

Assessment of Various Properties of Concrete and Environmental Impact of Utilizing Waste Marble Dust in Concrete: A Review

Kamaldeep Kaur¹, Gurpreet Singh²

^{1,2}*Department of Civil Engineering, Punjabi University, Patiala, Punjab, India*

doi.org/10.64643/IJIRT209465

Abstract—Waste marble dust is generated during the process of preparing marble for use in flooring or decorative applications. Each year, a large amount of marble waste is produced by the construction industry, which leads to numerous environmental and health issues when it is disposed of improperly. Therefore, researchers have discovered an effective solution to address these problems by using waste marble dust as a substitute for fine aggregates in concrete. This approach not only benefits the environment but also reduces the need for soil mining. Researchers have conducted experiments to evaluate the mechanical and durability properties of concrete when fine aggregates are replaced with marble dust at various levels, ranging from 0% to 100%. In these experiments, several properties of the concrete were tested, including compressive strength, tensile strength, flexural strength, workability, modulus of elasticity, ultrasonic pulse velocity, porosity, SEM, XRD, water absorption, and sorptivity. By comparing the results with reference concrete (which contains 0% waste marble dust), it was determined whether waste marble dust is a viable alternative to fine aggregates. After analyzing the test results and discussion, it was concluded that the utilization of waste marble dust as a partial replacement for fine aggregates improves some of the properties of concrete and can be effectively used as a construction material.

Index Terms—concrete, waste marble dust, construction industry, compressive strength, tensile strength, porosity, ultrasonic pulse velocity, workability, environment

I. INTRODUCTION

In civil engineering construction and repair works, concrete is widely accepted as a material. Consequently, a large quantity (approximately 14 billion cubic meters) of concrete is produced

annually. In addition to cement, coarse and fine aggregates are essential materials used in the production of conventional concrete, and they are used extensively. Due to the heavy use of these materials, there may be a future shortage of fine and coarse aggregates. As 30% of the total volume of concrete consists of fine aggregates (Idrees & Faiz 2019), it can be stated that a shortage of sand may occur in the future due to the overuse of fine aggregates in the construction sector. Therefore, researchers are now experimenting with alternative materials for concrete ingredients from waste to reduce the use of natural materials and protect the environment from problems caused by improper waste disposal. Moreover, using waste materials in concrete is considered an efficient way to manage waste and produce high-quality concrete (Tavakoli & Hashempour, 2018).

Manufacturing units, the construction industry, thermal power plants, and agriculture are some of the sources of waste materials. Waste from these sources is often dumped in open areas or water bodies, causing environmental pollution (Ahmad et al., 2021). Therefore, using these waste materials as ingredients in concrete is an effective way to address environmental issues and reduce the consumption of natural materials. Waste marble dust is a by-product of the construction industry. Marble stones have been used for decoration and flooring since ancient times, and waste marble dust is produced during the cutting, burnishing, and shaping of marble stones. Approximately 17 million tons of stones are used annually in India, leaving behind 7 million tons of waste (Krishnan et al., 2017). Marble waste cannot be recycled (Anwar et al., 2015) and, when dumped in landfills, causes soil infertility and health hazards (Rao, 2016). From an environmental perspective,

although marble is an inert material, the marble stone industry is one of the most damaging sectors (Asish et al., 2022). It poses threats to the biological system and climate. Dumped marble stones degrade soil quality by reducing its porosity and altering its water absorption properties. Dry marble dust contaminates the air and causes health problems, while it also affects the nature of water and adversely impacts aquatic flora and fauna.

Considering the need to utilize such waste products, numerous researchers have incorporated waste marble dust into concrete as a replacement for fine aggregates due to its physical properties and concluded that it is a sustainable material that can partly replace fine aggregates without compromising the essential properties of concrete.

1.1 Properties of waste marble dust-

1.1.1 Physical properties- Saran & Das (2019) determined the physical properties of marble dust and

found that waste marble dust is a white-colored powder with a density of 575 kg/m³. It has a specific gravity of 2.4. According to Gameiro et al. (2014), angular and elongated particles of waste marble dust influenced the bonding between cement and aggregates. This led to a significant reduction in water absorption due to capillary action in mixes containing 20 percent waste marble dust. Ofuyatan et al. (2019) noted that the fine particles and binding characteristics of marble dust were responsible for the lower slump value. However, these same properties also contributed to the improved strength of concrete. Therefore, it can be concluded that the physical properties of marble dust, such as fineness modulus, water absorption, and density, have a major impact on the mechanical properties of concrete. Various researchers have determined the physical properties of marble dust, as listed in Table 1.

Table 1: Physical properties of waste marble dust

Property	Saran & Das 2019	Vardhan et al 2019	Sakalkale 2014	Aliabdo et al. 2014	Vigneshpandian et al 2017	Gameiro et al 2014	Idrees & Faiz 2019
Specific gravity	2.5	2.88	2.68	2.50	2.67		3.10
Density (kg/m ³)	575						
Bulk density (kg/m ³)		1565				2684	
Mean particle size (µm)	0.1						
Fineness modulus		2.23			2.505		1.20
Minimum surface area (m ² /kg)	2500						
Particle shape	Spherical						
Water absorption (%)		1.1				0.14	1.6
Specific surface area (m ² /g)		0.249					
Fineness Blaine measurement (cm ² /gm)				3996			

1.1.2 Chemical composition- Chemical composition refers to the chemical elements and compounds present in a material. These are important for understanding how construction materials affect the properties of concrete. Both the mechanical and durability properties of concrete can be influenced by the presence of certain chemical compounds in the ingredients. From the chemical composition of marble dust, as provided by different researchers in Table 2, it was observed that the percentage of calcium oxide (CaO) was higher than other elements, ranging from 28.7% to 52.46%. The presence of CaO helps in increasing the strength of concrete, as stated by Mahdi et al. (2020).

Table 2. Chemical composition of waste marble dust

Component	Symbol	Saran & Das 2019	Ofuyatan et al 2019	Demirel 2010	Sakalkale 2014	Aliabdo 2014	Vardhan et al 2019	Varadharajan et al 2020
		Value (%)						
Silica	SiO ₂	28.35	1.29	28.35	28.35	1.12	4.7	5.87
Alumina	Al ₂ O ₃	0.42	0.39	0.42	0.42	0.73	0.2	0.56
Ferric oxide	Fe ₂ O ₃	9.70	0.78	9.70	9.70	0.05	0.5	0.8
Calcium	CaO	40.5	52.46	40.45	40.45	83.22	28.7	41.54
Magnesium	MgO	16.5	0.54	16.25	16.25	0.52	22.3	15.55

Manganese oxide	MnO	0.004	-	-	-	-	-	
Loss of ignition	LOI	2.08	-	-	-	2.5	43.7	
Potassium oxide	K ₂ O	-	0.11	-	-	0.09	0.05	0.073
Sulfur trioxide	SO ₃	-	-	-	-	0.56	-	0.11
Sodium oxide	Na ₂ O	-	-	-	-	1.12	0.06	0.07
Free CaO		-	-	-	-	0.15	-	

1.2 Applications of marble dust- Marble dust can be used either as replacement material or as additive in concrete or mortar. Apart from this, it is also used as the following (Chavhan & Bhole, 2014), (Saran & Das 2019), (Vardhan et al 2019).

