IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Study On The Non-Destructive Evaluation Of High-Strength Concrete Incorporating Marble Dust As A Partial Cement Replacement.

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Abstract: This study aims to evaluate concrete having Waste Marble Powder (WMP) as partial replacement of cement. Marble is a standout amongst the most imperative materials utilized as a part of the development business. Marble powder is produced from processing plants during the sawing and polishing of marble blocks and about 20 - 25% of the processed marble is turn into powder form. Disposal of the marble powder material from the marble industry is one of the environmental problems worldwide today. The present study is aimed at utilizing Waste marble powder construction industry itself as Marble powder contains high calcium oxide content of more than 50%. The potential use of marble dust can be an ideal choice for substituting in a cementitious binder as the reactivity efficiency increases due to the presence of lime. A total of five concrete mixes, containing 0%, 20%,40% partial replacement of cement with marble powder are investigated in the laboratory. The Results of an experimental investigation on the effects of concrete materials-, mix- and workmanship-related variables, on the Rebound Number and Ultrasonic Pulse Velocity of concrete, are presented. The investigations aimed at developing a method of combined use of both the non-destructive tests for assessment of strength of concrete with greater accuracy. Workmanship variables included different lengths of moist curing

Key Words*:* Rebound hammer test, Pulse velocity test, Non-destructive test, concrete, fine aggregate, marble powder, strength, workability, compressive strength

I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its versatility, durability, and relative economy. It is composed of cement, fine aggregate, coarse aggregate, and water. The cement acts as the binding material that holds the aggregates together, giving the concrete its strength and durability. With increasing global infrastructure demands, the consumption of cement has risen significantly. However, the production of cement is energy-intensive and contributes to environmental degradation through carbon dioxide emissions, accounting for nearly 5–8% of global CO_2 emissions.

Simultaneously, the marble industry, which contributes significantly to building aesthetics and finishing works, generates enormous quantities of waste in the form of marble powder or marble dust during the cutting, grinding, and polishing of marble blocks. Studies indicate that about 20–25% of processed marble is converted into powder form. Improper disposal of this waste leads to environmental problems such as soil pollution, water contamination, and air pollution due to airborne dust particles. Therefore, the recycling of marble dust has become a pressing need for both environmental and economic reasons.

Utilizing waste marble powder (WMP) as a partial replacement for cement in concrete presents a sustainable solution that can reduce environmental impacts, conserve natural resources, and lower the carbon footprint of construction materials. Marble powder contains high calcium oxide (CaO) content—usually exceeding 50%—making it potentially reactive when incorporated into cementitious systems. The lime present in marble powder can contribute to the hydration process, improving the pozzolanic reactions and potentially enhancing certain mechanical properties of concrete, particularly in the long term.

1.1 Objectives of the Study

The primary objectives of this study are:

1. To investigate the feasibility of using waste marble powder as a partial replacement for cement in high-strength concrete.
2. To evaluate the mechanical properties of concrete, particularly compressive strength, when cement is partially replaced with marble dust at varying percentages (0%, 20%, 40%).
3. To study the effect of marble dust on concrete properties using non-destructive testing methods, including:
   - Schmidt Rebound Hammer Test for surface hardness and rebound number.
   - Ultrasonic Pulse Velocity Test for evaluating the internal quality and uniformity of concrete.
4. To develop a combined assessment methodology using both NDT techniques for more accurate prediction of concrete strength.
5. To assess the influence of workmanship variables, such as curing duration, on the performance of concrete containing marble dust.

1.2 Scope of the Study

This study focuses on high-strength concrete incorporating waste marble powder as a partial replacement of cement. The research covers:

1. **Materials**: Ordinary Portland cement, fine and coarse aggregates, waste marble powder, and potable water.
2. **Mix Design**: M60 grade concrete is designed, and mixes with 0%, 20%, and 40% cement replacement by marble dust are prepared.
3. **Testing Methods**:
   - Laboratory casting and curing of concrete cubes and cylinders.
   - Non-destructive evaluation using Schmidt Rebound Hammer and Ultrasonic Pulse Velocity tests at 7 and 28 days of curing.

4. **Analysis**: Comparative assessment of compressive strength obtained from NDT with conventional destructive testing results to determine the optimum percentage of marble powder replacement.

