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Experimental Analysis on the Properties of Concrete Paving Blocks Prepared with Brick Dust And Expanded Polystyrene

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Abstract

An experimental analysis had been conducted to study the effect of brick dust and expanded polystyrene as partial replacement of sand and coarse aggregate on the compressive strength, water absorption and bulk density of hexagonal concrete paving blocks. The replacement varied as 0%,10%,20% and 30% in the block samples of M30 and M35 grade. Hexagonal block Samples of each side 110 mm and height 60 mm were prepared for the test. The experimental result showed that Compressive strength of M30 and M35 blocks varied between 39.44 N/mm^2 to 15.05 N/mm^2 and 44.74 N/mm^2 to 19.72 N/mm^2 with percentage increase in brick dust and expanded polystyrene. Water Absorption of M30 and M35 blocks varied between 1.95% to 4.04 % and 1.85 % to 3.05 % with percentage increase in brick dust and expanded polystyrene. And Bulk density of M30 and M35 blocks varied between 24.08 KN/m^3 to 19.77 KN/m^3 and 24.18 KN/m^3 to 20.05 KN/m^3 with percentage increase in brick dust and expanded polystyrene. The result showed that Compressive strength and Bulk density of the resulting block samples decreased with the increase in percentage of expanded polystyrene and brick dust while the Water absorption increased with increase in percentage of expanded polystyrene and brick dust.

Keywords

Paving blocks, Expanded polystyrene, Brick dust, Compressive Testing

1. Introduction

Concrete paving blocks are the common paving material in building premises, parking areas, pedestrians, residential areas etc. So, the demand of its constituents (cement, sand and aggregate) is so high. Most of the aggregates are obtained from the environment and excessive extraction has caused serious environmental problems.If the alternatives of these constituents aren't searched on time, we may face the great scarcity on the near future.

One of the potential marginal materials suitable for replacing sand in concrete is brick dust. Brick is the popular building material for laying walls in Nepal.Most of the bricks get wasted in the factory and other during transportation and construction activities. So the wasted bricks can be reused as the replacement of fine aggregates.

Also, the coarse aggregate could be partially replaced by expanded polystyrene(EPS).Recently, millions of tons of polystyrene waste are produced across the world. This high amount of waste EPS may cause serious environment pollutions. Due to scarcity of space for land filling, the costs of disposal of this amount of EPS is considerable. On the other hand, combustion of EPS in the atmosphere leads to the emission of some toxic fumes which in turn pollutes the environment[1]. Therefore, reuse of EPS waste is an environmentally-friendly manner which leads to remove the environmental concerns due to their land filling or combustion.

So, in this study, it is attempted to partially replace fine aggregrates by brick dust and coarse aggregrate by eps beads in the hexagonal concrete paving blocks.

1.1 Need of Research

Cachim[2] studied the properties of concrete made with crushed bricks replacing natural aggregates. The result shows that when using up to 15% of crushed bricks as concrete aggregate there are no negative effects on concrete strength, while replacement of 30% natural aggregate with crushed brick reduce strength up to 20%.Cabral et.al.[3] modeled mechanical properties of concrete with recycled aggregate. Results of the investigation of Poon et al[4] shows that the production of non-structural precast concrete blocks is possible with low grade recycled aggregate. Kaviya[5] studied the Compressive Strength Of Paving Blocks Prepared With Stone Crusher Dust And Flyash. Pradhan and Maharjan [6] study the effect of expanded polystyrene beads and aggregate ratios in compressive strength and thermal insulation of light weight concrete bricks. Ghimire and Maharjan [7] studied the properties of concrete brick with partial replacement of sand by saw dust and partial replacement of coarse aggregate by expanded polystyrene.

Although various researches have been conducted in analysing strength of concrete by replacing its constituent parts with waste products, the research has not been done by replacing both sand and coarse aggregate with brick dust and EPS in hexagonal concrete paving blocks.