- Filler
- Industrial bricks
- Modified concrete/ mortar
- Admixture
- Paint primer
- White cement component

II. EFFECT OF UTILIZATION OF WASTE MARBLE DUST ON PROPERTIES OF CONCRETE

2.1 Workability

Boobalan et al (2020) studied the workability of concrete using slump test and compaction factor test with a constant water cement ratio of 0.5. The slump test showed that as replacement percentages increased, workability decreased. The compaction factor test showed minimal variation in compaction factor values. It can be concluded that using marble dust as a fine aggregate does not improve the workability of concrete, probably because marble dust requires more water.

Sakalkale et al (2014) conducted slump tests to evaluate workability at replacement levels of 0%, 25%, 50%, and 100% of fine aggregates with marble dust. At 0% replacement, workability was lowest compared to 25%, 50%, and 100%. The respective workability values were 54mm, 62mm, 78mm, and 95mm. The results suggest that workability increased by 14.8%, 44.44%, and 75.93% at 25%, 50%, and 100% replacement levels.

Saran & Das (2019) used the slump test to analyze the workability of fresh concrete. The study found that using marble dust negatively affected workability. In comparison to normal concrete, slump values decreased by 3.57%, 7.14%, 7.14%, 10.72%, and 42.86% for mixes with 10%, 20%, 30%, 40%,

and 50% marble dust. This may be due to the higher water requirement of marble dust compared to standard sand.

Vardhan et al (2019) observed that despite marble dust having less water absorption than standard sand (as per zone III), its use reduced the workability of fresh concrete. Slump tests showed a reduction in slump values by 10%, 15%, 20%, 30%, 35%, and 40% for mixes with 10%, 20%, 30%, 40%, 50%, and 60% marble dust.

Varadharajan et al (2020) conducted slump tests on fresh concrete with marble powder and rice husk ash as partial replacements for fine aggregates. Rice husk ash was added at 5% and 20%, while marble powder was used at 10%, 20%, and 30%. The results indicated a decrease in workability, likely due to marble powder's larger surface area leading to higher water demand.

Ghani et al (2020) used slump tests to assess the workability of concrete with 0%, 20%, 40%, 60%, and 80% marble dust as fine aggregates. The results showed that as the quantity of marble dust increased, workability decreased. Mixes with 20%, 40%, 60%, and 80% marble dust saw reductions in workability of 26%, 65%, 93%, and 100%, respectively. This is possibly because marble dust concrete requires more water to maintain workability.

Gameiro et al (2014) replaced 0%, 20%, 50%, and 100% of fine aggregates with marble dust. Workability was measured by slump value, and a significant decrease was noted in fresh concrete. The authors suggested that using different water cement ratios may help maintain workability.

Idrees & Faiz (2019) used waste materials like marble powder and quarry dust as sand replacements. They created various mixes by replacing 0%, 12.5%, 25%, and 50% of sand with marble powder and 0%, 12.5%, 25%, and 50% of sand with quarry dust. Additional mixes used 12.5% and 25% of both marble powder and quarry dust. Slump tests showed that marble powder reduced workability, while quarry dust improved slump values.

Table 3. Workability of concrete mixes incorporating marble dust investigated by various researchers

Study	w/c	Marble dust replacement (%)	Other materials	Slump value (mm)
Boobalan et al (2020)	0.5	0	-	142
		25		139
		50		136
		75		134
		100		132
Sakalkale et al (2014)	0.48	0	-	54
		25		62
		50		78
		100		95
Saran & Das (2019)	0.42	0	-	28
		10		27
		20		26
		30		26
		40		25
		50		16
Vardhan et al (2019)	0.5	0	-	100
		10		90
		20		85
		30		80
		40		70
		50		65
		60		60
Varadharajan et al (2020)	0.43	0	0% Rice Husk Ash	34
		10		30
		20		26
		30		23
Ghani et al (2020)	-	0	-	90
		20		67
		40		32
		60		7
		80		0
Gameiro et al (2014)	0.55	0	100% Basalt sand	113
	0.55	20	80% Basalt sand	143
	0.56	50	50% Basalt sand	143
	0.54	100	0% Basalt sand	135
	0.49	0	100% River sand	133
	0.5	20	80% River sand	127
	0.5	50	50% River sand	132
	0.54	0	100% Granite sand	127
	0.55	20	80% Granite sand	116
	0.56	50	50% Granite sand	130
Idrees & Faiz (2019)	-	0	0% quarry dust	90
		12.5	0% quarry dust	79
		25	0% quarry dust	75
		50	0% quarry dust	62
		12.5	12.5% quarry dust	82
		25	25% quarry dust	68

2.2 Compressive Strength

Ahmed et al (2019) concluded that at a 5% replacement level, maximum gain in strength was

achieved at 7, 14 and 28 days. However, a declining trend was observed in compressive strength as the replacement percentage increased. Based on their

findings, it was stated that the optimal replacement level of fine aggregate with marble dust is 5%, which can be used without negatively affecting the strength of concrete.

Boobalan et al (2020) conducted experiments on the compressive strength of concrete at 7, 14 and 28 days. They used replacement levels of 0%, 25%, 50%, 75% and 100%. Test results showed that up to 50% replacement, the strength improved, but a drop-in strength was observed at 75% and 100% replacement levels. Therefore, the optimal replacement level was found to be 50%, which can be used without affecting the strength properties of concrete.

Demirel (2010) found that as the amount of waste marble dust increased, the compressive strength values improved at 3, 7, 28 and 90 days. The replacement levels used were 0%, 25%, 50% and 100%. When comparing concrete mixes with 100% replacement level to the reference mix with 0% marble dust, an increase in compressive strength was observed at all tested ages. The increases were 49.8%, 9.74%, 9.67% and 4.61% at 3, 7, 28 and 90 days respectively.

Sakalkale et al (2014) replaced fine aggregates with marble dust at 0%, 25%, 50% and 100% levels. They prepared test specimens for each replacement level and tested them on a compressive testing machine. From their observations, the compressive strength at 0% replacement was 21.33 N/mm², 21.78 N/mm² and 31.73 N/mm² for 3, 7 and 28 days respectively. At 25% replacement, the compressive strength values were 22.22 N/mm², 22.34 N/mm² and 33.11 N/mm² for the same curing periods. With 50% replacement, the compressive strength was 22.43 N/mm², 23.11 N/mm² and 35.54 N/mm². However, at 100% replacement, the strength values were 13.52 N/mm², 9.76 N/mm² and 21.32 N/mm². The results showed an increase in strength at 25% and 50% replacement levels, but a decline was noticed at 100% replacement.

