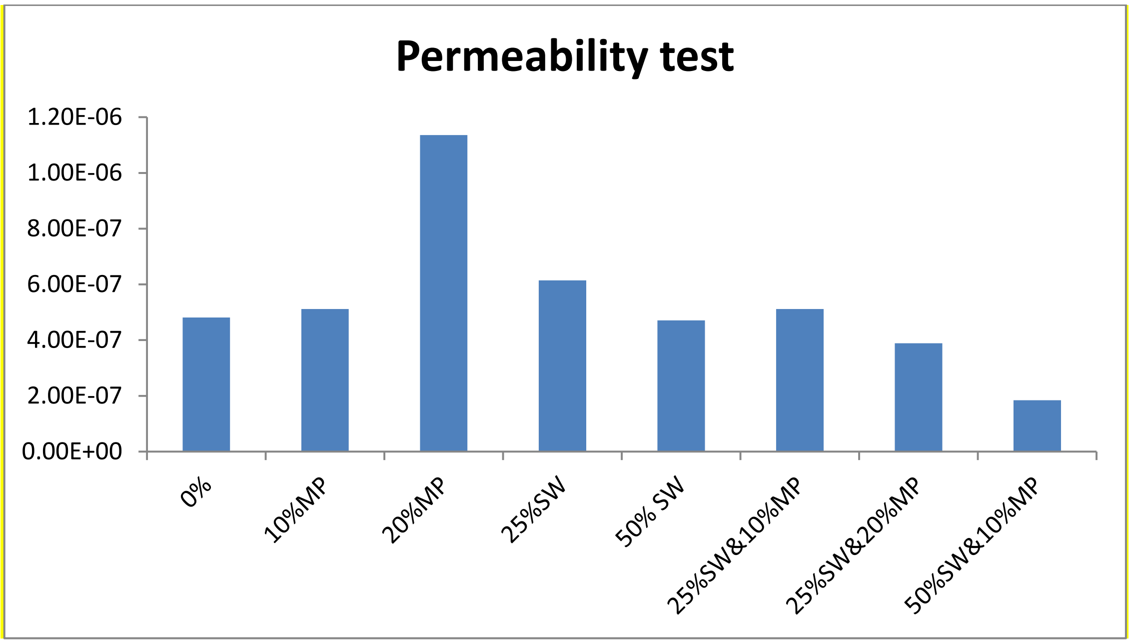


Figure 4.37:Effect Of SW and MP On Permeability Of Concrete

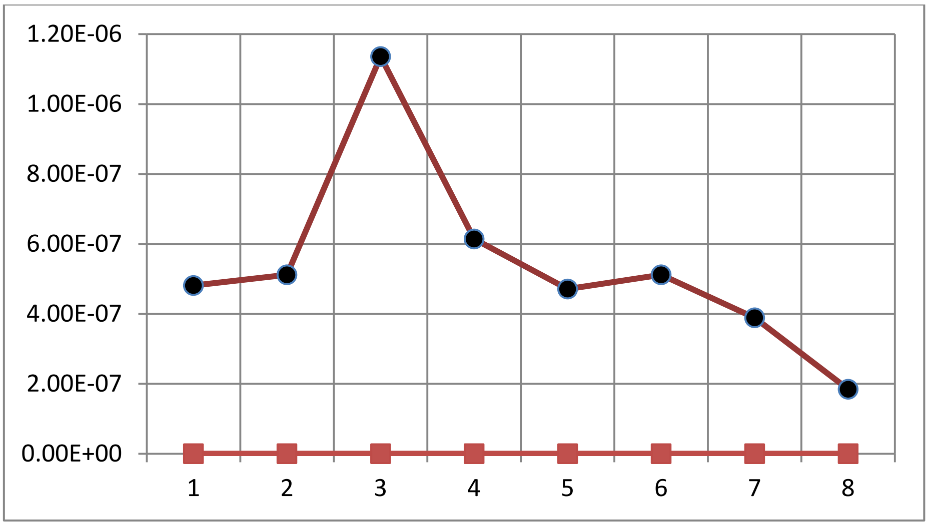


Figure 4.38: Effect Of SW and MP On Permeability Of Concrete

4.1.6 Flexural strength of concrete

The flexural strength of concrete is affected by use of marble powder as well as crushed stone. Figure 4.28 shows the values of flexural strength of concrete for the different mixes. The standard concrete cylinder without any marble powder and crushed stone was taken as standard. The increase in flexural strength is significant for addition of 10% marble powder. The increase is almost 13%. The results are shown in the table below.