1.2 Research Objectives

The main objective of this research is to investigate experimentally the effect of the partial replacement of sand by brick dust and coarse aggregate by EPS on compressive strength, bulk density and water absorption properties of the resulting hexagonal concrete paving block.Followed by the main objectives , specific objectives includes

- To determine compressive strength of hexagonal concrete paving block sample with 0%, 10%, 20% and 30% replacement of sand and coarse aggregate by brick dust and EPS respectively.
- To determine water absorption of the prepared concrete paving block sample.
- To determine bulk density of the prepared concrete paving block sample.

2. Methodology

Material Collection
Materials such as cement OPC 53 Grade,sand,coarse aggregate,brick dust and expanded polystyrene were used to make hexagonal concrete paving block samples.

Mix Design
The minimum compressive strength of concrete paving blocks according to IS 15658.2006[8] is 30 Mpa with minimum 50 mm thickness for non-traffic condition(Building premises, monument premises, landscapes, public gardens parks, domestic drives, paths and patios) and 35 Mpa with minimum 60 mm thickness for light traffic condition(Pedestrian plazas, shopping complexes, car parks, of like driveways, housing colonies, office complexes, tourist resorts local authority foot ways, residential roads, etc).So,the mix design was calculated for M30 and M35 grade of concrete as per IS 10262:2000 [9].Hexagonal mould of each side 110 mm and height 60 mm Size is used to prepare the sample. As shown in Figure 1, concrete is placed in the mould and placed on the vibrator and allowed to set for two days. Sample is detached from the mould by the application of heat.

Figure 1: concrete in the mould

Pouring and Compaction: The prepared concrete was placed into the moulds with the help of trowel and compacted with the help of electric concrete vibrator.
Curing: The prepared paving block sample were left on curing tank at 27-30 degree Celsius for sufficient strength gain.
Compressive Strength Test:
The compressive strength of concrete block samples is determined with the help of Compression Testing Machine after twenty-eight days of curing. Procedure of IS 15658.2006[10] is used to test compressive strength of concrete block.Three M30 blocks each of 0,10,20 and 30 % and three M35 blocks each of 0,10,20 and 30 % replacement were tested for twenty eigth days compressive strength.Load was applied till

crack was seen and the ultimate load was noted.

Compressive Strength = $\frac{UltimateLoadinN}{AreaofCrosssectioninmm^2}$

Figure 2: Paving blocks under compressive loading

Water absorption test:
Water absorption test was conducted by saturating concrete sample specimens by immersion in potable water for 24 hours. The concrete block sample specimens were then allowed to drain for a minute before wiping off visible surface water using a damp cloth. The saturated specimens were then oven-dried at a temperature of 105 degree Celsius for not less than 24 hours but until a constant dry mass was obtained. Finally, the water absorption was calculated using the following expression: Water Absorption(%)= $\frac{M_s - M_d}{M_d}$
Where, M_s and M_d are the mass of the saturated and dry concrete block specimens, respectively.

Bulk Density test:
Bulk Density is defined as the ratio of weight to volume of a substance. Concrete block sample is kept in the ventilated oven and dry it at a temperature of 105°— 115°C till it achieves appreciable constant mass. Then the concrete brick samples are cooled in room temperature and its mass as M is recorded. After that, dimension of the block is measured and volume is calculated. Finally, bulk density is calculated using the following expression:

Bulk Density = $\frac{Weight}{Volume}$

Table1: properties of the materials

S.No	Physical properties of the materials	
	Material	Values obtained
1	Cement	
	Normal Consistancy	31%
	Initial Setting Time	115 Minutes
	Final Setting Time	265 minutes
2	sand	
	Fineness modulus	2.86
	Specific Gravity	2.65
3	Brick dust	
	Fineness modulus	2.99
4	Coarse Aggregate	2.36
	Fineness modulus	
	Specific Gravity	2.67
	Impact value	11.53
	Maximum Nominal Size	12.5
5	Expanded Polystyrene	
	Maximum Nominal Size	4.75
6	Water	portable water