Aliabdo et al (2014) experimented with marble dust in concrete, first as a cement replacement and then as a fine aggregate replacement. They used replacement levels of 0%, 5%, 7.5%, 10% and 15%. Test results showed that when marble dust was used as a cement replacement, the compressive strength decreased due to the reduction in cement content. However, when used as a fine aggregate replacement, the

compressive strength increased with higher replacement percentages. The study also tested two water-cement ratios, 0.4 and 0.5. It was concluded that marble dust was more effective with a 0.4 water-cement ratio. At 28 days, the increase in strength was 17%, 21%, 15% and 22% for 5%, 7.5%, 10% and 15% replacement levels respectively.

Vigneshpandian et al (2017) performed compressive strength tests on cubes at 28 days with 0%, 25%, 50% and 100% utilization of marble dust as fine aggregates. Their results showed that strength improved up to 50% replacement level, but a significant reduction was observed at 100% substitution. The maximum strength was achieved at 50%, which was approximately 28% higher than the control mix. At 100% replacement level, the strength was 6.81% lower than the reference mix.

HS Lakshmi (2017) replaced 0%, 10%, 20% and 30% fine aggregates with marble dust in concrete and checked the compressive strength at 7, 14 and 28 days. After comparing the test results of the control mix with those of mixes that included marble dust, it was found that at 10% and 20% replacement levels, there was an improvement in the compressive strength. However, at 30% replacement level, the strength values decreased slightly compared to the 20% replacement level, although the strength at 30% was still higher than that of the control mix. The average increase in compressive strength for the 7, 14, and 28-day periods was 2.11% for 10% replacement, 8.03% for 20% replacement, and 4.36% for 30% replacement.

Saran & Das (2019) added 10%, 20%, 30%, 40%, and 50% marble dust in place of fine aggregates. Compressive strength tests were conducted on specimens cured separately in normal water and in water mixed with NACL at 7 days and 28 days. The specimens cured in normal water were tested first, and the results showed that the addition of marble dust significantly increased the strength of the concrete as the percentage of substitution increased. Moreover, curing the specimens in NACL water along with the use of marble dust further improved the compressive strength compared to those cured in normal water.

Vardhan et al (2019) tested the compressive strength of concrete at 28 days and 90 days. Concrete mixes were cast with 0%, 10%, 20%, 30%, 40%, 50%, and 60% marble dust as fine aggregates. The test results

showed that up to 40% use of marble dust, the strength values increased. However, at 50% and 60% levels, there was a minor reduction in strength. When comparing the control mix with the modified mixes, improvements in compressive strength of 9.7%, 15.8%, 21.1%, 22.4%, 21.3%, and 20.2% were observed for the mixes containing 10%, 20%, 30%, 40%, 50%, and 60% marble dust, respectively. This improvement may be due to an enhanced concrete matrix and better bond strength.

Kannan et al (2019) created concrete mixtures using 0%, 15%, 30%, 45%, 60%, and 75% of marble powder and quarry dust as a replacement for fine aggregates. To evaluate the compressive strength, cube samples were made and tested after 7 days and 28 days of curing. The test results showed that the strength increased significantly up to a 60% replacement level, but at 75%, the strength decreased. Despite this decrease, the strength at 75% replacement was still higher than the control mix at 28 days. Therefore, it can be concluded that using industrial waste materials affects the strength of concrete.

Varadharajan et al (2020) used rice husk ash along with marble powder to replace standard sand. The replacement percentages for marble dust were 10%, 20%, and 30%. The compressive strength was tested at 7 days and 28 days. When comparing the strength of mixes with marble dust to the control mix at 7 days, it was found that the strength increased by 3.7%, 6%, and 12.3% for 10%, 20%, and 30% replacements respectively. The results at 28 days

followed a similar trend, showing that using waste materials improved the strength of hardened concrete. Ghani et al (2020) studied the compressive strength of concrete with 0%, 20%, 40%, 60%, and 80% marble powder at 14, 28, and 70 days. The test results showed that concrete with 20% and 40% marble powder had higher strength compared to the mix without marble powder. However, the strength decreased at 60% and 80% replacement levels. This trend was consistent across all tested periods, 14, 28, and 70 days. It was also noted that the initial strength gain was faster for marble powder blended concrete. The highest strength was achieved at a 40% substitution level, with strength values of 39.85%, 38.55%, and 45.45% at 14, 28, and 70 days respectively.

Idrees & Faiz (2019) conducted compressive strength tests on concrete specimens containing 0%, 12.5%, 25%, and 50% marble powder (MP) and quarry dust (QD) individually, as well as combinations of 25% (12.5% MP + 12.5% QD) and 50% (25% MP + 25% QD) at 28 days. The experimental findings indicated that 12.5% marble powder increased the compressive strength. However, further addition of marble powder led to a decrease in strength. Similar trends were observed with quarry dust and combinations of both materials. The use of 12.5% marble dust increased the compressive strength by 25.93% compared to the control mix.

Table 4. Compressive strength of concrete mixes incorporating marble dust investigated by various researchers

Study	w/c	Marble dust replacement (%)	Other materials	Compressive strength (N/mm ²)						
				3 days	7 days	14 days	28 days	56 days	70 days	90 days
Ahmed et al 2019	0.5	5	-		22.07	23.85	40.88			
		15			17.77	18.67	25.78			
		25			17.78	21.04	25.04			
		35			17.92	18.37	22.22			
		45			16.89	18.37	24.30			
		50			18.07	19.70	30.67			
		100			17.33	20	21.63			
Boobalan et al 2020	0.5	0	-		21.33	21.78	31.73			
		25			22.22	22.36	33.11			
		50			22.44	23.11	34.67			
		75			21.16	21.19	26.31			
		100			13.33	14.22	21.33			
Demirel 2010	0.51	0	-	14.33	35.5		48.68			60.51
		25		15.8	35.54		50.25			61.44
		50		17.66	36.43		50.69			61.50

		100		21.46	38.97		53.39			63.30
Sakalkale et al 2014	0.48	0 25 50 100	-	21.33 22.22 22.43 13.35	21.78 22.34 23.11 9.76		31.73 33.11 35.54 21.32			
Aliabdo et al 2014	0.5 0.4	0 5 7.5 10 15 0 5 7.5 10 15	-		31 33.5 35.5 36.5 34.5 42 45.5 46 46.5 45.5		40 43 44.5 46.5 43 48.5 57 58.5 59 56	45.5 47 48 49 46.5 55.5 59 61.5 62.5 61		
Vigneshpandian et al 2017	0.42	0 25 50 100					31.42 33.02 40.22 29.28			
HS Lakshmi 2017	0.50	0 10 20 30			13.58 13.76 14.98 14.30	17.32 17.52 19.02 18.20	22.33 23.10 23.60 23.27			
Saran & Das 2019	0.42	10 20 30 40 50			24.84 25.96 26.91 27.91 28.75		38.94 40.02 42.72 44.53 44.92			
Vardhan et al 2019	0.5	0 10 20 30 40 50 60					36 39.5 42 43.5 44.5 44 43.7			45 48.5 50.7 54 55 54.7 53.8
Kannan et al 2019		0 15 30 45 60 75	Quarry dust		32.54 34.29 35.11 35.98 36.71 30.14		36.40 39.03 40.45 44.44 47.85 41.16			
Varadharajan et al 2020	0.43	0 10 20 30	Rice husk ash		25.7 26 26.9 29.5		34.3 36.2 37.9 40			
Ghani et al 2020		0 20 40 60 80				24.48 29.65 34.24 31.12 14.67	27 33.15 37.41 33.75 15.66		27.25 36.63 39.64 36.60 17.87	
Idrees & Faiz 2019	0.55	0 12.5 25 50 12.5 25	0% quarry dust 0% quarry dust 0% quarry dust 0% quarry dust 12.5% quarry dust 25% quarry dust				28.69 36.13 27.82 27.30 30.24 27.74			

