An Experimental Study on Rigid Pavements by Using Various Waste Materials

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Abstract- In this study, the possibility of using fly ash, copper slag & marble slurry powder in concrete production is examined by studying the effects of blending of fly ash, copper slag & marble slurry powder with partial replacement of natural sand and also the performance of fresh and hardened concrete. This study represented the results of experimental investigation carried out to determine compressive strength and flexural strength of concrete mixes for grade M25 & M30. The cement concrete so investigated could be utilized as the rigid pavements on the low volume roads. It might be a forward step towards sustainable construction of green highways.

Keywords- Fly ash, Copper Slag, Marble Slurry Powder, Concrete, Environment.

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1. INTRODUCTION

Green highways may be described as those which are environmental friendly and sustainable in all aspects including design, construction and maintenance. Recycling of waste material is the major environmental sustainability concept and leads to sustainable development especially for huge utilization of waste in highway construction. A rigid pavement, due to its long life is an economic and cost effective pavement solution as compared to flexible pavements. The prime objective of the research is to study the possible application of copper slag, fly ash & marble slurry powder in cement concrete for utilization in various components of low volume road construction. The research has been devoted to analyze the effect of copper slag, fly ash & marble slurry powder on the properties of cement concrete mix. The motive of the research is to achieve the desirable utilization of copper slag, fly ash & marble slurry powder in cement concrete in an environmental friendly manner. The design of two grades of concrete mixes i.e. M-25 and M-30 were carried out as per guidelines of IS: 10262-2009. In this study compressive strength and flexural strength of concrete with different proportion of copper slag, fly ash & marble slurry powder partially replacing natural sand were investigated. The aim of this project was to determine the feasibility of incorporating low carbon copper slag, fly ash and marble powder in concrete. The utilization of copper slag, fly ash and marble powder would also reduce the energy consumption associated with production of natural road aggregates.

2. LITERATURE REVIEW

Waste can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits. In present time, many researchers have established that the use of waste materials like fly ash, blast furnace slag, copper slag, silica fume, and rice husk, hypo sludge etc. can, not only improve the various properties of concrete -both in its fresh and hardened states, but also can contribute to economy in construction costs. Presently large amounts of fly ash are generated in thermal industries with an important impact on environment and humans. Marble stone industry generates both solid waste and stone slurry. Copper slag is generated during extraction and refining of copper metal from its concentrate.

The surface of roadway should be stable and non-yielding to allow the heavy wheel loads of road traffic to move with least possible rolling resistance. The pavement carries the wheel loads and transfer the load stresses through a wider area on the soil sub grade below. Flexible pavements are those, which on the whole have low or negligible flexure strength and are rather flexible in their structural action under the loads. The flexible pavement layers transmit the vertical or compressive stresses to the lower layer by grain to grain transfer through the point of contact in the granular structure. The load spreading ability of this layer therefore depends on the type of the materials and the mix design factors. Bituminous concrete is one of the best flexible pavement layer materials. Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. They are made of Portland cement concrete-either plain, reinforced or prestressed concrete. The main point of difference in rigid pavement as compared to the flexible pavement, rigid pavement are placed directly on the prepared sub grade or on a single layer of granular or stabilized material. Any concrete which posses the requisite compressive strength and flexural strength as per IRC 58: 2002 could be adopted for Rigid pavements. In this study the endeavor was made to prepare green concrete having the concrete characteristics as per IRC 58:2002.

J. Chai & C. Raungrut (2003) reported that bottom ash has a high potential to develop to be a good pozzolanic material. **Unal and Uygunoglu, (2003); Alyamac and Ince, (2009); Guneyisi et al., (2009); Corinaldesi et al., (2010);**Many studies have been conducted in literature on the performance of the concrete containing waste marble dust or waste marble aggregate, such as its addition into self-compacting concrete as an admixture or sand. **Hameed and Sekar (2009)** reported that marble dust can be used either to produce new products or as an admixture so that the natural sources are used more efficiently and the environment is saved from dumpsites of marble waste. **H.K. Kim and H.K. Lee (2011)** detailed experimental investigation carried out to evaluate the effect of fine and coarse bottom ash on the flow characteristics and density of concrete mixture and found that both of fine and coarse bottom ash aggregates had more influence on flexural strength than compressive strength.

