Volume-11, Issue-05, May2022
JOURNAL OF COMPUTING TECHNOLOGIES (JCT)
International Journal
Page Number: 01-07

Parametric Study of Concrete with Replacement materials Fly Ash, Met kaolin and Marble Pieces for Cement and Coarse Aggregates

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***Abstract*— During the extraction and smelting of dimensional stones like marble, a large amount of non-biodegradable waste is produced. This has grown into a global annoyance over time, causing environmental damage in several ways. As a result, a method for securely disposing of or reusing marble debris has become vital. The construction sector, on the other hand, is one of the largest users of natural resources for the manufacture of materials, binders, and aggregates. As a result, in recent years, a number of experiments have been carried out in which various forms of marble debris, fly ash, and metakaolin have been put into concrete with the goal of substituting cement, aggregates, or both. The influence of replacing traditional components with fly ash, Metakaolin, and marble refuse on the fresh, mechanical, and durability aspects of concrete was investigated. It may be determined that replacing 10% of the cement with sand has no negative influence on the qualities of concrete or mortars. When marble debris is blended with fly ash and then utilized as a binding, it is more helpful than just replacing conventional Portland cement. Fly ash, Metakaolin, and marble waste, on the other side, may be used to replace fine and coarse aggregate in the range of 50 to 75 percent. The effectiveness of the waste is determined by the geological formation of the coarse aggregate as well as the particle size distributions of the fine aggregate it replaces.**

***Keywords*— Metakaolin, Silica Fume, Waste Marble Pieces, Properties of Concrete, Physical Properties of Concrete etc.**

I. INTRODUCTION

Concrete is the largest widely utilized building materials on the planet. Cement is the primary component of concrete, and its manufacture necessitates a significant quantity of energy. The cement industry is a significant source of greenhouse gas production. It emits around 3.95 billion tones of greenhouse gases each year, accounting for about 7% of all greenhouse gas emissions on the planet's surface. The introduction of alternate cementitious materials in cement decreases the amount of energy necessary for cement manufacturing, as well as the time and expense involved, while also reducing environmental risks. It is vital to incorporate the usage of diverse non-conventional and renewable resources in cement and concrete production as a method of maintaining ecological balance. It has been discovered that a significant proportion of industrial, residential, and agricultural runoff may be recycled as a cement or aggregate alternative in concrete. Aggregates absorb around 70 to 80 percent of the overall volume of concrete. Sustainability is among the key issues that affect the usage of natural coarse aggregates since it leads to additional environmental issues. As a result of the economic, environmental, and technical advantages received from their use, alternate aggregates are becoming increasingly important in today's building context. The utilization of garbage is the greatest option for achieving sustainable growth.

Fly ash, an industrial byproduct created during coal combustion in thermal power plants, is employed as a partly alternative material for cement in this study. Fly ash's environmental impact and disposal as an industrial waste have caused problems for the power generation sector. The use of fly ash in concrete not only solves the problem of disposal, but it also decreases the amount of greenhouse gases released into the environment. The use of fly ash to substitute a major amount of the cement in the cement and concrete producing sector can significantly cut carbon emissions. Fly ash generates a promising efficiency in concrete due to its physical, chemical, and mineralogical qualities. Furthermore, the spherical form of fly ash particles contributes in lowering the concrete's water-cement ratio. According to continuing study, concrete containing a large percentage of class F fly ash has outstanding strength and tribological features, including minimal permeability to chloride ions and other hostile agents. Unless an activator is added to the mix, total substitution of cement with fly ash for conventional concrete is not possible. Fly ash combines with calcium hydroxide, a chemical generated during the hydration of cement in concrete, when it is substantially applied. This process results in the formation of a cementitious binder phase, which is responsible for the development of concrete strength.