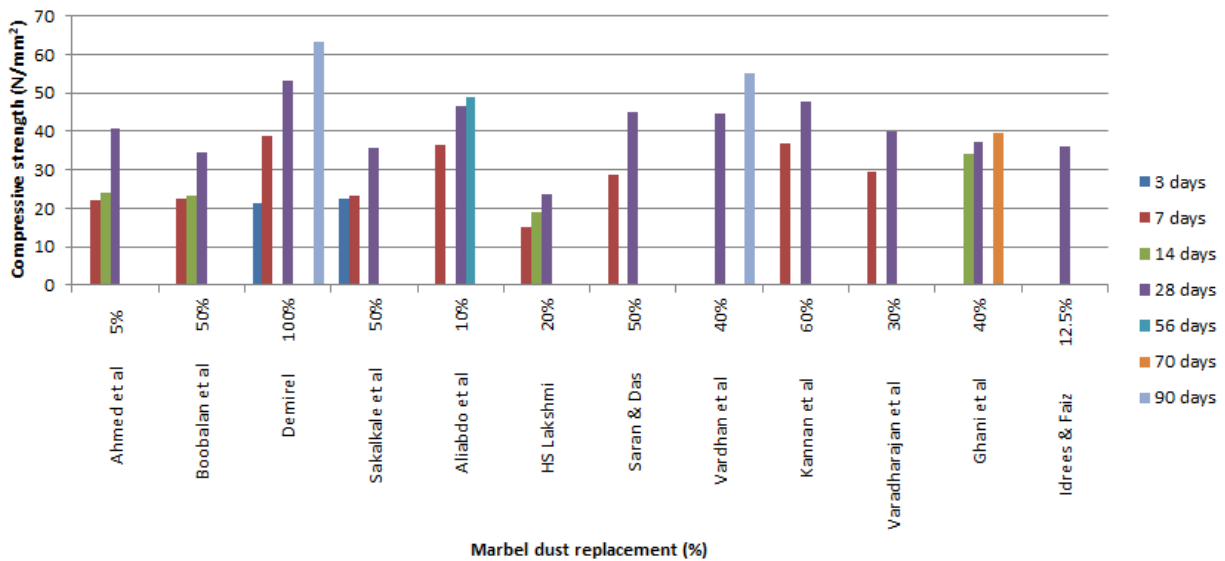


Figure 1. Compressive strength of concrete containing optimum percentage of marble dust replacement.

In above graph, the compressive strength values at different curing ages of concrete containing optimum percentage of marble dust are shown. The data is taken from various researcher's study results; from which it can be deduced that optimum values of replacement of fine aggregates with marble dust, are different. As we can observe from graph that Boobalan et al., Sakalkale et al. and Saran & Das stated that the 50% replacement level gave the optimum values of compressive strength; whereas, according to other researchers the optimum values were less than 50%. The reason behind this variation in values may be the source of marble dust as the properties of natural materials vary with their location of origin. Apart from this, another materials such as rice husk ash, quarry dust etc. were used along with marble dust, which might have influenced the optimum value.

2.3 Tensile Strength

Boobalan et al (2020) conducted tests to measure the tensile strength of concrete with replacement levels of 0%, 25%, 50%, 75%, and 100% after 7, 14, and 28 days. The studies were carried out using cylindrical samples. The highest tensile strength was observed at 0% replacement. As the replacement increased, the tensile strength decreased. Comparing 0% and 100% replacement levels, the tensile strength reduced by

45.09%, 43.35%, and 52.89% at 7, 14, and 28 days respectively.

Sakalkale et al (2014) found that the mix with 0% marble dust had the highest tensile strength, which decreased as the marble dust content increased. The tensile strength values for the mix with 0% marble dust were 5.35 N/mm², 5.50 N/mm², and 8.12 N/mm² at 7, 14, and 28 days respectively. For the mix with 100% marble dust, the tensile strength was 2.94 N/mm², 3.11 N/mm², and 3.82 N/mm² at the same time periods. Comparing these two mixes, it was clear that the tensile strength decreased significantly with the addition of marble dust as a fine aggregate.

Aliabdo et al (2014) used marble dust to replace cement in one mix and fine aggregates in another. The replacement levels were 0%, 5%, 7.5%, 10%, and 15%, and the water-cement ratios were 0.4 and 0.5. The results showed that for the mix where marble dust replaced cement and the water-cement ratio was 0.5, the tensile strength increased up to 10% replacement levels compared to the reference mix. With a 0.4 water-cement ratio, the tensile strength continued to rise with higher replacement levels. For the mixes where marble dust replaced fine aggregates, similar trends were observed for both 0.4 and 0.5 water-cement ratios. At a 0.4 water-cement ratio, there was a 20%, 23%, 28%, and 20% increase in 28-day tensile strength at 5%, 7.5%, 10%, and 15% replacement levels respectively.

Vigneshpandian et al (2017) tested the tensile strength of concrete using 0%, 25%, 50%, and 100% marble dust as a substitute for fine aggregates. The experimental data showed that the use of marble dust reduced the tensile strength. The control mix, with 0% marble dust, had the highest tensile strength. As marble dust content increased, the tensile strength decreased. The reduction in tensile strength compared to the control mix was 17.57%, 30.79%, and 39.76% at 25%, 50%, and 100% replacement levels respectively.

Saran & Das (2019) used 10%, 20%, 30%, 40%, and 50% marble dust as a substitute for fine aggregates. They tested the effect of NACL water on the tensile strength of concrete at 7 and 28 days by using normal water and NACL water for curing. The tensile strength of the concrete mixes increased with higher percentages of marble dust for both curing conditions. When comparing specimens cured in normal water and those cured in NACL water, it was found that NACL slightly improved the tensile strength values.

Kannan et al (2019) replaced fine aggregates with a combination of marble powder and quarry dust at 0%, 15%, 30%, 45%, 60%, and 75% replacement levels to evaluate the tensile resistance of concrete. The 7-day test results showed that tensile strength increased up to 60% replacement level, but at the highest replacement level, the strength decreased slightly but remained higher than the control mix. A similar trend was observed for the 28-day tensile

strength, except that the strength of mixes with 0% and 75% industrial by-products was the same.