1.3 Literature Review Summary

Recent studies have highlighted the potential of WMP in concrete:

- Marble powder can improve the workability and cohesiveness of concrete due to its fine particle size.
- Partial replacement of cement by marble dust up to 20–30% does not significantly reduce compressive strength at 28 days.
- Non-destructive testing, particularly the combination of rebound hammer and ultrasonic pulse velocity tests, provides a reliable method for predicting compressive strength, detecting defects, and assessing durability.
- Longer curing periods positively affect concrete strength with marble dust due to pozzolanic reactions of calcium oxide present in marble powder.

These studies form the basis for the current experimental investigation and highlight the importance of optimizing marble dust replacement for maximum concrete performance.

1.4 Methodology Overview

The methodology adopted in this study includes:

1. **Material Collection and Characterization**: Collection of cement, aggregates, and marble powder. Characterization of marble powder for chemical composition, fineness, and particle size distribution.
2. **Mix Proportioning**: Design of high-strength concrete mix (M60) according to IS 10262:2019 standards, with 0%, 20%, and 40% replacement of cement by marble dust.
3. **Specimen Casting and Curing**: Casting of concrete cubes and cylinders, followed by curing for 7 and 28 days.
4. **Testing**: Conducting Schmidt Rebound Hammer and Ultrasonic Pulse Velocity tests to evaluate concrete strength and internal quality.
5. **Data Analysis**: Comparing NDT results with conventional compressive strength tests to establish correlations and determine the optimum replacement level of marble powder.

II.METHODOLOGY

Methodology is a systematic approach to conduct research, Methodology describes the complete procedure from surveying of literatures to comparison of results of conventional mix and mixes with partial replacement of feldspar and quartz as fine aggregate.

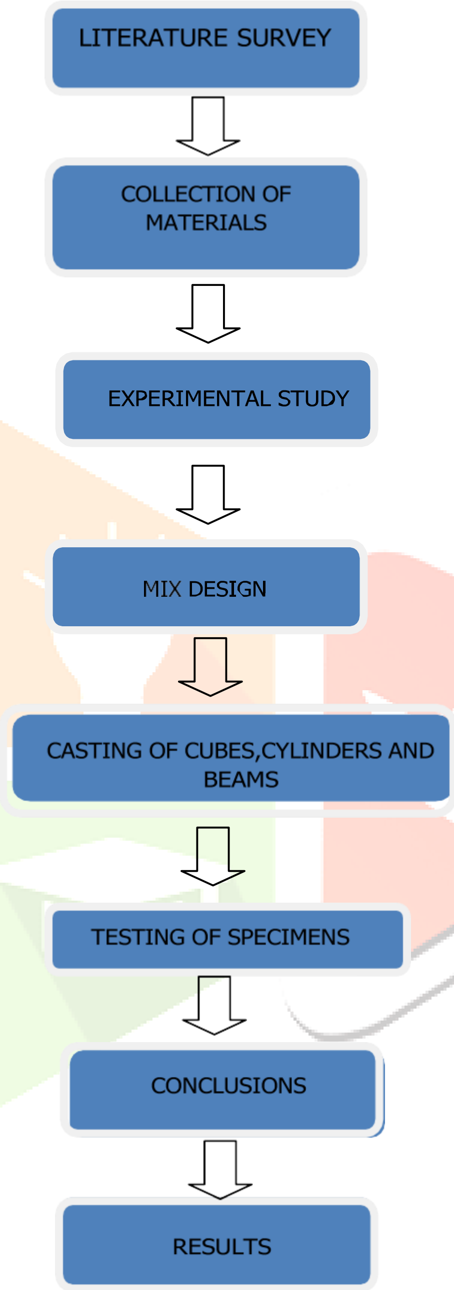

Fig.2.1 Flowchart of methodology

III. METHODOLOGY &MIX DESIGN

3.1 Collection of raw materials

FINE AGGREGATE: the sand used for our investigation is collected form Amaravathi Region sand which is conforming to Zone II as per Indian Specification 383-1970 codal provisions.

