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Review Article

Experimental Study on the Engineering Properties of Marble Waste Powder from Hyderabad Marble Market Sindh Pakistan for Making Concrete Including Recycled Coarse Aggregates

Mushtaque Ahmed Pathan[1*], Rafique Ahmed Lashari[1], Maryam Maira[2], Jamshed Ahmed Pathan[3]
[1]Center for Pure & Applied Geology, University Of Sindh, Jamshoro, Sindh, Pakistan
[2]Deparment of Environmenta Engg & Mgmt, Muet Jamshoro, Sindh Pakistan
[3]Department of Architecture, Muet Jamshoro, Sindh, Pakistan

***Corresponding author:** Mushtaque Ahmed Pathan
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Abstract

Pakistan, especially NWFP, possesses huge marble reservoirs. The promotion and development of marble industry could bring prosperity and development for the country. Swat, Buner, Chitral, Kohistan, Mardan, Hazara, Nowshera and Kohat divisions are high potential areas for quality marble in the province. Mohmand, Khyber, Bajaur, Orakzai and Kurram Agencies from Federally Administered Tribal Areas (FATA) have huge marble reservoirs. Pakistan offers big investment opportunities in mining, value addition and manpower development in the sector. Recent reports suggest that Saudi Arabia is interested in Pakistani marble to build its new cities with an expenditure of around $260 billion. Italy and other countries, it is learnt, want barter trade of their marble machinery & technology in exchange for the Pakistani marble. All this shows great investment potential in Pakistan's marble and granite sector. As an estimate of Pakistan Stone Development Company (PASDEC), 297 billion tons of Marble and Granite reserves are available in the country. More than 1,225 quarries and 2,000 processing units are operational. A group of committed business men agreed to form a Strategy Working Group (SWOG) to address how the industry can reposition itself through a better strategy. Marble is gaining popularity due to its increasing usage in construction industry. Nowadays in the modern architectural designs of houses and plazas include the final touch of marble in exterior as well as interior portions due to its attractive look. The research purpose of the study is to investigate the mechanical properties of concrete with different replacement levels of ordinary Portland Cement with Waste marble powder and natural coarse aggregates with recycled coarse aggregates. The standard cubes (150mmX150mmX150mm) were casted. Laboratory experimentation was carried out to analyze the performance of M25 grade mix cases were casted and tested. The compressive strength effect of concrete of various amount of replacement of cement viz., 5%, 10%, 15% with Waste marble powder and various amount of replacement of natural coarse aggregates with 15%, 30% and 45% with Recycled coarse aggregates. The resultant concrete was tested for parameters like compressive strength, slump and workability and compared with conventional concrete.

Keywords: Recycled coarse Aggregates, Workability, Concrete, Marble Powder Compressive Strength.

INTRODUCTION

The construction industry requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on but the cement concrete remains the main construction material used in construction industries. For the purpose of geotechnical investigation of suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and by products in cement and concrete used for new constructions [1]. The Marble has been commonly used for different purposes like flooring, cladding etc., as a building material since the ancient times. The waste industrial marble disposal as the marble powder material, consisting of very fine powder, today constitutes one of the environmental problems around the world. In Pakistan, marble dust is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public

health. Mostly the major use of the marble dust in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. Recycling of materials is the act of processing the used material for use in creating new product. The use of natural aggregate is getting more intense with the advanced development in infrastructure area. Just to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement material. In the construction industry the recycled aggregate comprised of crushed, graded inorganic particle processed from the materials that have been used in the construction and demolition wastes. These materials are from building, roads, bridges etc [2]. The Pakistani Construction industry faces a challenge when it comes to dump the constructional demolished waste. The major portion of this constructional waste consists of coarse aggregates. Earlier these waste coarse aggregate were used for land filling or thrown outside locality or in water bodies. On the other side to reconstruct a demolished structure again, the virgin coarse aggregate are used. This practice depletes the parent rocks. Now, the rate of formation of parent rock is much less than the rate of depletion. Therefore, it can be considered as a call of nature to use the recycled aggregate in construction. Further, if the recycled coarse aggregate are used in conventional construction work it would saves the cost of materials [3].