Varadharajan et al (2020) substituted marble powder and rice husk ash as fine aggregates. They used replacement levels of 10%, 20%, and 30%. The experiments tested the tensile strength at 7 and 28 days, and similar results were observed for both time periods. The tensile strength increased for all replacement percentages. For 10, 20, and 30 percent substitution levels, an increase of 7.3, 11, and 20 percent was observed in the 7-day split tensile strength respectively. At 28 days, the improvement in strength was 8.4, 13.23, and 23.11 percent for the same substitution levels of marble dust in the concrete mix.

Ghani et al (2020) replaced fine aggregate with 20%, 40%, 60%, and 80% marble powder in the concrete mix. The split tensile strength of the concrete was tested at 14, 28, and 70 days. The results showed that using 20% marble dust gave higher tensile strength than other mixtures, but increasing the marble dust content beyond that caused a decrease in strength gain.

Idrees & Faiz (2019) used replacement levels of 0%, 12.5%, 25%, and 50% of natural sand with marble dust and quarry dust, either alone or in combination in a 50:50 ratio. The tensile strength test results indicated that up to 12.5% substitution, strength increased, but further replacement resulted in lower tensile strength. The strength increased by 27.94 percent compared to the reference mix.

Table 5. Tensile strength of concrete mixes incorporating marble dust investigated by various researchers

Study	w/c	Marble dust replacement (%)	Other materials	Tensile strength (N/mm ²)						
				3 days	7 days	14 days	28 days	56 days	70 days	90 days
Boobalan et al 2020	0.5	0	-		5.35	5.49	8.11			
		25			5.04	5.15	7.93			
		50			4.54	4.78	6.91			
		75			4.02	3.95	5.04			
		100			2.94	3.11	3.82			
Sakalkale et al 2014	0.48	0	-	5.35	5.50		8.12			
		25		5.04	5.16		7.93			
		50		4.54	4.79		6.91			
		100		2.94	3.11		3.82			
Aliabdo et al 2014	0.5	0	-		3		3.75	4.1		
		5			3.3		4	4.4		
		7.5			3.4		4.2	4.6		
		10			3.38		4.1	4.3		
		15			3.1		3.65	4.05		
	0.4	0			3.3		4	4.6		
		5			3.6		4.3	5.00		
		7.5			3.7		4.5	5.1		

		10 15			3.8 3.6		4.58 4.3	5.15 4.9		
Vigneshpandian et al 2017	0.42	0 25 50 100					2.51 2.069 1.737 1.512			
Saran & Das 2019	0.42	10 20 30 40 50			2.36 2.8 3.1 3.67 3.82		2.6 2.95 3.3 3.74 3.85			
Kannan et al 2019		0 15 30 45 60 75	Quarry dust		2.2 2.36 2.40 2.57 2.6 2.4		2.5 2.58 2.86 2.91 3.2 2.5			
Varadharajan et al 2020	0.43	0 10 20 30	Rice husk ash		1.95 2.1 2.20 2.33		2.49 2.67 2.75 2.95			
Ghani et al 2020		0 20 40 60 80				2.60 2.96 2.74 2.59 2.34	2.93 3.14 2.97 2.83 2.52		3.25 3.29 3.011 2.71 2.49	
Idrees & Faiz 2019	0.55	0 12.5 25 50 12.5 25	0% quarry dust 0% quarry dust 0% quarry dust 0% quarry dust 12.5% quarry dust 25% quarry dust				4.46 5.70 4.42 4.38 4.84 4.23			

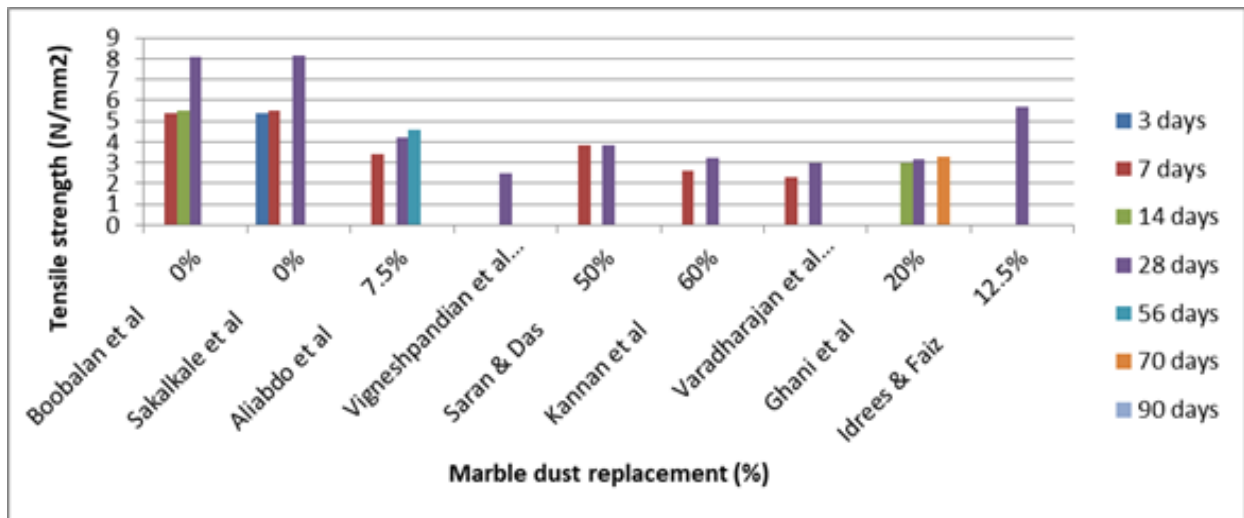


Figure 2. Tensile strength of concrete containing optimum percentage of marble dust.

The figure 2 represents the tensile strength values containing optimum percentage of marble dust as fine aggregates substitute at different curing ages of concrete. According to Boobalan et al, Sakalkale et al

and Vigneshpandian et al maximum tensile strength was given by concrete mix with 0% marble dust and tensile strength kept on decreasing with addition of marble dust; however the same researchers showed

that the use of marble dust evidently modified the compressive strength property of concrete. Furthermore, results of studies conducted by Saran & Das and Kannan et al revealed that addition of marble dust significantly improves the tensile strength. The discrepancy among the results may be due to the use of marble dust having different properties or weather conditions of the place of conduct of study.

2.4 Flexural Strength

Boobalan et al (2020) casted prism specimens to evaluate the flexural strength of concrete at 0%, 25%, 50%, 75%, and 100% replacement levels of marble dust. The results indicated that up to 50% replacement, there was a notable increase in flexural strength, but at 75% and 100% replacement levels, the flexural strength values started to decrease. The study observed that the 7, 14, and 28 days strength of the mix using 100% marble dust showed a reduction of approximately 24.83%, 26.36%, and 20.76% respectively.