3. Results and Discussion

3.1 Properties of materials used

Physical and mechanical properties of constituents used in preparing paving blocks of grade M30 and M35 were obtained. The normal consistency of cement used was 31%. The initial and final setting time of cement used for the experiment was found as 115 minutes and 265 minutes respectively as shown in Table 1.The observed values were within the requirements of IS 8112:2013[11] i.e. for initial setting time, it should not be less than 60 minutes and for final setting time, it should not be more than 600 minutes. The fineness modulus of sand was found to be 2.86. And from the result of sieve analysis, the fine aggregate falls into the category of Grading zone II according to the clause 4.3 of IS 383:1970 [12]. The fineness modulus of Brick Dust was found to be 2.99. And from the result of sieve analysis, the fine aggregate falls into the category of Grading zone II according to the clause 4.3 of IS 383:1970 [12]. The nominal maximum size of EPS used for preparing concrete paving block sample was 4.75 mm.The impact value of the aggregate used was found to be 11.53 and the nominal maximum size of coarse aggregate used was 12.5 mm.

3.2 Compressive Strengh Test

The result obtained from compressive strength test for all concrete paving block sample of different

Table 2: Compressive Strength of M30 and M35 blocks at 28 days

Sample		Sand Replacement by Brick Dust(%)	Coarse Aggregate Replacement by EPS(%)	Area (mm^2)	Breaking Load(KN)		Conversion Factor	Compressive Strength (N/mm^2)		Average Compressive Strength (N/mm2)	
M30	M35				M30	M35		M30	M35	M30	M35
A_1	E_1	0	0	31436	1200	1380	1	38.17	43.90	39.44 ±1.14	44.74 ± 0.8
A_2	E_2	0	0	31436	1250	1410	1	39.76	44.85		
A_3	E_3	0	0	31436	1270	1430	1	40.40	45.49		
B_1	F_1	10	10	31436	880	980	1	27.99	31.17	27.14 ± 0.8	30.85 ±1.45
B_2	F_2	10	10	31436	850	920	1	27.04	29.27		
B_3	F_3	10	10	31436	830	1010	1	26.40	32.13		
C_1	G_1	20	20	31436	620	730	1	19.72	23.22	18.66 ± 0.97	24.17 ± 0.95
C_2	G_2	20	20	31436	560	760	1	17.81	24.18		
C_3	G_3	20	20	31436	580	790	1	18.45	25.13		
D_1	H_1	30	30	31436	480	620	1	15.27	19.72	15.05 ±0.36	19.72 ±1.27
D_2	H_2	30	30	31436	460	580	1	14.63	18.45		
D_3	H_3	30	30	31436	480	660	1	15.27	21.00		

proportion of brick dust and EPS after 28 days of curing for M30 grade is shown in Table 2. It was observed that for M30 grade concrete paving block sample type A. The average compressive strength was 39.44 N/mm^2. Similarly, for sample type B, C and D the average compressive strength were 27.14 N/mm^2 ,18.66 N/mm^2,and 15.05 N/mm^2 respectively. The values of compressive strength obtained were within the range of standard deviations. The compressive strength of sample A was found to be greater than target average compressive strength at 28 days (i.e 38.25 N/mm^2) for M30 concrete, which is the required compressive strength value according to IS 10262.2009[10]. A graph is plotted between compressive strength and percentage of Brick Dust and EPS as shown in figure 3. Here,the values of compressive strength decreased from 0% replacement of brick dust and EPS to 30% replacement. Decrease in compressive strength of sample type of M30 grade is due to increase in percentage change of brick dust and EPS in sand and coarse aggregate respectively.