3. EXPERIMENTAL PROGRAM

In the present research, an experimental work has been carried out for the characterization and utilization of copper slag, fly ash & marble slurry powder in the cement concrete with the partial replacement of fine aggregates by copper slag, fly ash & marble slurry powder. In this study, two grades of concrete mixes i.e. M-25 and M-30 were selected which are most commonly used in the rigid pavements. The mix design as per IS : 10262- 2009 for concrete of grade M-25 and M-30 was done by using conventional materials for a design slump of 100 - 125 mm. After that fine aggregates were replaced by copper slag, fly ash & marble slurry powder with 10, 20, 30 and 40%, by weight of aggregates in the both mixes. The compressive strength at 7 days and 28 days were determined in the laboratory. The beam specimens were prepared and flexural strength at 28 days was determined for all the mixes as per relevant Indian standards.

3.1 Materials for Experimental Investigation:

(a) Copper Slag: It was procured from Birla Copper (Hindalco Industries Ltd.), Dahej (Gujrat).

(b) Fly Ash: It was procured from Kota Thermal Power Plant.

(c) Marble Slurry Powder: The marble powder used in this work is taken from Makrana.

(d) Coarse Aggregates: Well graded coarse aggregates (20 mm and 10 mm) were procured from local crusher situated at Gunawata,Jaipur.

(e) Fine Aggregate (river sand): It was procured from Banas River, Tonk.

(f) Cement : Ordinary Portland Cement of 43 Grade (Shree Cement) was procured.

(g) Chemical Admixture: Naphthalene Formaldehyde and PCE Mix base (SHALIPLAST HPRA CS-2).

3.2 Proportioning of Aggregates

By the trial and error method, the proportioning of coarse aggregates (size 20 mm and 10 mm) and fine aggregates was carried out to achieve the desired gradation. The combined gradation was achieved by using 36% coarse aggregates (20mm), 24% coarse aggregates (10mm) and 40% fine aggregates. The combined gradation and specified limits are shown in Table 1. Also Figure1 showed the combined gradation curve along with specified upper and lower limits.

Table1. Combined Aggregate Gradation

Sieve Size (mm)	% Passing						Combined Gradation	Specification Limits as per IS:383-1970	
	Coarse Aggregates (20 mm size)		Coarse Aggregates (10 mm size)		Fine Aggregates			Lower Limit	Upper Limit
	100%	36.00%	100%	24.00%	100%	40%	100%		
40	100	36.00	100	24.00	100	40.00	100.00	100.00	100.00
20	89.23	32.12	100	24.00	100	40.00	96.12	95.00	100.00
4.75	0.62	0.22	12.80	3.07	98.60	39.44	42.73	30.00	50.00
0.60	0.00	0.00	0.00	0.00	38.70	15.48	15.48	10.00	35.00
0.15	0.00	0.00	0.00	0.00	1.00	0.40	0.40	0.00	6.00

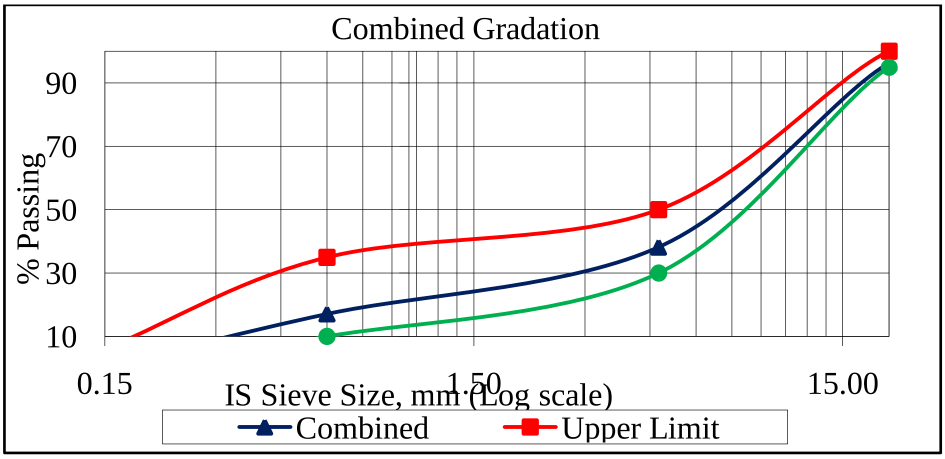

Figure.1 Combined Aggregates Gradation

The concrete mix was designed by using conventional fine aggregates and termed as control mix. In this study M-25 and M-30 grade of concrete mixes were designed. Final quantity for different mix proportion of 1 cumec concrete of M-25 grade and M-30 grade are shown in the Tables respectively.