Sakalkale et al (2014) conducted tests on specimens with 0%, 25%, 50%, and 100% replacement of fine aggregates with marble dust at 3 days, 7 days, and 28 days. The test outcomes showed an increase in flexural strength up to 50% replacement, but at 100% replacement, the strength was lower than the mix with 0% marble dust. When comparing the 0% and 50% marble dust mixes, there was a percentage increase in flexural strength of 7.14%, 13.33%, and 15.21% at 3, 7, and 28 days respectively.

Vigneshpandian et al (2017) tested flexural strength by replacing 0%, 25%, 50%, and 100% of fine aggregate with marble dust after 28 days curing period. The observations showed a 2.52% and 15.81% increase in flexural strength compared to the mix with 0% marble dust. However, the mix containing 100% marble dust had a 3.45% lower strength than the control mix. Varadharajan et al (2020) assessed the flexural strength of hardened concrete when fine aggregate was replaced with marble dust at 10%, 20%, and 30% intervals. Testing was done after 7 days and 28 days of curing. For 7 days, the mixes with 10%, 20%, and 30% replacement levels showed increases of 6%, 10.12%, and 12.20% respectively compared to the 0% marble dust mix. At 28 days, the improvement was noted as 7.31%, 13.65%, and 15.23% respectively for the 10%, 20%, and 30% replacements.

Idrees & Faiz (2019) mentioned that replacing 12.5% of fine aggregates with marble dust improves the flexural strength of concrete. However, further replacement at 25% and 50% levels had a negative impact on the flexural strength of concrete. Similar results were observed when natural sand was replaced with quarry dust at the same replacement levels. The maximum improvement was observed as 40.9% at 12.5% replacement level compared to the mix with 0% marble dust.

Table 6. Flexural strength of concrete mixes incorporating marble dust investigated by various researchers

Study	w/c	Marble dust replacement (%)	Other materials	Flexural strength (N/mm ²)			
				3 days	7 days	14 days	28 days
Boobalan et al 2020	0.5	0	-		2.94	3.30	4.43
		25			3.04	3.56	4.70
		50			3.15	3.74	5.10
		75			2.85	2.93	4.26
		100			2.21	2.43	3.51
Sakalkale et al 2014	0.48	0	-	2.94	3.30		4.43
		25		3.04	3.56		4.70
		50		3.15	3.74		5.10
		100		2.21	2.43		3.51
Vigneshpandian et al 2017	0.42	0					3.923
		25					4.022
		50					4.444
		100					3.7877
Varadharajan et al 2020	0.43	0	Rice husk ash		4.90		9.05
		10			5.29		9.5
		20			5.42		9.81
		30			5.80		10.60
Idrees & Faiz 2019	0.55	0	0% quarry dust				7.02

		12.5	0% quarry dust			9.89
		25	0% quarry dust			6.85
		50	0% quarry dust			6.75
		12.5	12.5% quarry dust			7.86
		25	25% quarry dust			6.84

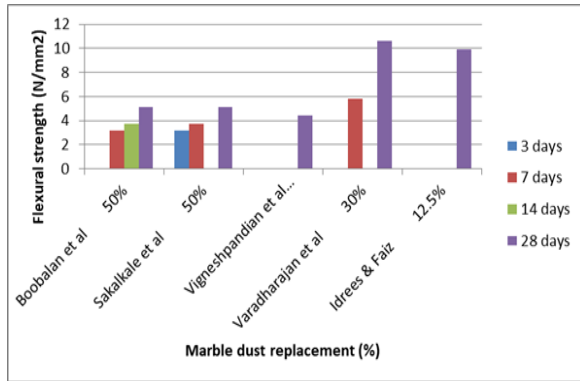


Figure 3. Flexural strength of concrete containing optimum percentage of marble dust.

Figure 3 represents the flexural strength of concrete containing optimum values of marble dust at curing periods of 3, 7, 14 and 28 days. From the comparison, it can be deduced that the addition of marble dust significantly improves the resistance against bending. However, the recommended values of marble dust replacement are different in each study. Though, 3 out of 5 research studies claimed that the optimum replacement level is 50% for improvement in flexural strength, there are some studies which revealed that the optimum value is less than 50%. The difference in optimum values is noticed in all the properties of concrete. There can be multiple reasons for this dissimilarity such as marble dust obtained in different conditions, physical properties of waste material, variation in chemical composition or weather conditions of the place.

2.5 Unit Weight

Demirel (2010) studied how the unit weight of concrete mix changed over time at 3, 7, 28, and 90 days when different amounts of fine aggregate were replaced with marble dust specifically 0%, 25%, 50%, and 100%. The results showed that as the percentage of marble dust increased, so did the unit weight. Compared to the mix with no replacement, the unit weight increased by 0.76%, 2.19%, and 3.13% at 25%, 50%, and 100% replacement levels, respectively. This happened because marble dust has

a higher specific gravity and smaller particle size than fine aggregates.

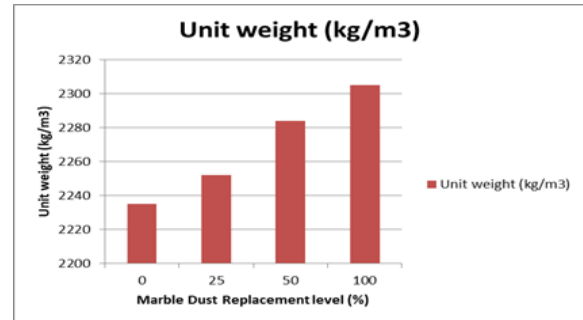


Figure 4- Unit weight of concrete containing marble dust (Demirel 2010)

Ghani et al (2020) used waste marble dust as a substitute for fine aggregates at percentages of 20, 40, 60, and 80. They found that as the amount of marble powder in the concrete increased, the unit weight of the concrete decreased. This is likely because marble powder has a lower bulk density, which affects the overall weight of the concrete. The figure shows the bulk density values for each of the different mixtures.

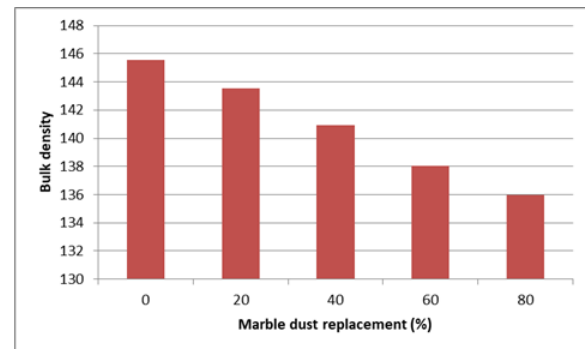


Figure 5. Variation in bulk density values for concrete mixes containing 0%, 20%, 40%, 60% & 80% marble dust (Ghani et al 2020)

2.6 Porosity

Demirel (2010) investigated the porosity with 0%, 25%, 50% and 100% replacement levels of fine aggregates with marble dust. It was concluded from results that increased percentage of marble dust decreased the porosity of concrete; which was due to the fact that marble dust acted as filler material in the

fix and make it denser leaving minimal voids in the mix. Aliabdo et al (2014) assessed the porosity at the age of 56 days with 0.4 and 0.5 water cement ratio. They prepared different mixes at 0%, 5%, 7.5%, 10% and 15% replacement of cement as well as fine aggregates with marble dust. From the study, it can be deduced that due to filler properties of marble dust, the porosity of all the mixes was decreasing.

