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EXPERIMENTAL STUDY ON PROPERTIES OF CONCRETE PAVERS BY PARTIALLY REPLACING OPC WITH MARBLE POWDER

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Abstract — *Concrete paving blocks have been widely used in various countries to a certain extent of time as a standard practice for providing pavements. It is used because of its firmness in regions such as walkways, parking lots and parks where normal type pavements are not suitable or less resilient due to many operative and environmental restraints. The Marble industry is dumping the marble powder in their surroundings directly impacting the environment in different forms. In dry form, its particles moving with blowing air create dust pollution. On other hand, this powder flows with run-offs and ultimately affect aquatic life. Moreover, the demand for cement is quite high in developing countries due to rapid infrastructural growth which results in supply paucity and increase in cost of material. Experimental study was carried out to conclude various mechanical properties of concrete paving blocks having compressive strength more than 7200 psi in comparison using marble powder from three distinct sources as cement replacement. Concrete paver samples with varying proportions 0%, 10%, 15%, 20%, 25% and 30% of marble powder from different sources were casted and tested to find the properties like compressive strength with respect to 7 days & 28 days, flexural strength and water absorption with respect to 28 days. From the results it was concluded to replace the marble powder up to 20% by Mohmand source, 15% by Buner and 10% by Ziarat with cement to achieve improved properties. The usage of cement in civil works is increasing day by day and its demand is quite high in developing countries thus leading to environmental pollution due to emission of CO2 during production process. Replacing cement with marble powder up to certain limit will not only reduce the CO2 emissions and manufacturing cost of pavers but will solve the disposal problem of marble waste in effective way.*

Keywords- *Paving blocks, Marble Powder, Varying proportions, High Strength concrete, Nominal Concrete, Replacement Ratio*

I. INTRODUCTION

Concrete paving blocks are readymade solid cement concrete blocks available in various sizes and shapes. Concrete paving blocks have been widely used in various countries to a certain extent of time as a standard practice for providing pavements because of its firmness in regions such as walkways, parking lots and parks where normal type pavements are not suitable or less resilient due to many operative and environmental restraints. Concrete paving blocks (sometimes called "Pavers") are visually good-looking, useful, and cost efficient and needs no or minor cost if properly placed and maintained. The marble industry is one of them, the very old and major sector in Pakistan.

Cement in one of the key components of concrete and its usage in civil works is increasing day by day. As a binding material in concrete, the demand is quite high in developing countries thus leading to environmental pollution due to emissions of Carbon dioxide during production process. In order to overcome the issue, marble wastes may be used as a substitute to cement. Marble has been used as construction material since early periods. The rapid utilization of natural reserves by marble industry have been a major reason of concern in recent times and the wastes produced in turn requires high attention. Every day large quantities of waste are produced in the regions of Khyber Pakhtunkhwa and FATA merged areas of Mohmand marble quarrying areas, Buner, Malakand, Kohat, Orakzai and Baluchistan etc.). It is estimated that such waste amounts 50% to 60% of the mined rocks. Marble stones are cut into the desired shape and size, thus leaving 30% loss of original mass in the form of dust. The Industry's removal of the marble dust, containing very fine particles, are dumped in the factory surroundings and open areas, resulting environmental pollution. It is of great significance to find alternate ways of using marble wastes in construction industry in order to minimize the effect on environment. A potential way to reduce this type of problem is in the utilization of marble powder in concrete paving blocks by partially replacing cement with marble powder is therefore reasonable.

II. Literature Review

The purpose of this study to assess the properties of high strength concrete pavers by partially replacing cement with marble powder. However, several studies have been done in past using industrial waste as partial replacement of cement in nominal concrete and the recent research work is as under.