COARSE AGGREGATE: The coarse aggregate of max 60% of 20mm size and 40% of 12.5mm with an angular shape which is well graded

MARBLE DUST: Marble dust is collected from Indian Mart

Figure 3.1 Marble Dust

3.2 Batching

By considering the mix proportions the volume of cube is calculated and calculating the quantity of materials required for cube.

Figure 3.2 Batching

3.3 Mixing

The object of mixing is with alkaline activators to blend all the ingredients of concrete into a uniform mass. Though mixing of the materials is essential for the production uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency. In this study the process of hand mixing was adopted.

Figure 3.3 Mixing of concrete

3.4 Casting of specimen

The cube specimen is of size 150*150*150mm. Before placing the concrete in the mould, its interior surface and base plate were lightly oiled to prevent the unevenness of the specimen. The mixed concrete is placed in the oiled mold in layers, each layer of having 5cm thick. After placing each layer it is pampered 30 times using a slandered tampered rod. The strokes penetrated into the underlying layer and the bottom layer was ridded throughout its depth.

3.5 Curing of specimen

Providing adequate moisture, temperature, and time to allow the **concrete** to achieve the desired properties for its intended use. . When these recommendations are properly specified and performed in the field

As soon as the concreting is completed, the mould is stored in a rapid curing at 101 c for 4 hours. Later the specimen is placed at room temperature until taken for testing.

Figure.3.4 Curing of specimen

3.6 HIGH STRENGTH CONCRETE MIX DESIGN

The mix composition is chosen to satisfy all performance criteria for the concrete. The various methods of mix design are applied for determining the qualities & quantity of concrete. High-strength concrete is prepared by decreasing the water-cement ratio to less than 0.35. Such concrete has strength exceeding 40 MPa. Working with high-strength concrete is a significant issue because of its lower level of performance. The design method preferred in this report is Indian Standard Institution (ISI) Concrete design method and hence has been discussed.

MIX PROPORTIONS

Cement= 543.33 kg/m3

Water= 163 kg/m3

Fine Aggregate(FA)= 568.128 kg/m3 Coarse Aggregate(CA)= 1220.736 kg/m3 Super Palsticizer(SP)= 5.433 kg/m3

Cement: Water: FA: CA: SP = 1: 0.3: 1.05: 2.25: 0.01

IV.TESTS ON CONCRETE

4.1 Compressive strength

The concept of compressive resistance, which refers to a material or structure's ability to withstand surface loads without cracking or deflecting. When a material is subjected to compression, it tends to shrink in size, whereas in tension, it elongates. The test procedure for determining compressive resistance involves...

Fig 4.1: Compressive strength test

Concrete cubes are casted for design mix at M60 replacement of marble dust.

The compressive strength for M60 grade is tested for 7 and 28days age of curing and the obtained results are tabulated in the form of table and graph.

Table 4.1 Cube Compressive Strength for 7-Days & 28-days

% Replacement of Cement with Marble Dust	7 Days Cube Strength (N/mm^2)	28 Days Cube Strength (N/mm^2)
0%	43.32	64.50
20%	39.40	61.40
40%	35.85	59.19