The result obtained from compressive strength test for all concrete paving block sample of different

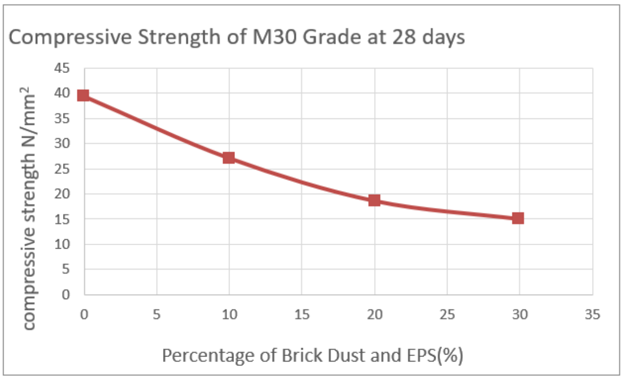

Figure 3: variation of Compressive Strength of M30 Grade Concrete containing different percentage of Brick Dust and EPS

proportion of brick dust and EPS after 28 days of curing for M35 grade is shown in Table 2. It was observed that for M35 grade concrete paving block of sample type E. The average compressive strength was 44.74 N/mm^2. Similarly, for sample type F, G and H the average compressive strength were 30.85 N/mm^2 ,24.17 N/mm^2,and 19.72 N/mm^2 respectively. The

Table 3:Water absorption of M30 and M35 blocks

Sample		Sand Replacement by Brick Dust(%)	Coarse Aggregate Replacement by EPS(%)	Wet Weight (kg)		Dry Weight(kg)		Water Absorption(%)		Average Water Absorption(%)	
M30	M35			M30	M35	M30	M35	M30	M35	M30	M35
A_1	E_1	0	0	4.612	4.612	4.524	4.524	1.95	1.95	1.95 ± 0.01	1.85 ± 0.2
A_2	E_2	0	0	4.413	4.72	4.328	4.628	1.96	1.99		
A_3	E_3	0	0	4.614	4.605	4.526	4.532	1.94	1.61		
B_1	F_1	10	10	4.26	4.242	4.122	4.212	3.35	0.71	2.33 ± 0.95	2.06 ± 1.31
B_2	F_2	10	10	4.312	4.326	4.22	4.186	2.18	3.34		
B_3	F_3	10	10	4.192	4.212	4.132	4.124	1.45	2.13		
C_1	G_1	20	20	3.912	4.022	3.812	3.92	2.62	2.60	2.85 ± 0.27	2.55 ± 1.87
C_2	G_2	20	20	3.926	4.032	3.82	3.862	2.77	4.40		
C_3	G_3	20	20	3.912	4.004	3.792	3.978	3.16	0.65		
D_1	H_1	30	30	3.912	3.902	3.728	3.782	4.94	3.17	4.04 ± 1.26	3.05± 0.1
D_2	H_2	30	30	3.880	3.906	3.712	3.792	4.53	3.01		
D_3	H_3	30	30	3.844	3.884	3.744	3.772	2.67	2.97		

values of compressive strength obtained were within the range of standard deviations. The compressive strength of sample A was found to be greater than target average compressive strength at 28 days(i.e 43.25 N/mm^2) for M35 concrete, which is the required compressive strength value according to IS 10262.2009[10]. A graph is plotted between compressive strength and percentage of Brick Dust and EPS as shown in figure 4. Here, the values of compressive strength decreased from 0% replacement of brick dust and EPS to 30% replacement. Decrease in compressive strength of sample type of M35 grade is due to increase in percentage change of brick dust and EPS in sand and coarse aggregate respectively.