Chudiwal et al (2018) in a research study stated that paver block are used as a pavement which can be sustained easily and if any problem arises can be changed easily. It gives us diversity in quality i.e. size, shape, color and thickness with rates low-priced than concrete pavement. Paver blocks can be categorized according to their loading condition i.e. non-traffic, light traffic, medium and heavy traffic condition. The objective of the project is to make environmentally friendly

paver block which resolves removal problem of fly ash, marble dust and increasing strength of concrete. Test results attained recommends that no three materials at a time can be used to exchange cement but 10% and 15% replacement with marble dust and Wollastonite powder one-to-one gives good results than usual cement concrete. So this ratio can be implemented as it costs inexpensive than normal concrete for paver block. [1]

Patel and Singh (2017) investigated the effect on properties of concrete paving blocks by partially replacing cement with fly ash. Experimentation is done on M33, M43 and M53 mix, with partial replacement ratios of 5%, 10%, 15%, 20% & 25% of cement. Subsequently getting the best percentage level of all these, further experimental work is proposed for the use of all these three in a single paving block. The substituted material in this study is fly ash. Experimental work is done to find the workability test, water absorption, flexural strength test and compressive strength of the concrete paving blocks. [2]

Jegan and Sriram (2018) investigated the strength property of paver block using granite powder as cement replacement. Primarily, granite dust samples were collected and its properties were studied. Consistency and setting time of samples containing cement and granite powder at 25, 50 and 75 percent replacement were examined using paver block. By casting samples of zigzag paver block of size 250mmx123mmx80 mm with M40 grade of concrete mix were used. The results revealed that granite powder can be used successfully and more resilient in paver blocks. [3]

Pattnaik et al, (2018) studied the possibility of manufacturing concrete pavers with the locally available material such as cement, coarse and fine aggregates, glass powder and fly ash. Different concrete blends were prepared using equally substituted quantity of cement by waste glass powder and fly ash. Without any considerable change in strength properties of concrete pavers, these wastes can be effectually used. Improvement in compressive strength and flexural strength were attained up to 20% replacement of cement with fly ash and glass powder. [4]

Nishikant et al, (2016) in a research investigation studied the possibility of partially replacing fine aggregate with waste glass. Physical and mechanical properties of paving blocks using glass as partial replacement at 15%, 30% and 45% were examined. The waste glass material used was taken from waste accumulators. The results attained indicates that compressive strength property of the concrete pavers increased with the replacement of glass. The study showed that waste glass can effectually be replaced with fine aggregate up to 45% without considerable change in strength. [5]

Israr et al, (2016) in research study explained that suitability of cement sand mortar combined with waste marble powder. Marble powder is the waste produced from marble industry that is easily available but leads to environmental pollution. The use of marble wastes in civil works will not only save the environment from pollution but also produce environment friendly structures. The effect on the properties of cement sand mortar by partially replacing cement with marble powder has been considered by casting five samples with increasing replacement ratios upto 20%. From the results, it was concluded that waste marble powder at 10% replacement of cement was used to achieve the enhanced mechanical properties of cement sand mortar. [6]

Khaliq et al, (2016) in research study examined the suitability of marble powder waste in concrete construction. Different tests were suggested to study the properties of concrete including permeability test. Samples from two different sources were casted using cement partially replaced by marble powder at 0%, 5%, 10%, 15%, 20%, 25% and 30%. The results showed 6% decrease in compressive strength while 12% decrease in tensile strength when cement replaced with 5% marble powder. These limits slowly decreased with increasing replacement ratio of MP up to 30%. Best results were achieved at 10% replacement of MP. Enhancement in consistency and permeability were also observed. The permeability was enhanced with increasing MP proportion up to 10% without considerable decrease in compressive strength. From final results it was concluded that MP as a substitute to cement in civil works is a feasible option in view of its economy and environmentally friendly effects. [7]