II LITERATURE SURVEY

Wang, Yumei, et al. (2022) - This research analyses the use of waste marble powder in concrete with various cement substitution proportions, as well as the mechanical and physical qualities of this green concrete type. Artificial marble powder and natural marble powder are substituted at various amounts. The impact of several types of marble powder and their replacement ratios on the mechanical characteristics of concrete is examined. When the substitution rate of marble powder exceeds 10%, the compressive strength, splitting tensile strength, and flexural strength all vary dramatically; the strength declines as the substitution rate improves. When compared to the effectiveness of genuine marble powder, imitation marble powder has a weakening effect on concrete performance relative to its resin composition**[01]**.**Nochaiya, Thanongsak, Tawat Suriwong and Phongthorn Julphunthong (2022)** - The goal of this research is to find out how resistant concrete is to organic acid corrosion. Abrasion resistance and abrasive corrosion are two problems that commonly occur in pig farms. Cement was Acid corrosion substituted in the concrete mixes by fly ash and silica fume at various weight percentages up to 30%. The compressive strength and mass loss due to Fly ash organic acid corrosion were investigated on cubic mortar Silica fume and concrete specimens. The test findings showed that combining fly ash and silica fume in concrete improves the concrete's compressive strength, especially during lengthy curing times. The experiment findings showed that using a considerable quantity of fly ash and silica fume to increase the concrete's resistance to organic acid corrosion and abrasive corrosion is ineffective. When comparison to the reference combination, the concrete mixture with 5 wt% silica fume has the best resistance to organic acid corrosion and abrasive corrosion, with a mass loss minimization of 7.14 percent.**[02]**.**Reddy, Soma Prasanth, C. Sashidhar, and B. V. Kavyateja (2021)** - The inclusion of self-compacting concrete (SCC) mix provides several benefits to structural components cast using this type of mix. The findings of an experiment to see if fly ash and alccofine might be used as a substitute for cement in self-compacting concrete are presented in this publication. Fly ash (i.e. 30 percent) and alccofine were used to substitute cement in SCC mixtures (5, 10 and 15 percent). The compressive strength, split tensile strength, and modulus of rupture of SCC were all tested. The addition of 25% fly ash and 10% alccofine to self-compacting concrete enhanced compressive strength, split tensile strength, and flexural strength at all curing periods, according to the findings**[03]**.**Ekinci, Enes, et al. (2021)** - The impact of replacing natural fine aggregate with Malatya Beige marble in various amounts on the compressive strength of geopolymer mortar (GPM) samples is explored in this research. For all of this, marble waste was used to replace 0, 25, 50, 75, and 100 percent of natural aggregate in geopolymer composites using granulated blast furnace slag (GBFS) as the binding component. After getting the solid portion as indicated, alkali activator solutions of 5, 10, and 15 M NaOH were produced. The compressive strength of GPM samples prepared with three different activator molarities and five different aggregate mixture contents after seven and twenty-eight days was examined. Experiments have revealed that using marble waste instead of natural fine aggregate improves compressive strength significantly**[04].Mahesh, Pinnam, and B. Ajitha (2021)** - MK (Metakaolin) was utilized to partly replace Marble dust in this study at 0%, 5%, 10%, 15%, 20%, and 0%, 5%, 10%, 15%, 20% (constant). In terms of compressive, tensile, and flexural strength, MK-Marble dust concrete was contrasted to regular concrete of grade M40. The results show an enhancement in strength with the addition of MK and Marble dust. The optimum strength values of concrete were achieved at 10% MK and 10% Marble dust for all compressive, split tensile, and flexural strength.**[05].Kore, Sudarshan D, A. K. Vyas, and Syed Ahmed Kabeer KI (2020)** - IThis paper examines studies in which dimensional stone debris from marble mining and processing has been evaluated as a concrete element. The influence of replacing traditional components with marble waste on concrete's fresh, mechanical, and durability qualities was investigated. It may be established that using marble powder as a 10% substitute for cement has no negative effects on concrete or mortar qualities. When marble debris is blended with fly ash and then utilized as a binder, it is more helpful than just replacing conventional Portland Cement. Marble waste, on the other hand, may be used to replace fine and coarse aggregate in the range of 50 percent to 75 percent **[06]**. **Bheel, Naraindas, et al. (2020) -** This research looked at the characteristics of fresh, physical, and hardened concrete mixed with marble (MP) and tile powder (TP) in various proportions, including 0%, 5% (2.5 percent MP + 2.5 percent TP), 10% (5 percent MP + 5 percent TP), 15% (7.5 percent MP + 7.5 percent TP), and 20% (10 percent MP + 10 percent TP) by weight. A total of 60 concrete cylinders were cast using a water/cement ratio of 0.45, a mix ratio of 1:1.96:2.14, and cured for 7 and 28 days. The compressive and splitting tensile strength of concrete was tested using all these cylinders. After 28 days, the compressive and splitting tensile strengths of the 2.5 percent MP + 2.5 percent TP