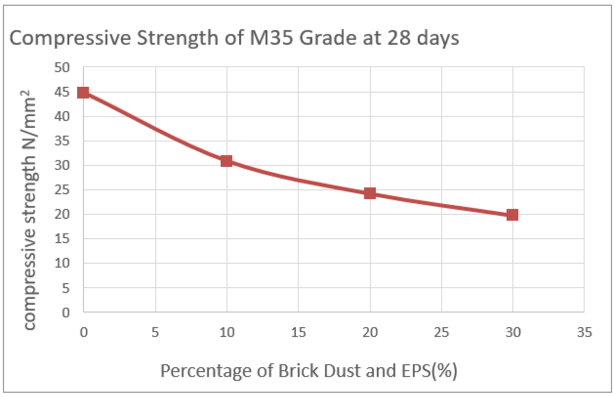

Figure 4: variation of Compressive Strength of M35 Grade Concrete containing different percentage of Brick Dust and EPS

3.3 Water Absorption Test

The result obtained from Water Absorption test for all concrete paving block sample of different proportion of brick dust and EPS for M30 grade is shown in Table 3.The average water absorption for sample type A,B,C and D were found to be 1.97%,2.33%,2.85% and 4.04%. Water Absorption percentage obtained were within the range of standard deviations. According to IS 15658:2006[8] the average water absorption of paving blocks should be less than 6%.Here all the values are less than 6%. A graph is plotted between water absorption and percentage of Brick Dust and EPS as shown in figure 5. Here, the values of water absorption increased from 0% replacement of brick dust and EPS to 30%

replacement. The increase in water absorption is due to the increase in brick dust and Eps content.

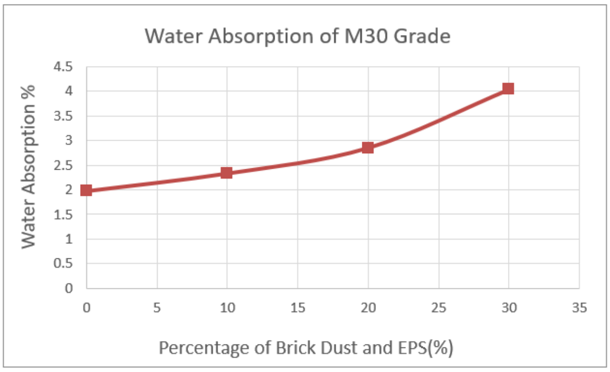

Figure 5: variation of Water Absorption of M30 Grade Concrete containing different percentage of Brick Dust and EPS

Similarly,the average water absorption for sample type E,F,G and H were found to be 1.85%,2.06%,2.55% and 3.05% for M35 grade concrete paving blocks as shown in Table 3.Water Absorption percentage obtained were within the range of standard deviations.Here all the values are less than 6%, which is ok according to IS 15658:2006[8]. A graph is plotted between water absorption and percentage of Brick Dust and EPS as shown in figure 6. Here, the values of water absorption increased from 0% replacement of brick dust and EPS to 30% replacement. The increase in water absorption is due to the increase in brick dust and Eps content.

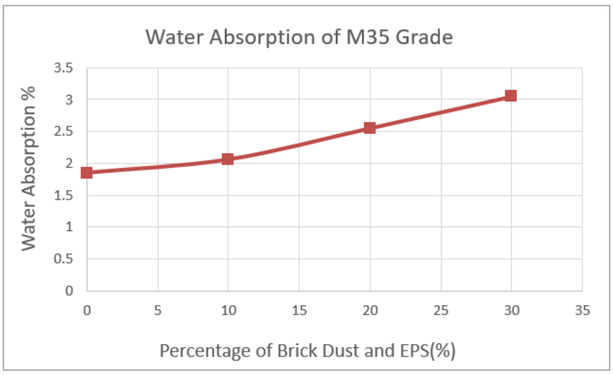

Figure 6: variation of Water Absorption of M35 Grade Concrete containing different percentage of Brick Dust and EPS

3.4 Bulk Density Test

The result obtained from Bulk density test for all concrete paving block sample of different proportion of brick dust and EPS for M30 grade is shown in Table 4. The average bulk density for sample type A,B,C and D were found to be 24.08 KN/m^3, 22.04 KN/m^3, 20.66 KN/m^3 and 19.77 KN/m^3. The value of bulk density obtained were within the range of standard deviations. According to IS 875(Part I)-1987:2006[13] the Bulk density of normal concrete is 24 KN/m^3.The bulk density of sample A is 24.08 KN/m^3, which is greater than the required value.A graph is plotted between Bulk Density and percentage of Brick Dust and EPS as shown in figure 7. Here, the values of bulk density decreased from 0% replacement of brick dust and EPS to 30% replacement. The decrease in bulk density is due to the increase in brick dust and Eps content.