Varadharajan et al (2020) conducted the water absorption test of concrete to check the porosity of concrete in hard state. The replacement proportion opted was 10%, 20% and 30%. It was observed from the test results that there was decrease in the water absorption capacity of concrete after incorporation of marble dust in concrete. The decreased porosity effects the durability of concrete.

Table 8. Porosity of concrete containing marble dust

Study	w/c	Replacement levels (%)	Porosity (%)
Demirel 2010	0.51	0	7.125

		25 50 100	7.085 6.729 6.596
Aliabdo et al 2014	0.5	0	11.89
		5	10.31
		7.5	9.50
	0.4	10	9.09
		15	9.42
		0	7.83
		5	6.27
		7.5	5.83
		10	5.66
		15	5.66

2.7 Ultrasonic pulse velocity (UPV)

Aliabdo et al (2014) conducted the UPV test at the age of 28 days with 0%, 5%, 7.5%, 10% and 15% replacement levels. According to the experiment observations, neither cement nor fine aggregate replacement had any notable influence on the ultrasonic pulse velocity test values. There was insignificant variation in the test values which can be observed from the Table 9.

Table 9. UPV values of concrete containing marble dust

w/c ratio	0.50					0.40				
Marble dust (%)	0	5	7.5	10	15	0	5	7.5	10	15
28 days UPV (km/s)	4.64	4.62	4.63	4.65	4.60	4.103	4.105	4.105	4.106	4.102

2.8 Drying shrinkage

Vardhan et al (2019) carried out an experiment to measure the ultimate drying shrinkage strain. Based on the experimental findings, it was found that all concrete mixtures showed a decrease in drying shrinkage values at various drying times. The highest drying shrinkage was recorded for the mix that contained 0% marble dust, and this value decreased as the percentage of marble dust increased. As shown in Figure 6, the drying shrinkage was reduced by 7.7%, 16.7%, 22%, 25.2%, 27.6%, and 30.5% for mixes with 10%, 20%, 30%, 40%, 50%, and 60% marble dust respectively, compared to the control mix.

Gameiro et al (2014) performed a drying shrinkage test on concrete that included 0%, 20%, 50%, and 100% marble powder as fine aggregates. They created three control mixes using basalt fine aggregates, river sand, and granite as natural sands. Marble dust replaced all types of fine aggregates at 20%, 50%, and 100% levels. A total of 12 mixes were made to assess the drying shrinkage of concrete. Figures 7-9 display the drying shrinkage of concrete with different fine aggregate combinations. Based on the drying shrinkage results, it was concluded that using marble dust was beneficial because it helped in making the concrete more compact. Initially, drying shrinkage was observed.

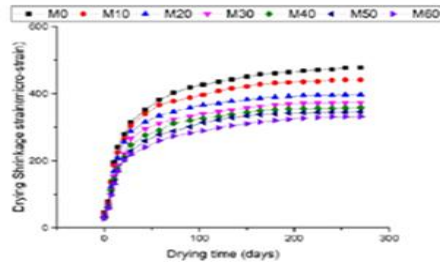


Figure 6. Drying shrinkage (Vardhan et al, 2019)

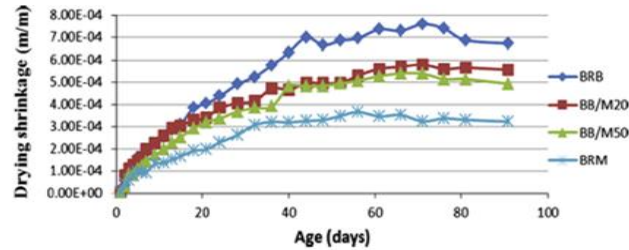


Figure 7. Drying shrinkage with basalt as fine aggregates (Gameiro et al, 2014)

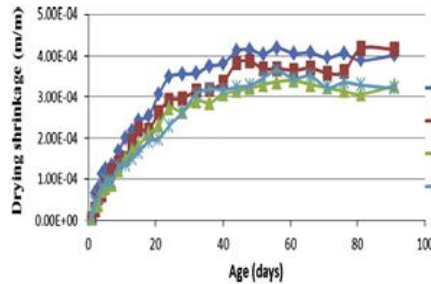


Figure 8. Drying shrinkage with river sand as fine aggregates (Gameiro et al, 2014)

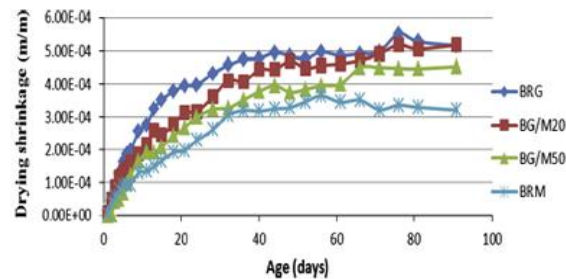


Figure 9. Drying shrinkage with granite as fine aggregates (Gameiro et al, 2014)

III. SUMMARY AND CONCLUSIONS

From the published literature, following conclusion can be inferred:

- The use of marble dust as a substitute for natural sand negatively affects the workability of fresh concrete. Due to the larger surface area of marble dust particles, more water is needed to achieve the same level of workability as in conventional concrete.
- Waste marble dust can be used as a partial replacement for natural sand in concrete without affecting its essential properties. However, when used in higher proportions, it can reduce the strength of the hardened concrete, thereby affecting its quality.
- The use of waste marble powder results in denser concrete and reduces drying shrinkage as the amount of marble dust in the mix increases. This is also evident from the porosity values of the concrete; as the percentage of fine aggregates replaced by marble powder increases, the porosity decreases, leading to lower water absorption.

- Although it is difficult to determine a single optimal replacement level of fine aggregate with marble dust, as different studies have reported varying results, it can be concluded that partial replacement of fine aggregate with marble dust significantly enhances the properties of concrete.
- In summary, marble dust can be used as a partial replacement for fine aggregate, offering a sustainable solution to reduce the use of natural sand and manage the environmental impact of waste marble disposal. Additionally, the inclusion of marble dust in concrete improves its strength and durability characteristics.