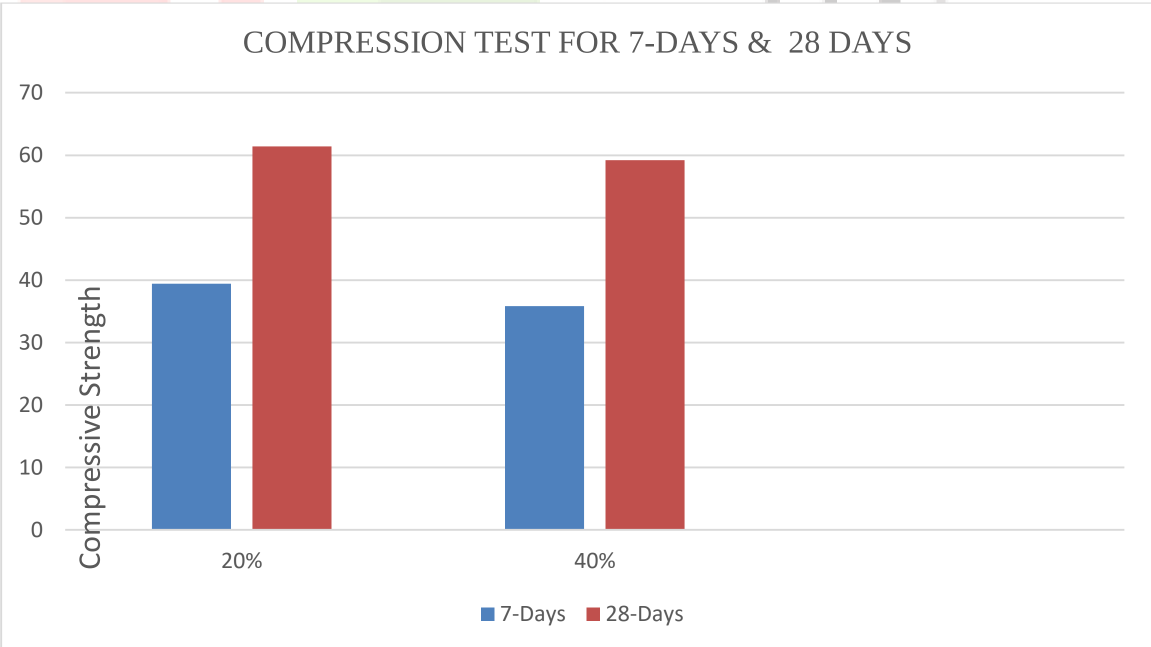

Fig.4.1 Compression test for 7-dasy & 28 days test

Table 4.2 Cylinder Compressive Strength at 7-days & 28-days

% Replacement of Cement with Marble Dust	7 Days Cylinder Strength (N/mm^2)	28 Days Cylinder Strength (N/mm^2)
0%	32.05	52.33
20%	31.65	50.36
40%	30.815	49.21