 ISSN(ONLINE):2278 – 3814

sample improved by 8.90% and 8.30%, respectively, according to the data**[07].**

III. METHODOLOGY

In general, cement refers to any sticky substance, but in a specific sense, it refers to the binding agent utilized in building and civil engineering projects. This type of cement is made up of fine powdered powders that, when combined with water, harden into a firm mass. Hydration, a chemical process among both the cement elements and water that forms submicroscopic crystal or a gel-like material with such a vast surface area, causes setting and hardening. Constructional cements, which could also set and harden in water, are sometimes referred to as hydraulic cements due to their hydrating capabilities. Portland cement is the greatest significant of them.

The term "Portland Cement" refers to a kind of cement rather than a brand name. Portland cement is produced by a number of cement producers. It is a primary element in concrete that is created from a carefully managed chemical mixture of calcium, silicon, aluminum, iron, and minor amounts of other chemicals, with gypsum introduced during the final grinding processing to regulate the concrete's setting period.

Test of Cement

- Consistency Test
- Test of Initial time setting
- Test of final setting time

Consistency Test

Apparatus: VI cat’s device, Balance, Cylinder for measuring, Glass platter with Stopwatch and Trowel with an enamel tray.

Procedure:

- Grab 400 g of cement.
- Since we are using OPC, we are going to assume that consistency is 29.5 percent. It’s a trial and error method.
- Take 29.5 percent water, which is (40029.5 percent) = 118 Grams of water.
- Wait 3-5 minutes after mixing the water and cement.
- As indicated within the video, thoroughly mix the cement.
- Fill the Vicat Mould using cement paste immediately.
- After filling the Mould, make careful to compress the paste firmly.
- Fill the Mould to the brim with cement paste. employing a trowel, eliminate any extra paste.
- Put the Mould ahead of the Vicat equipment.
- Remove the plunger and permit it to tolerate the paste.
- Wait 3 seconds after removal.
- Make a note of the reading on the Vicat measuring scale.(T1)

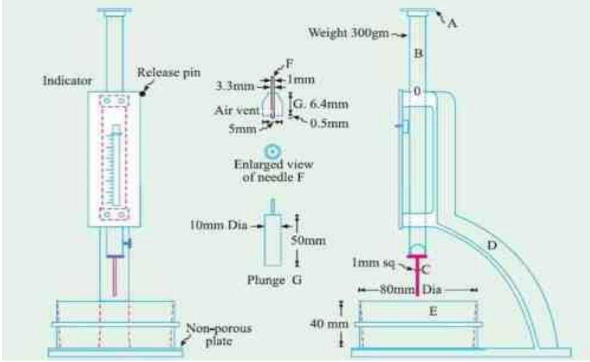

Fig. 3.1Vicat Apparatus Diagram

Initial Setting Time

Place the specimen block, which is enclosed within the Mould and lying on the non-porous plate, beneath the needle-bearing rod.

Lowering the needle carefully until it makes contact with the surface of the specimen block, and quickly withdraw it to enable it to pierce the test block.

At first, the needle entirely penetrates the test block. Repeat this method, swiftly withdrawing the needle every 2 minutes, until the needle fails to puncture the block for roughly 5 mm measuring from the bottom of the mould. observe of the following: (T2).

3.1.3 Final Setting Time

Replacing the needle of the Vicat's instrument with the needle with an annular connection to see the ultimate setting period.

The cement is taken into account finally set when, while carefully pressing the ultimate setting needle against the surface of the test block, the needle leaves an indentation and also the attachment doesn't. Keep track of the time (T3).