3.3 (a) For Copper Slag:

Table.2 Fine Aggregates blended Mix Proportion (M-25 Grade of Concrete)

Mix Name	Cement (kg)	Coarse Aggregates		FA (Fine Aggregates) (kg)	CS (COpper Slag) (kg)	Water (kg)
		20 mm (kg)	10 mm (kg)			
FA+CS (100+0)	350	683.15	448.59	745.38	0.00	185.42
FA+CS (90+10)	350	683.15	448.59	670.84	74.54	185.42
FA+CS (80+20)	350	683.15	448.59	596.3	149.08	185.42
FA+CS (70+30)	350	683.15	448.59	521.76	223.62	185.42
FA+CS (60+40)	350	683.15	448.59	447.22	298.16	185.42

Table.3 Fine Aggregates Blend Mix Proportion (M-30 Grade of Concrete)

Mix Name	Cement (kg)	Coarse Aggregate		FA (Fine Aggregates) (kg)	CS (Copper Slag) (kg)	Water (kg)
		20 mm (kg)	10 mm (kg)			
FA+CS (100+0)	360	685.50	450.13	747.95	0.00	179.48
FA+CS (90+10)	360	685.50	450.13	673.15	74.80	179.48
FA+CS (80+20)	360	685.50	450.13	598.35	149.60	179.48
FA+CS (70+30)	360	685.50	450.13	523.56	224.39	179.48
FA+CS (60+40)	360	685.50	450.13	448.77	299.18	179.48

3.4 (b) For Fly ash + Marble Slurry

Table.4 Fine Aggregate Blend Mix Proportion (M-25 Grade of Concrete)

Mix Name	Cement (kg)	Coarse Aggregate		Natural Sand (kg) NS	Fly Ash (kg) FA	Marble Powder (kg) MP	Water (kg)
		20mm kg	10mm kg				
NS+ FA+MP (97.5+1.25+1.25)	350	683.12	448.59	726.75	9.32	9.32	185.42
NS+ FA+MP (95+2.5+2.5)	350	683.15	448.59	708.11	18.64	18.64	185.42
NS+ FA+MP (92.5+3.75+3.75)	350	683.15	448.59	689.48	27.95	27.95	185.42
NS+ FA+MP (90+5+5)	350	683.15	448.59	670.84	37.27	37.27	185.42
NS+ FA+MP (87.5+6.25+6.25)	350	683.15	448.59	652.21	46.59	46.59	185.42
NS+ FA+MP (85+7.5+7.5)	350	683.15	448.59	633.57	55.91	55.91	185.42
NS+ FA+MP (90+10+0)	350	683.15	448.59	670.84	74.54	0	185.42
NS+ FA+MP (90+0+10)	350	683.15	448.59	670.84	0	74.54	185.42

Table.5 Fine Aggregate Blend Mix Proportion (M-30 Grade of Concrete)

Mix Name	Cement (kg)	Coarse Aggregate		Natural Sand (kg) NS	Fly Ash (kg) FA	Marble Powder (kg) MP	Water (kg)
		20mm kg	10mm Kg				
NS+ FA+MP (97.5+1.25+1.25)	360	685.79	450.32	729.55	9.36	9.36	179.5
NS+ FA+MP (95+2.5+2.5)	360	685.79	450.32	710.85	18.71	18.71	179.5
NS+ FA+MP (92.5+3.75+3.75)	360	685.79	450.32	692.26	28.06	28.06	179.5
NS+ FA+MP (90+5+5)	360	685.79	450.32	673.54	37.42	37.42	179.5
NS+ FA+MP (87.5+6.25+6.25)	360	685.79	450.32	654.83	46.78	46.78	179.5
NS+ FA+MP (85+7.5+7.5)	360	685.79	450.32	737.12	56.13	56.13	179.5
NS+ FA+MP (90+10+0)	360	685.79	450.32	673.54	74.84	0	179.5
NS+ FA+MP (90+0+10)	360	685.79	450.32	673.54	0	74.84	179.5

4. RESULTS AND DISCUSSIONS

The design of concrete mix of grade M-25 and M-30 was carried out as per IS: 10262-2009 by using conventional aggregates.