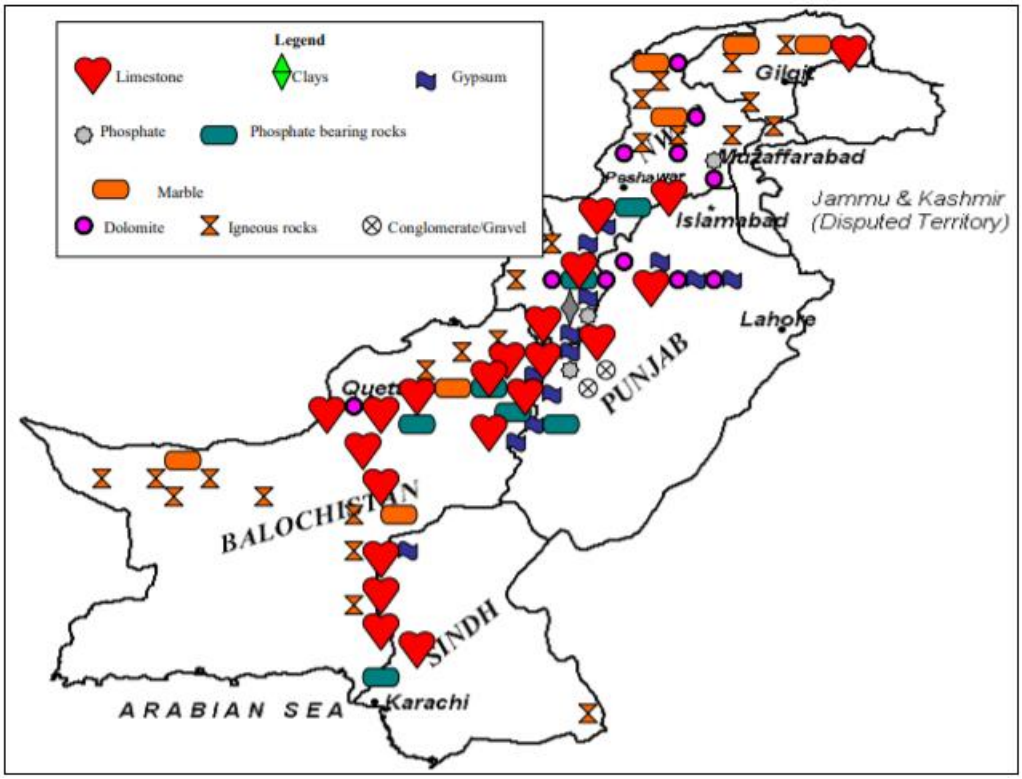

Fig-1: Map of Pakistan Showing main cement resources (limestone, shale/clay, gypsum), agrominerals (rock phosehate gypsum), marble, construction, dimension and décor stone resources (marble, dolomite, conglomerate and gravels, igneous rocks) of Pakistan

Geological Survey of Pakistan, Inf. Release No. 105 Year 2017

The technically recycled aggregate produced by two stages crushing of demolished concrete, screening and removal of contaminants such as reinforcement, wood, plastic etc. RILEM Committee 121-DRG has published recommendations for the use of recycled aggregates, classifying them into three groups. AI-Aggregates mainly from masonry rubble B-Aggregate obtained mainly from concrete rubble C-A mixture of natural aggregates (>80%) and rubble from the other two groups (with up to 10% of group I) [4].

To solve the problem of waste management in the country the Ministry of Environment and forests, Government of Pakistan constituted a committee to evolve a road map for the management of waste in Sindh and to suggest a policy and strategy for achieving the same. Demolished concrete produced by recycling aggregates is gaining importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other applications [3]. Central Pollution Control Board reported in 2004 that solid waste generation in India was about 48 million tons/annum and more than 25% of this is from construction industry which consists of about 6-7 million tons of concrete and brick waste. The waste quantities are estimated to reach to level of atleast 85 million by 2013. RCAs is very important promising

source of aggregates as 75 percent of any typical concrete is made of aggregates. RCAs represent a unique solution to the problems of large scale demolitions occurring now-a -days in India. This recycling industry for waste concretes helps reducing management/maintenance costs of dumpsites/landfills and transportation costs [5]. The objective of this experimental.