Table 4.27 Effect of SW and MP On Flexural strength Of Concrete

S/no	Batch no	% of marble powder	% of crushed stone	Flexural strength (psi)
1	B-1	0%	0%	563.5
2	B-2	10%	0%	637
3	B-3	20%	0%	612.5
4	B-4	0%	25%	622.3
5	B-5	0%	50%	627.2
6	B-8	10%	25%	328.3
7	B-9	20%	25%	372.4
8	B-10	10%	50%	573
9	B-11	20%	50%	583.1

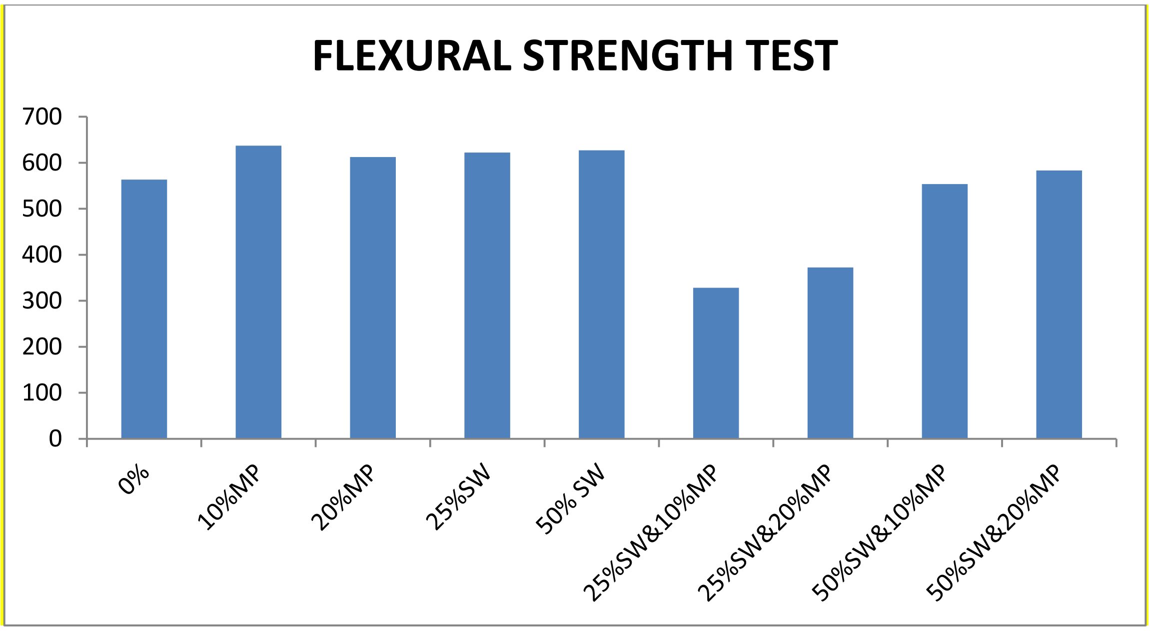


Figure 4.39: Effect Of SW and MP On Flexural strength Of Concrete

4.2 Discussion on Results

The compressive strength of concrete has improved by addition of marble powder as well as crushed stone. Therefore both of these materials can be satisfactorily used in the concrete but marble powder alone should not be increased more than 20% by weight of cement. Furthermore the permeability of concrete is drastically reduced by combining stone dust with marble powder and it can be used in concreting to reduce corrosion of steel especially in areas where the chloride or sulphate attack is a major problem. The only thing which is required is careful selection of different proportions of both the material keeping in view the desired results. The results show that if proper proportion of marble powder along with crushed stone is selected it will not only increase strength but also reduce permeability and enhance the life of structure by increasing durability. Chemical tests (XRF) on marble powder and crushed stone revealed that the local material has about 96% of lime i.e. calcium oxide (CaO) which can react with silica present in cement to form Calcium silicate which is a more stable compound and this may be a reason of the increase in strength of concrete. This fact has also been discussed in previous researches carried out by different authors.**[23]** Based on our study the following can be some useful utilizations of the concrete having marble slurry as filler material and crushed stone as replacement of sand.

The possible uses can be as under:

1. Plain concrete in any component or part of building.
2. RCC beams, slabs and columns.
3. Non-load bearing or partition walls
4. RCC structures exposed to severe weathering.
5. RCC slabs, beams and columns vulnerable to chloride or sulphate attack.
6. All pavements for walk ways, footpaths and rigid pavements.
7. It is suitable for damp proof course.

The use of marble slurry in concrete block making is a cost – effective way of disposing the solid waste produced in the marble industry. If the same is not taken care off, then by compulsion suitable means have to be introduced for disposing the marble waste in landfills.

Marble slurry concrete production is value added item, which can be exploited by the marble industry owners for profit maximization. Other Possible Uses of Marble Slurry and crushed stone are:

1. Paper, ceramics industry, paints, plastics and polymers,
2. glass rubber, sugar, pharmaceuticals, textiles or in articles such as soaps or candles**[24]**
3. Concrete paving blocks **[25]**
4. Production of cement **[26]**
5. Construction of road pavements up to 25 to 30 %
6. Construction of embankments
7. Backfill material for retaining walls
8. Landfill surfacing

4.3 Cost Analysis

Table: 4.28 Estimated quantities of materials required for I m^3 of compacted concrete