T2-T1 for the primary setup and T3-T1 for the ultimate setting

Where,

T1 = the very first time water is introduced to cement.

T2 =Duration when the needle didn't breakthrough 5 mm to 7 mm from the mould's bottom.

T3 = the time when the needle produces an imprint but still the connection doesn't.

Aggregate

Aggregate could be a material utilized in civil infrastructure that's blended with cement, bitumen, lime, gypsum, or similar adhesive to create concrete or mortar. The aggregates provide the finished product output, stability, resistance to wear and erosion, and other important physical characteristics. Fine aggregate is formed from sand, rock, or smashed slag screens, whereas coarse aggregate is created from pebbles (gravels), broken stone fragments, slag, still as other coarse substances.

Coarse Aggregate-

A sieve with such a 4.75 mm aperture would not pass coarse-grained particles. Coarse Aggregate is made up of particles that are largely retained on a 4.75 mm sieve and will pass through a 3-inch screen. The more coarse the aggregate, the more cost-effective mixture. Larger bits have less surface area of the particles than smaller ones of the same volume. The use of coarse aggregate with the biggest allowable maximum size allows for a decrease in cement and water usage. When coarse aggregates are used in excess of the maximum size allowed, they can interlock and create arches or obstacles inside the concrete form. This permits the region below to become a void, or at the very least, to be refilled with finer sand and cement particles.

Fines Aggregate-

Fine aggregate is made up of particles that pass through the 9.5 mm filter, almost totally pass through the 4.75 mm sieve, and are mostly retained on the 75 m sieve. The fine aggregate should have a rounded form for enhanced workability and economy, as seen through the use of lesser cement. The fine aggregate's function is to fill in the gap in the coarse aggregate and to act as a workability factor.

Test used for Aggregate

- Abrasion test
- Impact test
- Crushing Test

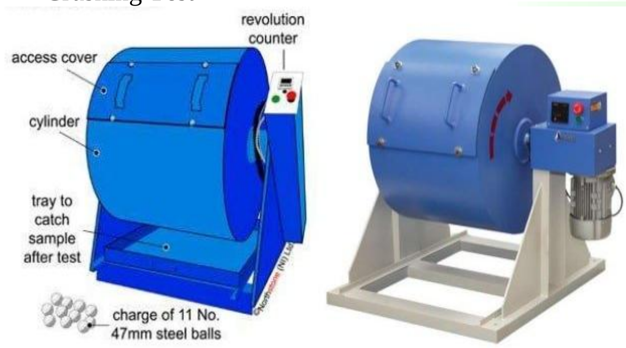

Fig. 3.2 Los Angeles Machine

Apparatus

Los Angeles abrasion machine, Abrasive Charge, Sieve, A weighting balance,Oven drying machine, tray, cup.

Table 3.1. 0% replacement of Coarse Aggregate with Waste Marble Pieces and Varying Percentage Replacement of Cement by Combined SF and Metakaolin

Sample	Silica Fume	Metakaolin	Marble Pieces	Cement	Sand	Aggregate
Standard	0%	0%	0%	100 %	100 %	100%
1	4%	4%	0%	92%	100 %	100%
2	8%	8%	0%	84%	100 %	100%
3	16 %	16%	0%	68%	100 %	100%
4	24 %	24%	0%	52%	100 %	100%

Table 3.24% replacement of Coarse Aggregate with Waste Marble Pieces and Varying Percentage Replacement of Cement by Combined SF and Metakaolin

Sample	Silica Fume	Metakaolin	Marble Pieces	Cement	Sand	Aggregate
1	0%	0%	4%	100 %	100 %	96%
2	4%	4%	4%	92%	100 %	96%
3	8%	8%	4%	84%	100 %	96%
4	16 %	16%	4%	68%	100 %	96%
5	24 %	24%	4%	52%	100 %	96%

Table 3.38% replacement of Coarse Aggregate with Waste Marble Pieces and Varying Percentage Replacement of Cement by Combined SF and Metakaolin