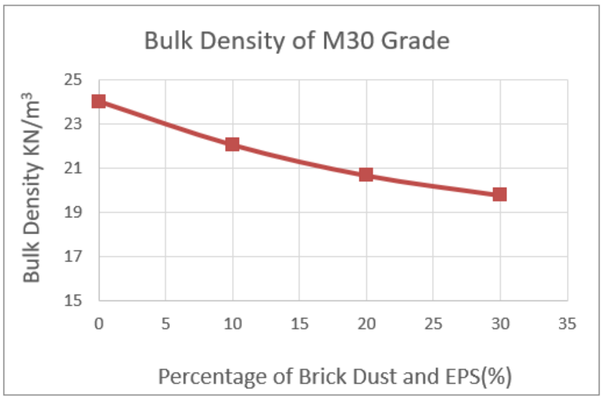

Figure 7: variation of Bulk Density of M30 Grade Concrete containing different percentage of Brick Dust and EPS

Similarly,the average bulk density for sample type E,F,G and H were found to be 24.8 KN/m^3,22.13 KN/m^3,20.78 KN/m^3 and 20.05 KN/m^3 for M35 grade concrete paving blocks as shown in Table 4. The value of bulk density obtained were within the range of standard deviations. According to IS 875(Part I)-1987:2006[13] the Bulk density of normal concrete is 24 KN/m^3.The bulk density of sample E is 24.18 KN/m^3, which is greater than the required value.A graph is plotted between Bulk Density and percentage of Brick Dust and EPS as shown in figure 8. Here, the values of bulk density decreased from 0% replacement of brick dust and EPS to 30% replacement. The decrease in bulk density is due to the increase in brick dust and Eps content.

Table 4: Bulk Density of M30 and M35 blocks

Sample		Sand Replacement by Brick Dust(%)	Coarse Aggregate Replacement by EPS(%)	volumn(m^3)	Dry Weight(kg)		Bulk Density (KN/m^3)		Average Bulk Density (KN/m^3)	
M30	M35				M30	M35	M30	M35	M30	M35
A_1	E_1	0	0	0.0019	4.524	4.524	23.99	23.99	24.08 ±0.11	24.18 ± 0.3
A_2	E_2	0	0	0.0019	4.328	4.628	24.26	24.54		
A_3	E_3	0	0	0.0019	4.526	4.532	24.00	24.03		
B_1	F_1	10	10	0.0019	4.122	4.212	21.85	22.33	22.04 ± 0.285	22.13 ± 0.23
B_2	F_2	10	10	0.0019	4.22	4.186	22.37	22.19		
B_3	F_3	10	10	0.0019	4.132	4.124	21.91	21.86		
C_1	G_1	20	20	0.0019	3.812	3.92	20.21	20.78	20.66 ± 0.07	20.78 ± 0.3
C_2	G_2	20	20	0.0019	3.82	3.862	20.25	20.48		
C_3	G_3	20	20	0.0019	3.792	3.978	20.10	21.09		
D_1	H_1	30	30	0.0019	3.728	3.782	19.77	20.05	19.77 ± 0.08	20.05± 0.053
D_2	H_2	30	30	0.0019	3.712	3.792	19.68	20.10		
D_3	H_3	30	30	0.0019	3.744	3.772	19.85	20.00		