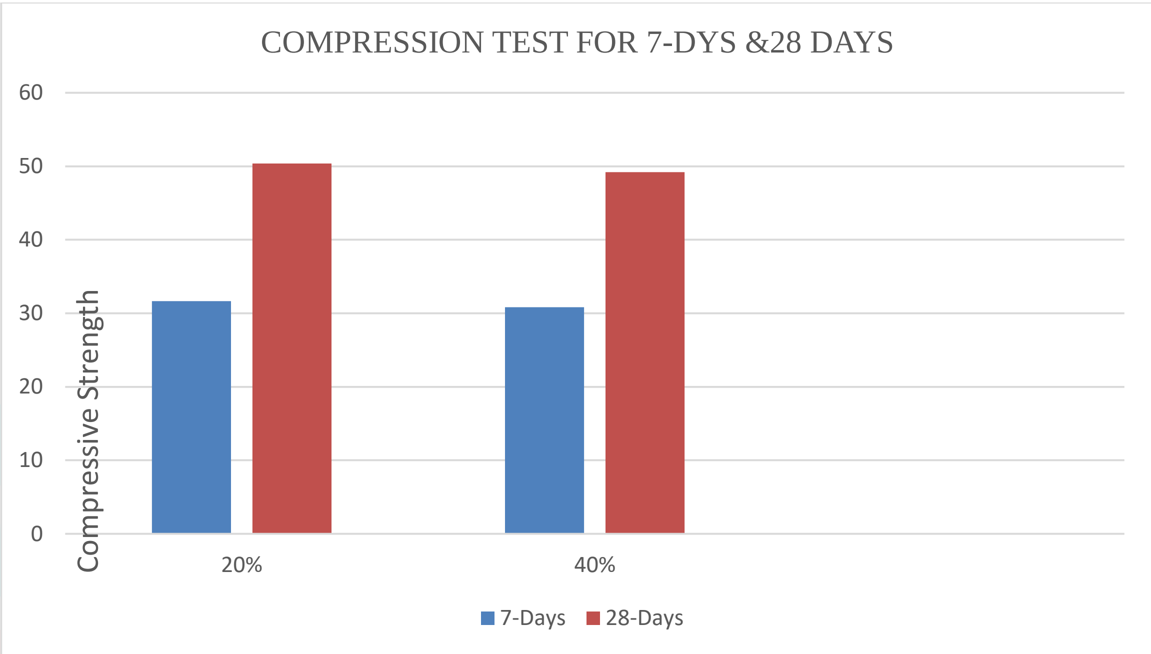

Fig.4.2 Compression test for 7-dasy & 28 days test

4.2 ULTRA SONIC PLUS VELOCITY TEST

Table 4.2.1: UPV Test Results at 7-Days & 28 Days

% Replacement of Cement with Marble Dust	Age of Cube	Compressive Strength (N/mm^2)	Pulse Velocity (m/sec)	Time (sec)
0%	7 days	42.48	5792	26.20
0%	28 days	66.35	5869	25.50
20%	7 days	39.06	5683	26.54
20%	28 days	60.22	5822	25.60
40%	7 days	38.26	5477	27.58
40%	28 days	59.98	5579	26.92