Sample	Silica Fume	Metakaolin	Marble Pieces	Cement	Sand	Aggregate
1	0%	0%	8%	100 %	100 %	92 %
2	4%	4%	8%	92%	100 %	92 %
3	8%	8%	8%	84%	100 %	92 %
4	16 %	16%	8%	68%	100 %	92 %
5	24 %	24%	8%	52%	100 %	92 %

Table 3.416% replacement of Coarse Aggregate with Waste Marble Pieces and Varying Percentage Replacement of Cement by Combined SF and Metakaolin

Sample	Silica Fume	Metakaolin	Marble Pieces	Cement	Sand	Aggregate
1	0%	0%	16%	100 %	100 %	84%

2	**4%**	**4%**	**16%**	**92%**	**100 %**	**84%**
3	**8%**	**8%**	**16%**	**84%**	**100 %**	**84%**
4	**16 %**	**16%**	**16%**	**68%**	**100 %**	**84%**
5	**24 %**	**24%**	**16%**	**52%**	**100 %**	**84%**

IV. RESULT AND DISSCUSUION

4.1Result of Cement

Table 4.1IST and FST of Cement Samples with Silica Fume and Metakaolin as Replacement Material

Sample	Silica Fume+ Metakaolin	Cement	IST (min.)	FST (min.)
Standard	**0%**	**100%**	**28**	**598**
1	8%	92%	32	607
2	16%	84%	36	611
3	32%	68%	38	618
4	48%	52%	42	624