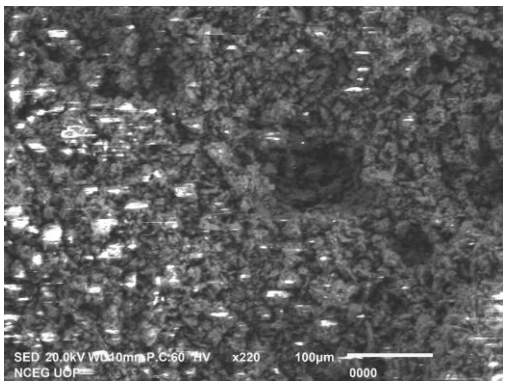
Khan et al, (2017) examined the feasibility of marble powder in ceramic clay. The study showed utilization of marble powder in varying proportions to produce bricks. The Brick specimens with replacement ratio of up to 30% were casted. Brick samples using marble powder at varying proportions of upto 30% were casted, dried out and then burnt at specified temperature. Different mechanical properties were examined for these bricks. A slight difference in result of bulk density was found. Water absorption and porosity of bricks increased by 52% and 36% while compressive strength decreased upto 4.84 MPa. [8]

Tufail et al, (2016) in a research study examined the impact of high temperatures on different properties of concrete using granite, quartzite and lime stone. Concrete blends were formed using aggregates of lime stone, granite and quartzite minerals. The specimens were applied to high temperature for 2 hours from 25 degrees Celsius to 650 degrees Celsius. Increase in compressive strength, tensile strength and modulus of elasticity was observed while decrease in ultimate strain. Concrete blend made of granite coarse aggregate was observed with high mechanical properties applied at all temperatures followed by quartzite and limestone concretes respectively. [9]

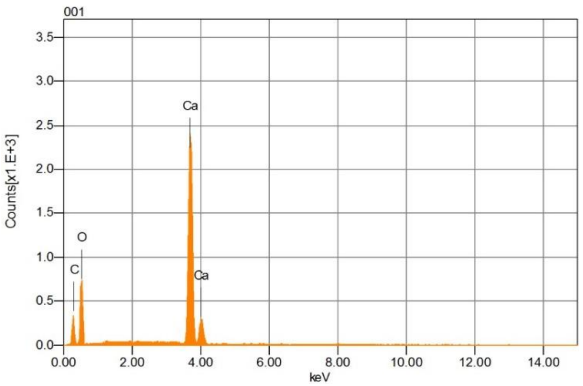
III. Materials for Testing

Marble Powder:
Samples of marble powder were collected from three geographically distinct sources of marble quarries. These samples were assessed for their chemical composition and surface morphology using Energy Dispersive X-Ray spectroscopy (EDS) techniques and Scanning Electron Microscopy (SEM).

Grain size distribution of each sample was also determined using hydrometer analysis. C