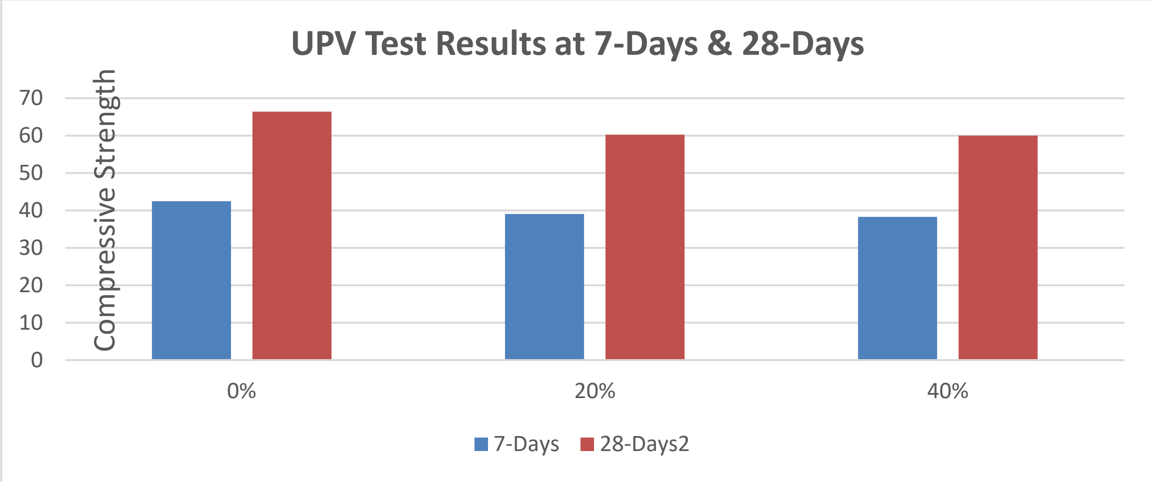

Figure 4.2.1: UPV Test Results at 7-Days & 28-Days

4.3 Schmidt Rebound Hammer Test

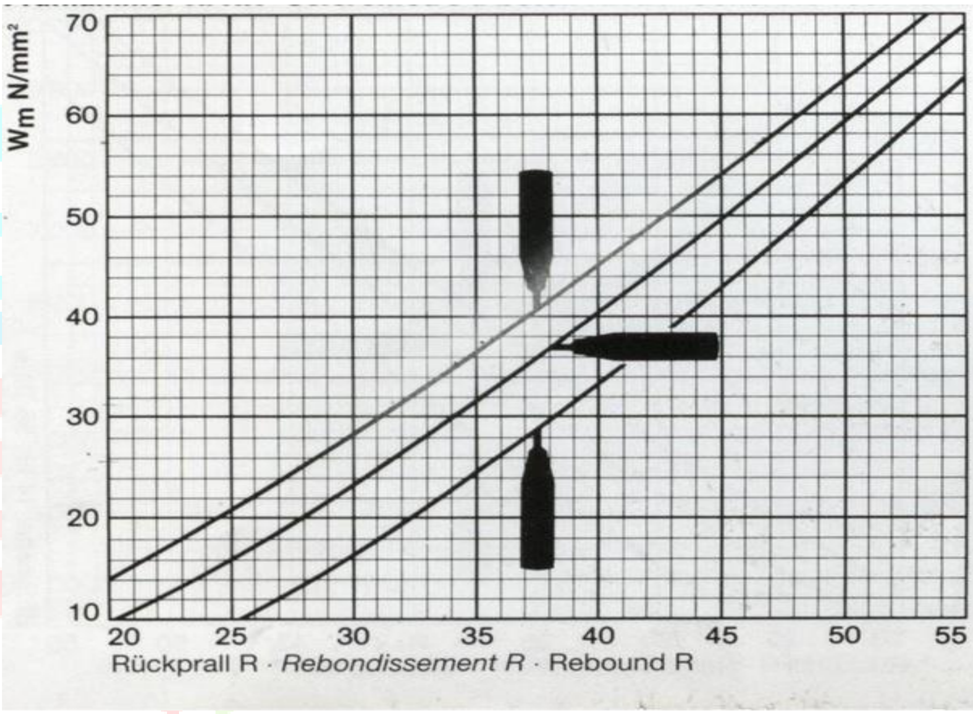

Figure.4.3.1 Schmidt Rebound Hammer Test Graph

Table 4.3.1: Schmidt Rebound Hammer Test – 7 Days & 28 Days (Cubes)

% Replacement of Cement	Cube	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
0%	Cube 1	43.15	64.382
	Cube 2	43.565	64.46
	Cube 3	43.36	64.42
	Average	**43.36**	**64.42**
20%	Cube 1	37.79	62.607
	Cube 2	37.92	60.21
	Cube 3	37.86	61.41
	Average	**37.86**	**61.41**
40%	Cube 1	35.22	59.19
	Cube 2	36.49	60.48
	Cube 3	35.85	59.84
	Average	**35.85**	**59.84**

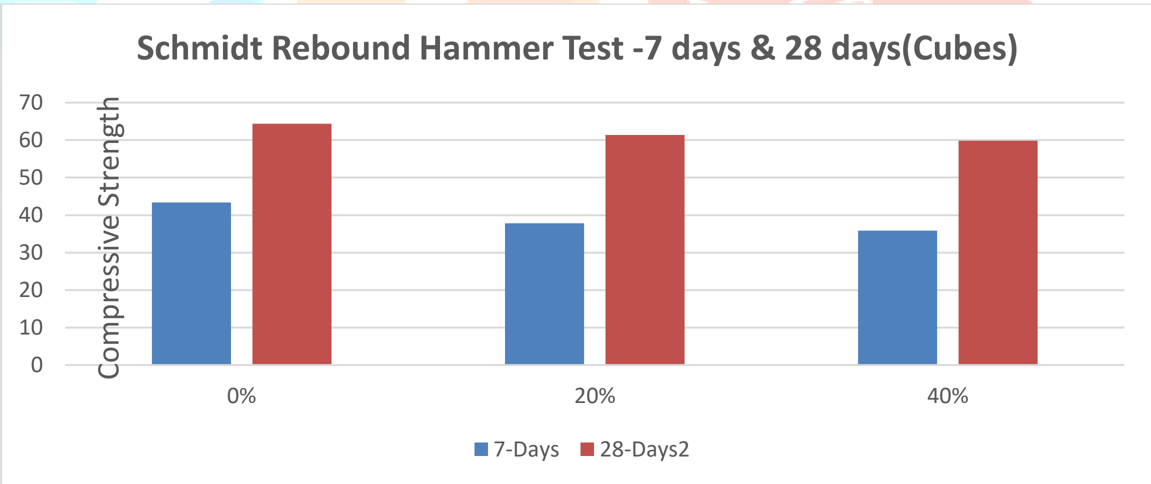

Figure 4.3.2: Schmidt Rebound Hammer Test – 7 Days & 28 Days(Cubes)

Table 4.3.2: Schmidt Rebound Hammer Test –7 Days & 28 Days(Cylinders)

% Replacement of Cement	Cylinder	Compressive Strength at 7 Days (N/mm²)	Compressive Strength at 28 Days (N/mm²)
0%	Cylinder 1	32.015	51.55
	Cylinder 2	32.99	53.05
	Cylinder 3	32.50	52.30
	Average	**32.50**	**52.30**
20%	Cylinder 1	32.48	51.33
	Cylinder 2	31.825	49.39
	Cylinder 3	32.28	50.36
	Average	**32.28**	**50.36**
40%	Cylinder 1	29.995	48.83
	Cylinder 2	30.815	49.59
	Cylinder 3	30.41	49.21
	Average	**30.41**	**49.21**