Material Used

Cement

Pak Land Cement Ordinary Portland Cement (OPC) of 43 grade was used throughout the course of the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 1489-1991 are listed in Table-1.

Waste Marble Powder

The samples of marble powder was collected from the deposits of marble factories during shaping. It was sieved by IS-90 micron sieve before mixing in concrete. The detail of properties of marble powder are given in Table-2.

Recycled Coarse Aggregates

Recycling is the system of processing the used material for use in creating new product. The usage of natural aggregate in construction is getting more and more intense with the advanced development in infrastructure area. In order to minimise the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally taken from Buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes. There are so many advantages through using the recycled aggregate. The properties of recycled coarse aggregates are listed in Table-3.

Aggregates

Coarse and fine aggregates are those chemically inert materials which when bonded by cement paste form concrete. Construction aggregates constitute the bulk of the total volume of concrete and hence they influence the strength of concrete to great extent. The properties of concrete are directly related to those of its constituents and as such aggregate used in a concrete mix should be hard, strong, dense, durable, free from l clay lumps, loam, vegetable and other such foreign matter. The ingredients of all such debris prevent adhesion of cement on the surface of aggregates and hence reduces the strength of concrete. The aggregates are classified into two categories:

Fig-2: Fine and Coarse Aggregates

Fine Aggregates

The material which passed through I.S. Sieve No. 480 (4.75mm) is termed as fine aggregates. Work of fine aggregates is to make concrete dense, by filling voids of coarse aggregates, reduces the shrinkage of cement and makes an economical mix. The natural sand or crushed stone dust is used as a fine aggregate in concrete mix. Sand is obtained from sea, river, lake or pit, but when used in a concrete mix, it should be properly washed and tested to ascertain that total percentage of clay, silt, salts and other organic matter do or does not exceed specified limit. Sand as obtained from the above sources may be round, subrounded or angular in grains. Sand with angular grains has good interlocking property which results in a strong mix while rounded grained sand does not afford sufficient interlock in the matrix.

Fig-3:

Fig-4: Some Beautiful Marble Varieties of Pakistan

Source: https://www.stonecontact.com/stone/pakistan/3

Fig-5: Picture of Cement Bags Majorly Used In Pakistan

Fig-6:

Fig-7: Picture of Marble Dust Majorly Used As Replacement of Cement in Pakistan

Coarse Aggregates

The material whose particles are of such size as are retained on ASTM Sieve No. 4 (4.75mm) is termed as coarse aggregates. Generally coarse aggregates, like fine aggregates, must consists of sound durable inert particles to make the concrete strong and weather resistant. These are free chemicals or coating or clay or other fine material that may affect bonding of cement paste. The different size of the coarse aggregates used depends upon the nature of work. Crushed hard stone and gravel are the common materials used as coarse aggregates for structural concrete. Coarse aggregates are usually obtained by crushing of all type of sedimentary, igneous and metamorphic like granite, gneiss, crystalline lime stone and good variety of sand stone etc. As far as possible flaky and elongated pieces of stone are avoided. The properties of coarse aggregate are given in Table-5.

Mix Design

A mix M25 Grade of concrete was designed as per ASTM C-150, C-33 for coarse and fine aggregates and the same was used to prepare the test samples. The weights of various constituent materials per m3 of concrete are given in Table-6.

Experimental Methodology

Workability of Concrete Mixes

Workability is the most elusive property of concrete. Simply is that, a concrete is said to be workable if it can be easily mixed, handled, transported, placed in position and compacted. More precisely, it defines that it can be fully compacted with minimum energy input. It must be confirmed that no sign of any segregation or bleeding in a workable concrete. In this experimental work slump of all mixes with constant water to cementitious material (w/cm) ratio for the same group were measured to get information about workability changes caused by the waste marble powder and recycled coarse aggregate.As it is shown in Table-7.