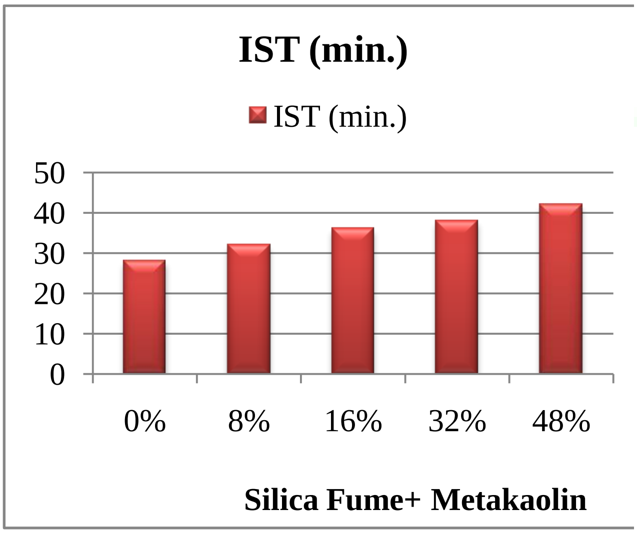

Fig. 4.1IST of Cement Replaced with Metakaolin and Silica Fume

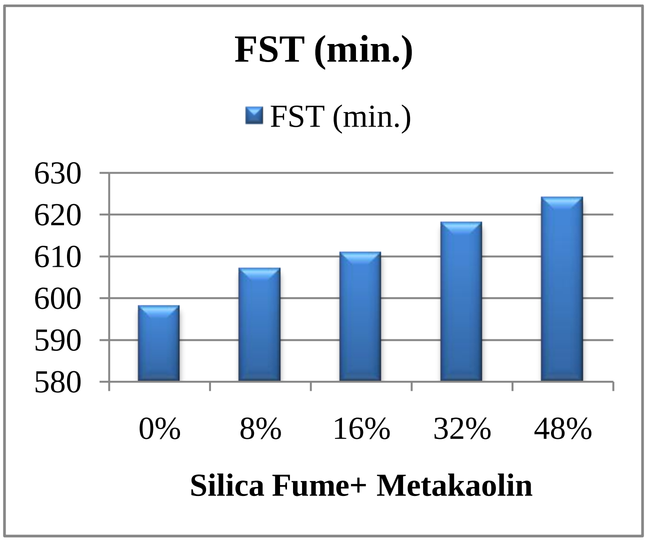

Fig. 4.2FST of Cement Replaced with Metakaolin and Silica Fume

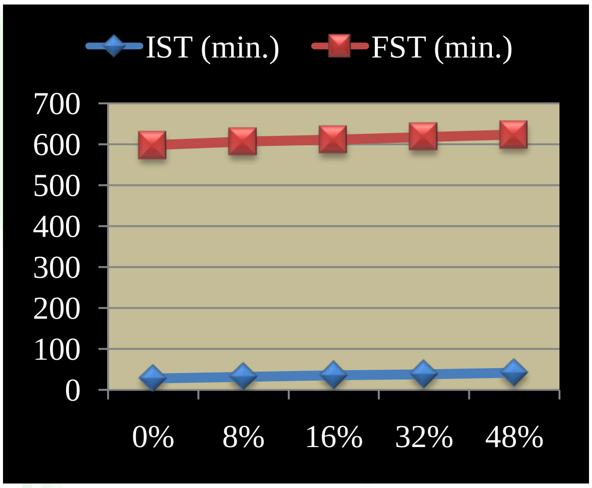

Fig. 4.3Combined Graph of Setting Time of Cement Replaced with Metakaolin and Silica Fume