4.1 (a) For Copper Slag:

Table.6 Slump Test Results

Slump test results		
Mix	**M-25**	**M-30**
Copper Slag(%)	**Slump Results (mm)**	
0	110	105
10	120	115
20	130	120
30	142	130
40	160	155

Table.7 Compressive Strength Test Results

Compressive Strength test results				
Mix	**M-25**		**M-30**	
Test Age (days)	**7 days**	**28 days**	**7 days**	**28 days**
Copper Slag (%)	**Compressive test Strength results (N/mm²)**			
0	20.79	31.92	21.61	32.02
10	21.56	32.51	23.16	32.99
20	22.37	33.56	23.99	33.59
30	21.01	28.71	24.23	31.75
40	20.11	25.52	21.11	29.07

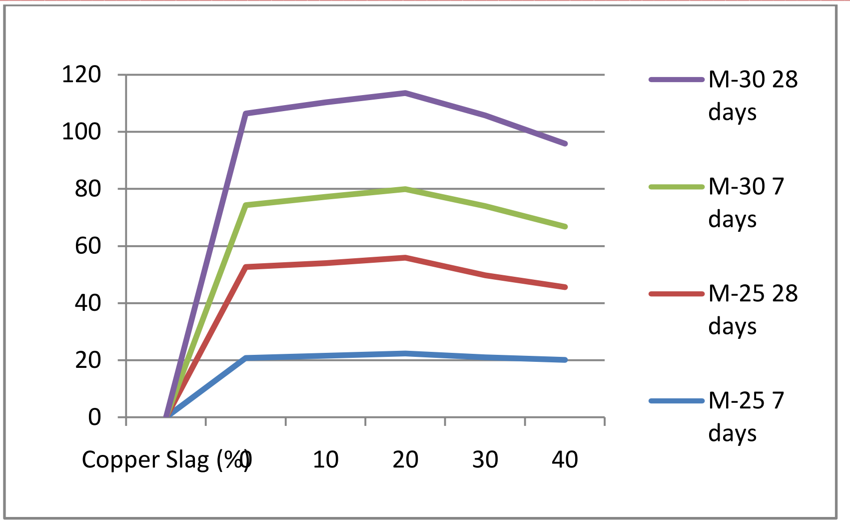

Figure.2 Compressive Strength (7 Days & 28 Days) v/s. % of Copper Slag of M-25 & M-30 Grade of Concrete

Table.8 Flexural Strength Test Results

Flexural Strength test results		
Mix	**M-25**	**M-30**
Test Age (days)	**28 days**	**28 days**
Copper Slag (%)	**Flexural Strength test results (N/mm²)**	
0	3.68	4.34
10	4.11	4.63
20	4.24	5.17
30	3.84	4.72
40	3.42	4.13

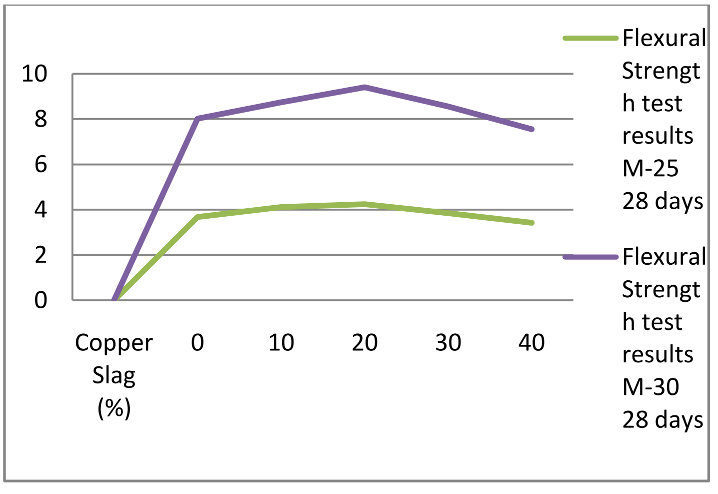

Figure.3 Flexural Strength (28 Days) v/s. % of Copper Slag of M-25 & M-30 Grade of Concrete