Compressive Strength Test

Compressive strength tests were conducted on concrete cubes of size 150 x 150 x 150 mm cast from concrete of each series, to check quality by obtaining the 28-days compressive strength. The different tests were carried out in accordance with IS: 516-1959 on Compression Testing Machine. The maximum compressive load on the specimen was recorded as the load at which the specimen failed to take any further increase in the load. The final average of three samples was taken as the representative value of compressive strength. The compressive strength of cubes was calculated by dividing the maximum compressive load by the cross-sectional area of the cube specimen.

The results of the compressive strength tests conducted on concrete specimens of different mixes cured at different ages are shown in Table-8. The compressive strength test was conducted at curing ages of 7 days and 28 days.

RESULTS

It can be noted that when marble powder is substituted as binder with cement and crushed tile aggregate is substituted as filler with coarse aggregate, the compressive strength was found to increase at lower replacements. In the 7-days and 28 days compressive strength of concrete mix containing 5% of marble powder and 15% crushed tile aggregate were found to increase from a value 21.23N/mm^2 to 22.55N/mm^2 and 33.67N/mm^2 to 34.87N/mm^2. With the increase in the percentage of replacement of recycled coarse aggregate from 15% to 30%, there is again an increase in the 7-days and 28 days compressive strength from 22.55 N/mm^{2}to 23.16N/mm^2 and 34.87N/mm^2 to 35.64N/mm^2. It shows that using Recycled coarse aggregate as coarse aggregate cause increase in the strength of concrete upto 30 percent replacement, but after 30% replacement, strength starts decreasing from 23.16 N/mm^2 to 21.73 N/mm^2 and 35.64 N/mm^2 to 34.06N/mm^2. The reason for decreasing the strength of samples as a result of enhancing the amount of RCA may due to increase in flaky aggregates and due to smooth surface textural fabric of tile aggregate and poor bonding properties of matrix with matrix with aggregate.

Figures (6 & 7) show that by increasing the percentage of replacement of waste marble powder with cement, the compressive strength values of concrete tends to increase at each curing age. In the 7-days and 28 days compressive strength of concrete mix containing 5% of marble powder and 15% crushed tile aggregate were found to increase from Value 21.23N/mm^2 to 22.55N/mm^2 and 33.67N/mm^2 to 34.87N/mm^2. With the increase in the percentage of replacement of waste marble powder from 5% to 10%, there is again an increase in the 7-days and 28 days compressive strength from 22.55 N/mm^{2}to 22.89 N/mm^2 and 34.87N/mm^2 to 35.44N/mm^2.The increase in the value of compressive strength at 7-days and 28 days curing period can be attributed to the fact that marble granules possess cementing properties. This is because of much effective in enhancing cohesiveness due to lower fineness modulus of the marble powder or granules both. However, there is a decrease in compressive strength values (7-days & 28 days) of concrete mix from 22.89 N/mm^{2}to 20.01 N/mm^2 and 35.44N/mm^2 to 33.18N/mm^2, when 15% marble powder takes replaced with cement and 15% recycled coarse aggregate replaced with coarse aggregate in control mix. This shows decreases in strength mainly occur due to that with further increase in replacement of marble powder with cement results in the replacement of Portland cement clinker with powder addition with different proportion which causes dilution of C_3S and C_2S which is responsible for strength.

Table-1: Physical properties of Cement

Sr. No	Properties	Observations
1	Fineness (90 micron IS Sieve)	4.1 percent
2	Initial setting time	60 minutes
3	Final setting time	380 minutes
4	Standard consistency	33 percent
5	Specific Gravity	3.16
6	28-days compressive strength	47.2Mpa

Table-2: Physical properties of Waste marble powder

Sr. No	Properties	Observations
1.	Color	White
2.	Form	Powder
3.	Specific Gravity	2.65
4.	Blaine Fineness	1500 m^2/kg

Table 3: Physical properties of Recycled Coarse Aggregates

Sr. No	Properties	Observations
1.	Specific gravity	2.27
2.	Impact Value	19 %
3.	Bulk density	1425 kg/m^3