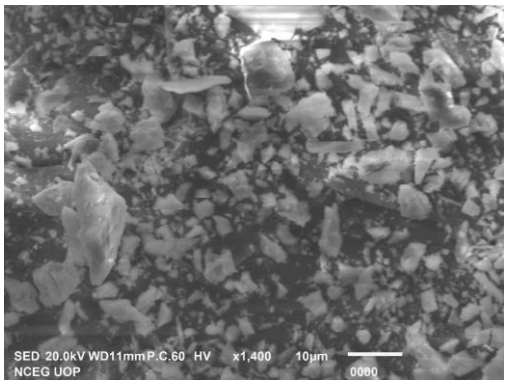


Electronic Microscopy of MP(Z) by SEM

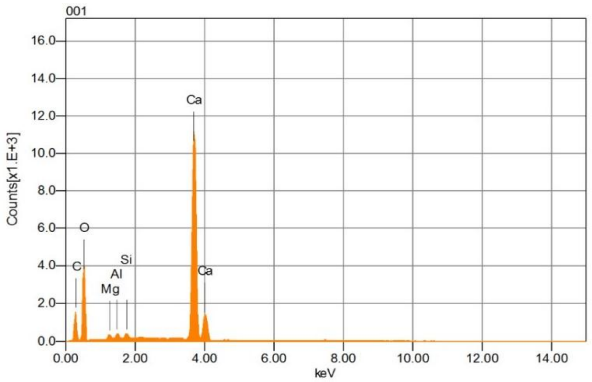


Chemical composition of MP(Z) by EDS technique

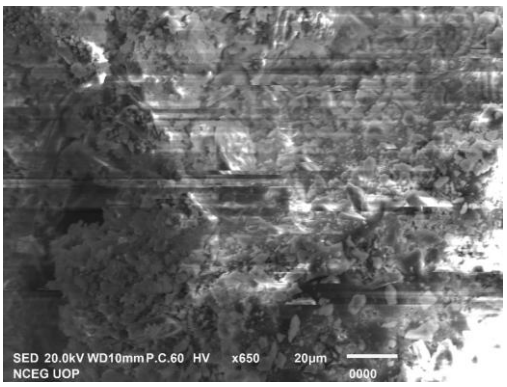
Chemical composition of MP(Z), MP(M) and MP(B) by EDS Technique



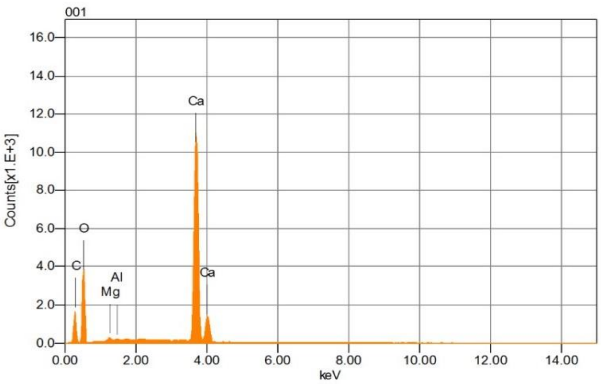
Electronic Microscopy of MP(M) by SEM



Chemical composition of MP(M) by EDS technique



Electronic Microscopy of MP(B) by SEM



Chemical composition of MP(B) by EDS technique

S. No	Components	Mass (%) MP(M)	Mass (%) MP(B)	Mass (%) MP(Z)
1	C	16.34 %	16.61 %	16.31 %
2	MgO	1.76 %	1.07 %	0.00%
3	Al2O3	1.62 %	0.71 %	0.00%
4	Si O2	1.83 %	0.00 %	0.00%
5	Ca O	78.44 %	81.61 %	83.69 %
	Total	100 %	100 %	100 %

Cement:
Kohat cement was used in preparation of samples with fineness of 312m^2/kg

Fine and Coarse Aggregate:
Sand was obtained from Lawrecpur with F.M of 1.0. Similarly, coarse aggregate was obtained from local quarries of Peshawar with specific gravity of 2.6.

IV. Sample Casting and Testing

In factory, trail mixes were done with paving block machine to make sure proper material proportions and water amounts using pressure and vibration till the desired strength of M_{55} grade concrete was achieved. The materials (cement, fine aggregate, and coarse aggregate) were added in mixer machine in dry form and then water was added till the desired moisture content achieved. The concrete pavers were casted using pressure and vibration until thorough compaction was achieved from the compacting machine.

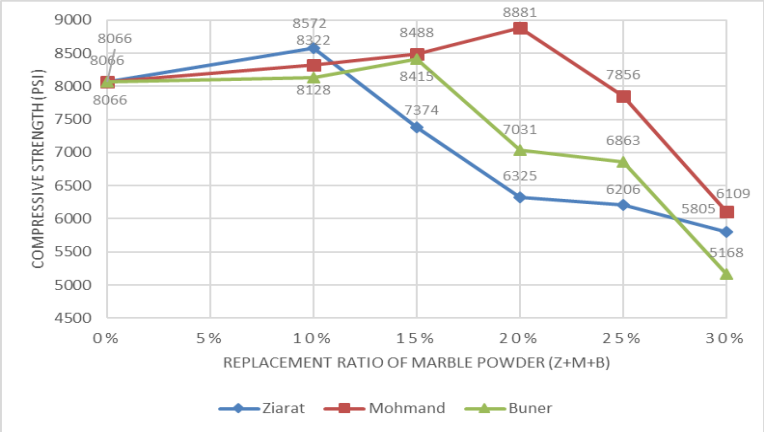

Proper tagging and marking of paving blocks after casting

Composition groups	Replacement of cement (%)	Number of samples
Z00, M00, B00	0	3x12 = 36
Z10, M10, B10	10	3x12 = 36
Z15, M15, B15	15	3x12 = 36
Z20, M20, B20	20	3x12 = 36
Z25, M25, B25	25	3x12 = 36
Z30, M30, B30	30	3x12 = 36
	Total:	**216**