Table.9 Effect of % Copper Slag on Density of Hardened Concrete

Density test results				
Mix	**M-25**		**M-30**	
Test Age (days)	**7 days**	**28 days**	**7 days**	**28 days**
Copper Slag (%)	**Average Density (Kg/ m³)**			
0	2531.95	2539.06	2550.32	2563.95
10	2540.25	2548.05	2557.73	2570.37
20	2543.01	2551.11	2567.31	2578.67
30	2553.98	2565.04	2574.32	2586.67
40	2563.06	2575.11	2588.15	2597.53

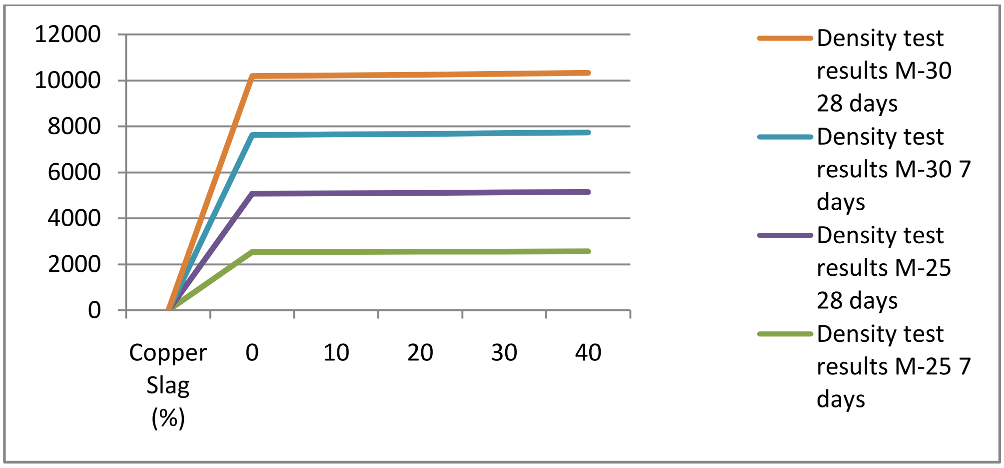

Figure.4 Density (7 Days & 28 Days) v/s. % of Copper Slag of M-25 & M-30 Grade of Concrete

4.2 (b) For Fly Ash & Marble Slurry Powder:

Table.10 Slump Test Results

Slump test results		
Mix	**M-25**	**M-30**
Fly Ash+ Marble slurry powder (%)	**Slump Results (mm)**	
(1.25+1.25)	120	115
(2.5+2.5)	125	120
(3.75+3.75)	135	130
(5+5)	85	90
(6.25+6.25)	45	50
(7.5+7.5)	15	10
(10+0)	135	140
(0+10)	70	75

Table.11 Compressive Strength Test Results

Compressive Strength test results				
Mix	**M-25**		**M-30**	
Test Age (days)	**7 days**	**28 days**	**7 days**	**28 days**
Fly Ash+ Marble slurry powder (%)	**Compressive strength test results (N/mm²)**			
0	21.32	28.6	25.93	37.57
(1.25+1.25)	19.38	27.05	25.36	36.08
(2.5+2.5)	21.81	30.86	26.76	38.22
(3.75+3.75)	22.38	31.92	27.92	39.65

(5+5)	24.46	34.25	28.87	40.31
(6.25+6.25)	21.1	28.9	26.9	38.23
(7.5+7.5)	19.6	27.88	26.21	37.1
(10+0)	25.45	35.96	28.81	41.02
(0+10)	25.06	35.07	28.41	40.73

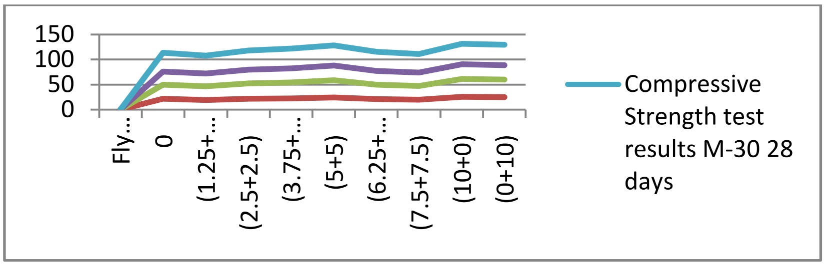

Figure.5 Compressive Strength (7 Days & 28 Days) v/s. % of Fly Ash & Marble Slurry of M-25 & M-30 Grade of Concrete