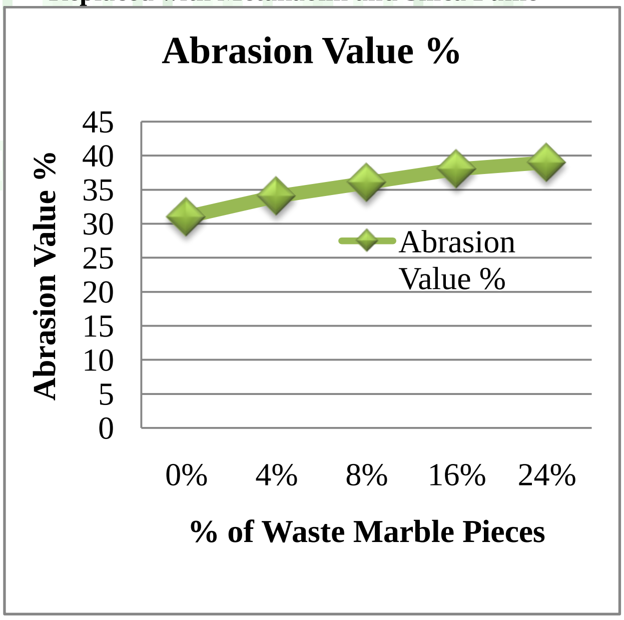

Fig. 4.4Abrasion Test Value of Aggregate with Waste Marble Pieces

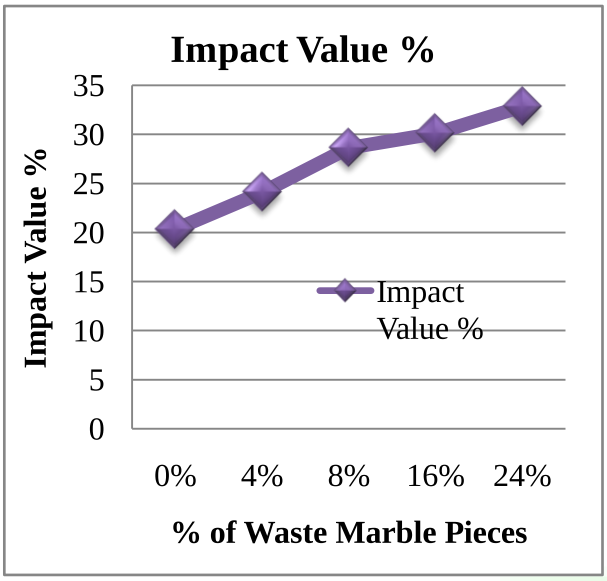

Fig. 4.5Abrasion Test Value of Aggregate with Waste Marble Pieces

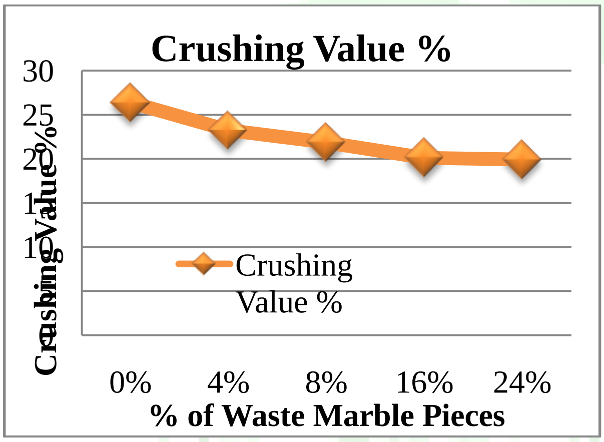

Fig. 4.6Crushing Test Value of Aggregate with Waste Marble Pieces

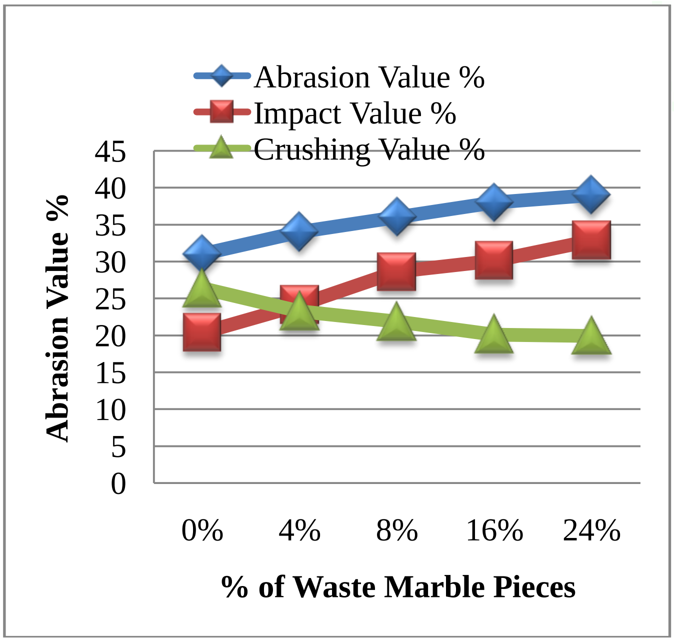

Fig. 4.7Various Test Value of Aggregate with Waste Marble Pieces

V.CONCLUSIONS

5.1Test Result of Cement

At 0% IST is 28min, 8% is 32min, 16% is 36min, 32% is 38min and at 48% is 42min.The minimum IST we can observe at 0% and the maximum IST obtained at 48% of SF+MK.At 0% IST is 598min, 8% is 607min, 16% is 611min, 32% is 618min and at 48% is 624min.The minimum FST we can observe at 0% and the maximum IST obtained at 48% of SF+MK.

5.2Test Result of Cement

The maximum abrasion value is obtained at 24% is 39%.The maximum impact value is obtained at 24% is 32.83%.The maximum crushing value is obtained at 0% and the minimum crushing value is at 24% s 19.92%.

5.3Test Result of Concrete

At 0% replacement of marble pieces maximum value of slump is 104mm and this will decrease as increase in SF+MIK and minimum value reach at 97mm.At 4% replacement of marble pieces maximum value of slump is 106mm and this will decrease as increase in SF+MIK and minimum value reach at 101mm.At 8% replacement of marble pieces maximum value of slump is 109mm and this will decrease as increase in SF+MIK and minimum value reach at 103mm.At 16% replacement of marble pieces maximum value of slump is 110mm and this will decrease as increase in SF+MIK and minimum value reach at 105mm.At 24% replacement of marble pieces maximum value of slump is 111mm and this will decrease as increase in SF+MIK and minimum value reach at 107mm.At 0% replacement of marble pieces maximum value of compressive strength at 7days is 19.42N/mm2 and this will increase as increase in SF+MIK and minimum value reach at 29.59N/mm2.At 4% replacement of marble pieces maximum value of compressive strength at 7days is 24.16N/mm2 and this will increase as increase in SF+MIK and minimum value reach at 31.73N/mm2.At 8% replacement of marble pieces maximum value of compressive strength at 7days is 29.06N/mm2 and this will increase as increase in SF+MIK and minimum value reach at 34.11N/mm2.

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