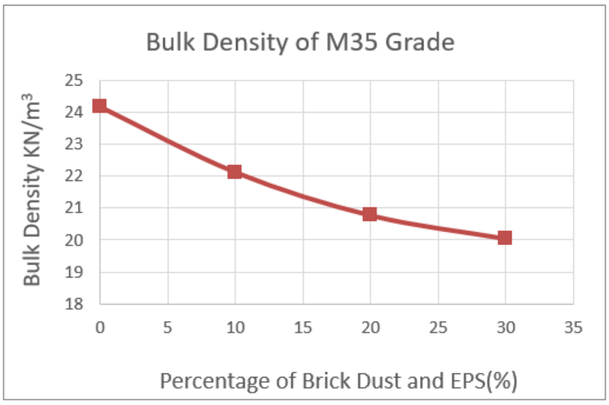

Figure 8: variation of Bulk Density of M35 Grade Concrete containing different percentage of Brick Dust and EPS

3.5 Comparative Analysis

Some of the research were done on concrete brick replacing sand by saw dust, rice husk, brick dust and so on. Similarly, coarse aggregate was replaced by EPS in concrete mix. Pradhan and Maharjan [6] conducted an experiment by partially replacing coarse aggregate by EPS to test the properties of M20 concrete bricks. It was found that with the increase in percentage content of EPS, compressive strength and bulk density decreased. Poon and Chan [14] studied on paving blocks made with recycled concrete aggregate and crushed clay brick. The compressive strength decreased with increase in crushed clay bricks content. Ghimire and Maharjan [7] studied the properties of concrete brick with partial replacement of sand by saw dust and partial replacement of coarse aggregate by expanded polystyrene. The compressive strength decreased with increase in saw dust and EPS percentage. Comparing the compressive strength of resulting M30 and M35 blocks with the past research of Ghimire and Maharjan[7], Pradhan and Maharjan[6],Poon and Chan[14] the obtained curve of compressive strength and bulk density follows the same trend as shown in figure 9.

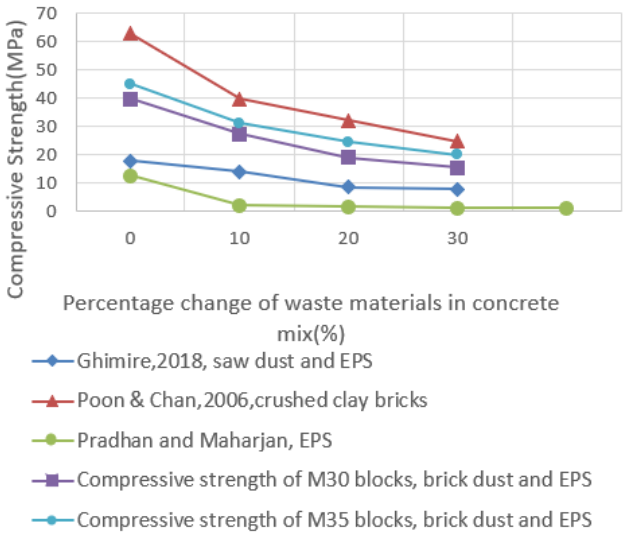

Figure 9: Variation of compressive strength with percentage change of waste material in constituent concrete

4. Conclusion

1. The Compressive strength of M30 concrete paving blocks varied between 39.44 to 15.05 N/mm^2. Similarly,the Compressive strength of M35 concrete paving blocks varied between 44.74 to 19.72 N/mm^2.This showed that with the increase in brick dust and EPS content the compressive strength of paving blocks decrease.
2. The Water Absorption of M30 concrete paving blocks varied between 1.95 to 4.04 %. Similarly,the Water Absorption of M35 concrete paving blocks varied between 1.85 to 3.05 % .This showed that with the increase in brick dust and Eps content the Water absorption of paving blocks increase.
3. The Bulk Density of M30 concrete paving blocks varied between 24.08 to 19.77 kN/m^3. Similarly,the Bulk Density of M35 concrete paving blocks varied between 24.18 to 20.05 kN/m^3. This showed that with the increase in brick dust and Eps content the Bulk Density of paving blocks decrease. Concrete become light weight after the addition of expanded polystyrene.

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