REFERENCES

- [1]. W. Ahmad, A. Ahmad, K. A. Ostrowski, F. Aslam, and P. Joyklad, "A scientometric review of waste material utilization in concrete for sustainable construction," *Case Studies in Construction Materials*, vol. 15, pp. 1–25, 2021.
- [2]. S. F. Ahmed, A. U. Haq, and M. M. Ejaz, "Partial replacement of fine aggregate by marble powder," *International Journal of Scientific &*

- Engineering Research, vol. 10, no. 12, pp. 959–961, 2019.
- [3]. A. A. Aliabdo, A. Elmoaty, and E. M. Auda, “Reuse of waste marble dust in the production of cement and concrete,” *Construction and Building Materials*, vol. 50, pp. 28–41, 2014.
- [4]. A. Anwar, S. Ahmad, S. Mohd., A. Husain, and S. A. Ahmad, “Replacement of cement by marble dust and ceramic waste in concrete for sustainable development,” *Indian Journal of Innovative Science, Engineering & Technology*, vol. 2, no. 6, pp. 496–503, 2015.
- [5]. S. C. Booblan, M. V. Nishanth, and M. Amarnath, “Impact of marble waste with partial replacement of fine aggregate in concrete,” *Journal of Xi’an University of Architecture & Technology*, vol. 12, no. 6, pp. 517–522, 2020.
- [6]. V. Corinaldesi, G. Moriconi, and T. Naik, “Characterization of marble powder for its use in mortar and concrete,” *Construction and Building Materials*, vol. 24, pp. 113–117, 2010.
- [7]. A. Evram, T. Akcaoglu, K. Ramyar, and B. Cubukcuoglu, “Effects of waste electronic plastic and marble dust on hardened properties of high-strength concrete,” *Construction and Building Materials*, vol. 263, pp. 1–10, 2020.
- [8]. F. Gameiro, J. de Brito, and D. C. Silva, “Durability performance of structural concrete containing fine aggregates from waste generated by marble quarrying industry,” *Engineering Structures*, vol. 59, pp. 654–662, 2014.
- [9]. A. Ghani, Z. Ali, F. A. Khan, S. R. Shah, and S. W. Khan, “Experimental study on the behavior of waste marble powder as partial replacement of sand in concrete,” *SN Applied Sciences*, 2020.
- [10]. S. Gupta and P. Saxena, “A review on partial replacement of fly ash, marble dust, and crushed concrete aggregate in concrete mixture,” *High Technology Letters*, vol. 27, no. 7, pp. 328–336, 2021.
- [11]. N. Gurumoorthy, “Influence of marble dust as partial replacement of cement in concrete,” *International Journal of Engineering Research & Technology (IJERT)*, vol. 3, no. 3, pp. 740–743, 2014.
- [12]. H. Hebhouh, H. Aoun, M. Belachia, H. Houari, and E. Ghorbel, “Use of waste marble aggregates in concrete,” *Construction and Building Materials*, vol. 25, no. 3, pp. 1167–1171, 2011.
- [13]. H. S. Lakshmi, “Partial replacement of fine and coarse aggregate by using marble powder and demolished waste,” *International Journal of Advance Research in Science and Engineering*, vol. 6, no. 7, pp. 298–303, 2017.
- [14]. M. Idress and A. Faiz, “Utilization of waste quarry dust and marble powder in concrete,” in *Proc. 5th International Conference on Sustainable Construction Materials and Technologies (SCMT5)*, United Kingdom, 2019, vol. 1, pp. 302–315.
- [15]. M. Kannan, Sandhya, and Swarnalakshmi, “Effect of marble powder and quarry dust as partial replacement for fine aggregate on concrete,” *International Journal of Engineering Research & Technology (IJERT)*, vol. 7, no. 11, pp. 1–5, 2019.
- [16]. S. Kou, C. Poon, and F. Agrela, “Comparisons of natural and recycled aggregates concretes prepared with the addition of different mineral admixtures,” *Cement and Concrete Composites*, vol. 33, pp. 788–795, 2011.
- [17]. S. Krishnan, A. C. Emmanuel, S. K. Kanaujia, and S. Bishnoi, “Hydration and mechanical properties of limestone calcined clay cement produced with marble dust,” in *Calcined Clays for Sustainable Concrete*, 2017, pp. 249–253.
- [18]. Z. H. Mahdi, W. A. Abbas, F. K. Abdulhussein, M. R. Abdulghani, and M. Q. Hasan, “Compressive strength and shrinkage of concrete containing calcium oxide (CaO) powder,” *IOP Conference Series: Materials Science and Engineering*, vol. 881, 2020.
- [19]. P. K. Mehta and P. J. M. Monteiro, *Concrete: Microstructure, Properties, and Materials*. New York, NY, USA: McGraw-Hill, 2015.
- [20]. S. Natarajan and P. Murugesan, “Synergistic effect of marble powder and green sand on the mechanical properties of metakaolin-cement concrete,” *Materials*, vol. 12, pp. 1–17, 2019.
- [21]. O. M. Ofuyatan, A. M. Olowofoyeku, J. Obatoki, and J. Oluwafemi, “Utilization of marble dust powder in concrete,” *IOP Conference Series: Materials Science and Engineering*, vol. 640, 2019.
- [22]. O. M. Omar, G. D. Elhameed, M. A. Sherif, and H. A. Mohamadien, “Influence of limestone

- waste as partial replacement material for sand and marble powder in concrete properties,” HBRC Journal, vol. 8, pp. 193–203, 2012.
- [23]. B. K. Rao, “Study on marble powder as partial replacement of cement in normal compacting concrete,” IOSR Journal of Mechanical and Civil Engineering, vol. 4, no. III, pp. 1–5, 2016.
- [24]. Z. A. Rid, S. N. R. Shah, M. J. Memon, A. A. Jhatial, M. A. Keerio, and W. I. Goh, “Evaluation of combined utilization of marble dust powder and fly ash on the properties and sustainability of high-strength concrete,” Environmental Science and Pollution Research, 2022.
- [25]. A. D. Sakalkale, G. D. Dhawale, and R. S. Kedar, “Experimental study on use of waste marble dust in concrete,” International Journal of Engineering Research and Applications, vol. 4, no. 10, pp. 44–50, 2014.
- [26]. T. N. S. S. Saran and T. V. Das, “Experimental investigation on concrete with partial replacement of fine aggregate by marble dust powder,” International Journal of Recent Technology and Engineering (IJRTE), vol. 7, no. 6C2, pp. 85–91, 2019.
- [27]. A. Singh and S. Mehta, “Partial replacement of fine aggregate with copper slag and marble dust powder in geo-polymer concrete: A review,” IOP Conference Series: Earth and Environmental Science, vol. 889, pp. 1–9, 2021.
- [28]. D. Tavakoli and M. Hashempour, “Use of waste materials in concrete: A review,” Pertanika Journal of Science and Technology, vol. 26, no. 2, pp. 499–522, 2018.
- [29]. K. Vardhan, R. Siddique, and S. Goyal, “Influence of marble waste as partial replacement of fine aggregates on strength and drying shrinkage of concrete,” Construction and Building Materials, vol. 228, 2019.
- [30]. G. V. Vigneshpandian, E. A. Shruthi, C. Venkatasubramanian, and D. Muthu, “Utilisation of waste marble dust as fine aggregate in concrete,” IOP Conference Series: Earth and Environmental Science, 2017.