Table.12 Flexural Strength Test Results

Flexural Strength test results		
Mix	**M-25**	**M-30**
Test Age (days)	**28 days**	**28 days**
Fly Ash+ Marble slurry powder (%)	**Flexural test results (N/mm²)**	
0	4.93	6.11
(1.25+1.25)	4.72	5.2
(2.5+2.5)	5.04	5.6
(3.75+3.75)	5.28	6.05
(5+5)	5.79	6.6
(6.25+6.25)	4.83	6.24
(7.5+7.5)	4.35	5.97
(10+0)	5.71	6.45
(0+10)	5.2	6.13

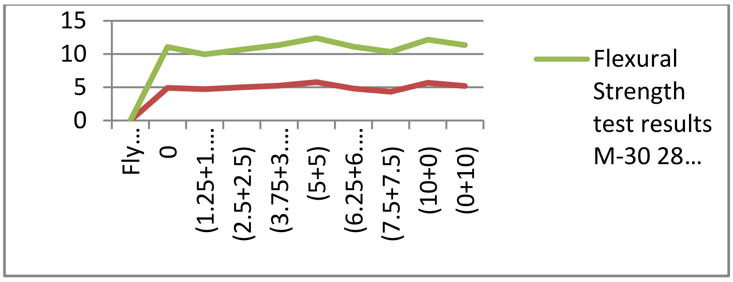

Figure.6 Flexural Strength (28 Days) v/s. % of Copper Slag of Fly Ash & Marble Slurry M-25 & M-30 Grade of Concrete

Table.13 Effect of % Fly Ash & Marble Powder on Density of Hardened Concrete

Density test results				
Mix	**M-25**		**M-30**	
Test Age (days)	**7 days**	**28 days**	**7 days**	**28 days**
Fly Ash+ Marble slurry powder (%)	**Average Density (Kg/ m^3)**			
0	2468.15	2471.11	2482.96	2488.89
(1.25+1.25)	2450.37	2459.26	2468.37	2474.07
(2.5+2.5)	2456.3	2462.22	2471.11	2477.04

(3.75+3.75)	2462.22	2468.15	2477.04	2480
(5+5)	2465.19	2471.11	2480	2491.85
(6.25+6.25)	2459.26	2465.19	2474.07	2482.96
(7.5+7.5)	2453.33	2456.3	2465.19	2471.11
(10+0)	2462.22	2468.15	2488.89	2494.81
(0+10)	2456.3	2465.19	2485.93	2488.89

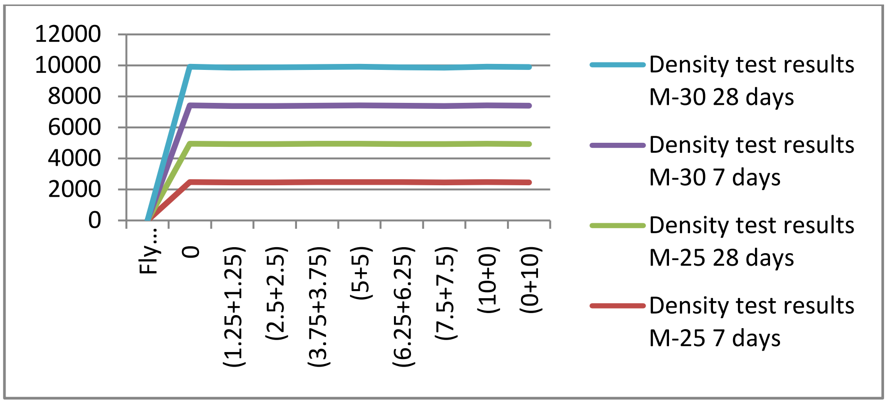

Figure.7 Density (7 Days & 28 Days) v/s. % of Fly Ash & Marble Slurry of M-25 & M-30 Grade of Concrete

5. CONCLUSION

The present study documents shall be the findings of an experimental research on the characterization of concrete utilizing copper slag, fly ash & marble slurry powder by the partial replacement of fine aggregates in which it can be utilized in the rigid pavement for low traffic roads near copper production industries. The bulk utilization of copper slag fly ash & marble slurry may lead to less utilization of natural resources of river sand. Environment friendly approach is most important aspect and is touched due to understanding of earth life balance along with pollution free society.

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