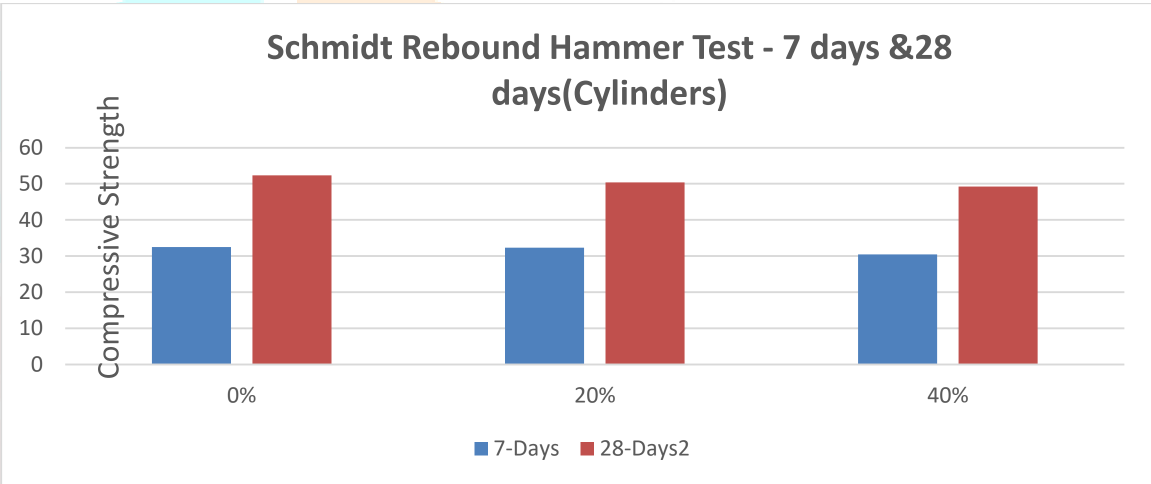

Figure 4.3.3: Schmidt Rebound Hammer Test – 7 Days & 28 Days(Cylinders)

V.CONCLUSION

1. Compressive Strength Test (Cubes & Cylinders)

1. Strength **decreases** as marble dust replacement increases.
2. **Cube Strength (7 & 28 days):**
   - 7 days: 43.32 → 39.40 → 35.85 N/mm²
   - 28 days: 64.50 → 61.40 → 59.19 N/mm²
3. **Cylinder Strength (7 & 28 days):**
   - 7 days: 32.05 → 31.65 → 30.815 N/mm²
   - 28 days: 52.33 → 50.36 → 49.21 N/mm²
4. **Optimum replacement:** 20% marble dust (good balance of strength and sustainability).

2. Ultrasonic Pulse Velocity (UPV) Test

1. Pulse velocity **decreases** with increasing marble dust, indicating slight reduction in density/quality.
2. 7-day UPV: 5792 → 5683 → 5477 m/s
3. 28-day UPV: 5869 → 5822 → 5579 m/s
4. Time for pulse **increases slightly** as marble dust increases.
5. **Optimum replacement:** 20% (maintains good concrete quality).

3. Schmidt Rebound Hammer Test

1. Compressive strength **decreases** with higher marble dust content for both cubes and cylinders.
2. Cube Strength (7 & 28 days): 43.36 → 37.86 → 35.85 N/mm² (7 days), 64.42 → 61.41 → 59.84 N/mm² (28 days)
3. Cylinder Strength (7 & 28 days): 32.50 → 32.28 → 30.41 N/mm² (7 days), 52.30 → 50.36 → 49.21 N/mm² (28 days)
4. **Optimum replacement:** 20% (strength close to normal concrete).

Overall Observation

1. All three tests show **strength decreases with more marble dust**.
2. **20% replacement** is **optimum**, giving good strength and sustainability.
3. 40% replacement reduces strength noticeably, but concrete still has acceptable properties.
4. Non-destructive tests (UPV & Schmidt hammer) **correlate well** with destructive compressive strength tests.

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