NOMINAL MIX			WATER CEMENT RATIO	WATER PER 50KG BAG OF CEMENT	CEMENT		SAND (m^3)	CRUSHED STONES (CUM)
CEMENT	F.A.	C.A.			BY WEIGHT (KG)	BY NUMBER OF BAGS		
1	1	-	0.25	12.5	1015	20.3	0.710	-
1	1.5		0.28	14	815	16.3	0.855	-
1	2	-	0.3	15	687	13.74	0.963	-
1	2.5	-	0.35	17.5	585	11.7	1.023	
1	3	-	0.4	20	505	10.1	1.06	-
1	4	-	0.53	26.5	395	7.9	1.106	-
1	6	-	0.7	35	285	5.7	1.197	-
1	8	-	0.9	45	220	4.4	1.232	-
1	1	2	0.3	15	560	11.2	0.392	0.784
1	2	2	0.42	21	430	8.6	0.602	0.602
1	1.5	3	0.42	21	395	7.9	0.414	0.828

1	1.66	3.33	0.48	24	363	7.26	0.419	0.838
1	2	3	0.5	25	385	7.7	0.539	0.808
1	2	3.5	0.53	26.5	330	6.6	0.462	0.808
1	**2**	**4**	**0.55**	**27.5**	**310**	**6.2**	**0.434**	**0.868**
1	2.5	3.5	0.57	28.5	305	6.1	0.534	0.748
1	2.5	4	0.6	30	285	5.7	0.499	0.798
1	3	4	0.65	32.5	265	5.3	0.556	0.742
1	2.5	5	0.65	32.5	255	5.1	0.446	0.892
1	3	5	0.69	34.5	240	4.8	0.504	0.84
1	3	6	0.75	37.5	215	4.3	0.452	0.904
1	4	8	0.95	47.5	165	3.3	0.462	0.924

Notes:

1. F.A.= Fine Aggregates, C.A.= Coarse Aggregates

2. The table is based on assumption that the voids in sand and crushed stone are 40 and 45 percent respectively.

3. Air content of 1 percent has been assumed.

4. For gravel aggregates decrease cement by 5 percent, increase sand by 2 percent and coarse aggregate in proportion to fine aggregate in mix.

4. No allowance has been made in the table for bulking of sand and wastage.

4.3.1 Calculations

For this 1 cubic meter of concrete is taken as standard. In this it is found that amount of sand used in 1 cubic meter of concrete is 0.434 cubic meter as shown in table above. Only one case will be discussed in which 50% of sand will be replaced with crushed stone.

This means that out of 0.434 cubic meter of sand 0.217 cubic meter of sand will be replaced by crushed stone.

The rates of sand in local market is RS 1200 /100 cubic feet

Rate of sand per cubic meter =1200/2.8338=RS 423

Rate of crushed stone in local market = 800/100 cubic feet

Ratio of rates =1200/800=1.5

Therefore rate of crushed stone per cubic meter =423/1.5=282

RS difference in the rates per cubic meter = 423-282 =141

Therefore in a cubic meter of concrete the amount difference is 0.217 x 141 = RS 31

4.4 Summary

The results of all the tests carried out in the project have been discussed and stated in this chapter along with discussions on the results. Cost analysis along with calculations have also been stated.

Chapter-5

CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

From the analysis and discussion of test results obtained from this research, the following conclusions can be drawn

1. Marble slurry is a waste and is adversely affecting human health, land, water resources and aesthetics of our local area. To overcome this problem it is required to find out beneficial uses of marble powder in different industries e.g. construction industry.
2. The optimum compressive strength is achieved by replacing 50% of sand with stone dust and 10% of marble powder as a filler material. The compressive strength of concrete has increased from 3072 psi to 3772 psi almost 23% at 28 days of curing.
3. The durability of this mix is increased and as a result its vulnerability to chloride attack as well as sulphate attack is reduced. The permeability of concrete has reduced from $4.8x10^{-7}$ to $1.84x10^{-7}$ which is 2.6 times less than the normal concrete.
4. Splitting tensile strength increased from 840 psi to 984 psi which is 17% more than the normal concrete.
5. A limited gain in modulus of elasticity is observed for i.e. it has increased from $4.43x10^{6}$ psi to $4.61x10^{6}$ which is 4% as compared to normal concrete.
6. The flexural strength of concrete is affected by use of marble powder as well as crushed stone. It has increased from 563.5 psi to 573 psi almost 2%.
7. The cost of concrete with 50% replacement of sand with 10% marble powder as additive is 31 rupees less per cubic meter and yet more stronger and durable than normal concrete.
8. However the workability of concrete is reduced from slump of 2.5 inches to 1.75 inches. As a result super plasticizer should be used.
9. The waste water from marble industry can be safely utilized in concreting as there is a scarcity of water in the world all over and to address the problem of pollution of water resources.

5.2 Recommendations:

We recommend that further research be done on the subject. The durability of crushed stone should be studied to analyze its compatibility with the concrete in the longer run. Mechanical testing should be done at 90 days and more duration to further check its strength and durability parameters. For this purpose the research should be done on masters level under the supervision of PhD doctors. The concrete should be exposed to sulphate and chloride attack also and then checked for its strength. Permeability test was carried out on limited scale since this facility was not available with us so we recommend that this parameter should be focused more in the future to find the optimum results.

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