Table-4: Physical properties of fine aggregate

Sr. No	Properties	Observations
1.	Fineness modulus of fine aggregate	2.55
2.	Specific gravity of fine aggregate	2.65
3.	Bulk density of fine aggregate	1668 kg/m^3
4.	Water absorption of fine aggregate	0.81 %

Table-5: Physical properties of coarse aggregate

Sr. No	Properties	Observations
1.	Fineness modulus of coarse aggregate	6.6
2.	Specific gravity of coarse aggregate	2.7
3.	Bulk density of coarse aggregate	1725 kg/m^3
4.	Water absorption of coarse aggregate	0.91 %

Table-6: Concrete Mix Design

		Ratio	kg/m3
a)	Cement Content	1	350
b)	Fine Aggregates Content	2.03	745.56
c)	Coarse Aggregates Content	3.53	1190.82
d)	Water	0.45	158.73

Table-7: Slump Value for different Concrete Mix

Mix ID	Cement	Marble Powder	Fine Aggregate	Coarse Aggregate	Recycled coarse Aggregate	Slump in mm
M1	100	0	100	100	0	110
M2	95	5	100	85	15	99
M3	95	5	100	70	30	93
M4	95	5	100	55	45	89
M5	90	10	100	85	15	90
M6	90	10	100	70	30	84 71
M7	90	10	100	55	45	81
M8	85	15	100	85	15	88
M9	85	15	100	70	30	80
M10	85	15	100	55	45	71

Table-8: Compressive Strength Values for various Concrete Mix

Mix ID	Cement	Marble Powder	Fine Agg.	Coarse Agg.	Recycled coarse Agg.	Compressive Strength (N/mm^2)	
						7 days	28 days
M1	100	0	100	100	0	21.23	29.25
M2	95	5	100	85	15	22.31	30.87
M3	95	5	100	70	30	23.16	35.25
M4	95	5	100	55	45	22.73	32.75
M5	90	10	100	85	15	23.89	33.45
M6	90	10	100	70	30	25.10	36.25
M7	90	10	100	55	45	23.67	35.72
M8	85	15	100	85	15	23.01	34.17
M9	85	15	100	70	30	23.43	35.14
M10	85	15	100	55	45	21.80	31.88

CONCLUSION

The replacement and usage of Marble Dust Powder in concrete improved its quality in terms of strength. The following conclusions are based on the study on the test result.

- The Compressive strength of Concrete cubes increases up to 10% replacement of cement by Marblr Dust Powder and further increasing of percentage of Marble Dust Powder leads to decrease in compressive strength of concrete.
- The Split tensile strength of concrete cubes increases up to 15% replacement of cement by Marble Dust Powder & further increasing of percentage of MDP leads to decrease in Split tensile strength of concrete.
- The 15 % increase in Flexural strength has been marked by replacement of cement by Marble Dust Powder and further increases in the percentage results to decrease in flexural strength.
- It is concluded that the MDP gives an excellent result in strength, as compared to the normal concrete. Marble Dust Powder can be used as a replacement material of cement, and 10% replacement of cement with
- Construction industry. Use of these waste material for sustainable development in the country.
- Marble dust Powder is environment friendly and a useful partial replacement of cement concrete.
- The experimental results showed that up to 10% of marble dust can be used as replacement of cement in concrete with an increase of compressive strength at 28 days.
- Workability of concrete in testing of slump increased with increase in the percentage of marble dust in concrete.
- The marble dust as replacement of cement in concrete thereby saving the environment from dust pollution as the results form a basis for strong recommendation for the use in construction industry.
- The use of marble dust in construction is cost effective because marble dust is available on low cost.
- Workabilkity decreases as the partial replacement level of waste marble powder with cement in concrete increases.
- The partial replacement of coarse aggregates with recycled coarse aggregates increases compressive Strength of concrete upto 10%.
- If the replacement level increased from 10% to 15% for waste marble powder and 30% to 45% of recycled coarse aggregates there is a decrease in the compressive strength of concrete.
- For the partial replacement of coarse aggregates with recycled coarse aggregates, same effect on the workability of concrete can be seen.

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