Compression Test 7 & 28 Days (ASTM C 936/C 936M):

Compressive strength was found using universal testing machine of the capacity 200 tons in lab as per ASTM Standards. In each type, three samples were tested and their average compressive strength was calculated by using the formula:

Compressive strength = Load / Area (Psi or MPa)

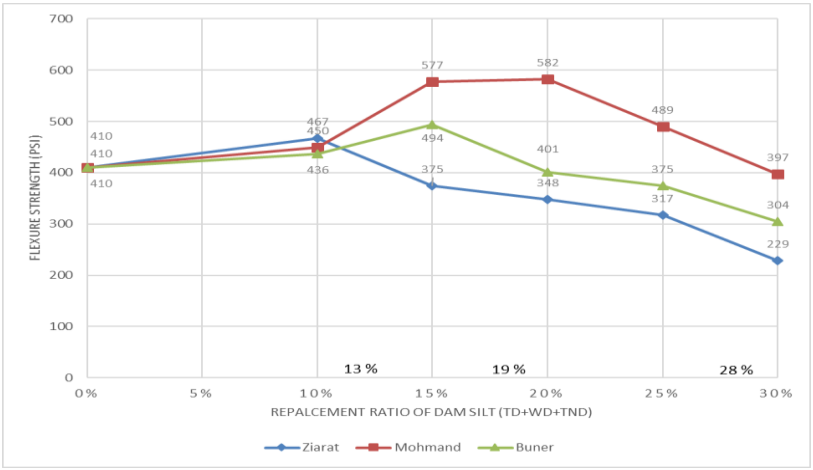


Compressive strength at 28 days in comparison

Flexural Strength:

The flexural strength of concrete paver was tested by Universal Testing Machine of capacity 200 tons using the below formula. The paver samples are placed in such a way that the axis of sample is line up with device and the load is applied on top surface. The reading on fracture of block was noted as maximum load.

Flexure strength = $3PL/2bd^2$



Flexure strength at 28 days in comparison

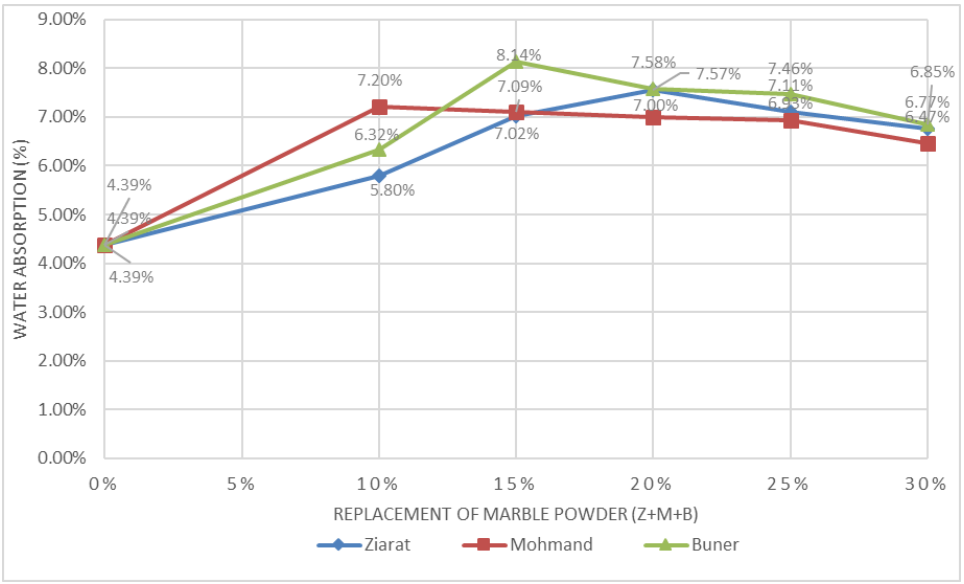
Water Absorption:

Water Absorption at 28 days are shown in Table 4.1

Absorption, % = (*Ws* –*Wd*)/*Wd*x100

S.No	Source	Replacement Ratio of marble Powder with Cement					
		0%	10%	15%	20%	25%	30%
		Average Water Absorption at 28 Days					
1	Ziarat	4.39%	5.80%	7.02%	7.57%	7.11%	6.77%
2	Mohmand	4.39%	7.20%	7.09%	7.00%	6.93%	6.47%
3	Buner	4.39%	6.32%	8.14%	7.58%	7.46%	6.85%

Table 4.1, Water absorption at 28 days in comparison



Water absorption at 28 days in comparison

V. Conclusions and Recommendations

Experimental study was carried out to conclude various mechanical properties of concrete paving blocks in comparison using marble powder from three distinct sources as cement replacement. Concrete paver samples with varying proportions of marble powder from different sources were casted and tested to find the properties like compressive strength with respect to 7 days & 28 days, flexural strength and water absorption with respect to 28 days. Based on the results of tested samples, the following conclusions have drawn:

1. It was found that for all the three sources, using marble powder up to replacement of 20% with cement, increase in 07 days compressive strength of concrete paver was observed with higher value of Ziarat source followed by Mohmand and Buner.

2. Increase in 28 days compressive strength property of concrete pavers were also observed by partial replacement of cement with MP. So, it is recommended to replace the Mohmand marble powder up to 20% to achieve the compressive strength of 8,881 psi, which is 10.10% more than nominal concrete paver strength. Similarly, it is recommended that the marble powder of Ziarat source can be used up to 10% replacement of cement to achieve the compressive strength of 8,572 psi which is 6.27% more than nominal concrete paver. Last but not the least, the MP from Buner source can be replaced up to 15% to get the maximum value of compressive strength i.e. 8,415 psi which is more than conventional concrete paver by 4.32%. Paving blocks using marble powder of Mohamand source gave comparatively highest value of compressive strength followed by Ziarat and Buner.

3. It was observed that replacing cement with Mohmand marble powder enhances the flexural strength of concrete paver at 20% to achieve the strength of 582 psi which is higher than conventional concrete by 41.95%. Similarly, replacing the Buner and Ziarat marble powder with cement at 10% and 15% gives the maximum value of flexure strength which is 20.48% & 13.9% more than conventional concrete paver. The flexure strength then gradually decreases as the replacement ratio increases.
4. High absorption values are achieved for all the three sources with maximum absorption of 8.14%, 7.57% and 7.2% using Buner, Ziarat and Mohmand MP at the replacement ratio of 15%, 20% and 10%. Though water absorption is not the degree of the quality of concrete however, most of the good quality concrete having absorption less than 10% [10]. The values are quite high the permissible limit which shows that porosity of blocks increased. It is recommended to find the permeability property of concrete paver as increase in permeability will quickly infiltrate the surface runoff to avoid standing water on pavement.
5. Best level for replacement of MP with cement was concluded for all three sources i.e. at 10% Replacement level, best results were obtained using Ziarat MP, at 20% for Mohmand source and 15% for Buner MP.
6. it is evident that using MP as replacement of cement have not only improved the mechanical properties of concrete paving blocks but saving in cost too.
7. This study is mainly concentrated to partial usage of marble powder in concrete pavers at varying percentages to assess the properties like, compressive strength, water absorption and Flexure strength. However, further research work can be done to determine other properties like porosity, permeability, abrasion and freezing-thawing to make the usage of marble powder more efficient and beneficial for construction works.

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