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PRODUCTION OF GREEN INTERLOCKING CONCRETE WALL BLOCKS USING INDUSTRIAL WASTES

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ABSTRACT:

Interlocking concrete wall blocks may vary in different sizes, shapes, and finishes, allowing the design much flexibility. They can easily be incorporated into different architectures with great compatibility. Their versatility allows them to be used for either mere ornamentation or functional application Also, with the interlocking mechanism, the wall remains stable and strong without any reinforcement . Interlocking concrete wall blocks, in general, offer a practical, durable, and cost-effective solution for many different constructions and landscaping need The main objective of this experimentation is to produce green interlocking concrete wall blocks using industrial wastes such as fly ash, waste foundry sand, recycled aggregate.

While preparing the interlocking concrete wall blocks cement is partially replaced by fly ash, natural sand by waste foundry sand and natural coarse aggregate by waste recycled aggregates.

Keywords: Green concrete, interlocking blocks, industrial wastes, sustainability, circular economy, eco- friendly construction.

Introduction:

Carbon dioxide (CO_2) emissions are associated with critical environmental problems such as global warming and climate change .The construction industry is one of the largest culprits when it comes to carbon dioxide emissions. Based on previous research, cement production emits approximately 0.8 tons of CO_2 for every tonne of cement produced; the cement industry alone is expected to emit 164 million tons of CO_2 in 2022
For the last ten years, scientists have studied the feasibility of replacing cement with alternative cementitious materials like fly ash, GGBS, rice husk, and silica fume. Scientists all over the world are still trying to find cement alternatives.

Objectives of the study:

Interlocking concrete wall blocks are the most innovative construction solution providing an efficient and cost-effective method for building strong, robust walls without mortar or adhesives. These blocks feature interlocking qualities, including grooves and tongues, that enable them to be laid together in such a way that it creates a stable unit when stacked. The interlocking blocks allow for this interlocking capability and eliminate traditional mortar, and they are easily installed, and so labor charges as well as the construction period would be considerably less.
The main objective of this experimentation is to produce green interlocking concrete wall blocks using industrial wastes such as fly ash, waste foundry sand, recycled aggregate.While preparing the interlocking concrete wall blocks cement is partially replaced by fly ash, natural sand by waste foundry sand and natural coarse aggregate by waste recycled aggregates.

3. Materials and methodology:

3.1 Cement:

Locally available Ordinary Portland cement of 43 grade was used in this experiment.

3.2 Fine aggregate

Locally available sand confirming to zone I (I.S.–383-2016) with specific gravity 2.6, and water absorption 1% was used.

3.3 Coarse aggregates

Locally available crushed angular gravels 20mm downsize are used, with specific gravity 2.76

3.4 Fly ash

Locally available fly ash in RMC plant was used in the experiment

3.5 Waste foundry sand

Waste foundry sand is a byproduct generated from metal casting processes in foundries. Waste foundry sand was brought from the industrial plants

3.6 Recycled aggregate

Recycled aggregate is material that has been recovered from demolished concrete structures. Recycled aggregate was brought from demolished concrete roads

3.7 Methodology:

The green interlocking concrete wall blocks are prepared by replacing 20% of cement by fly ash, 30% of natural sand by waste foundry sand and natural coarse aggregate are replaced by waste recycled aggregates in varying percentages.
`The wet concrete is tested for its workability through slump, compaction factor, V.B degree and percentage flow
The hardened concrete is tested for its compressive strength, tensile strength, flexural strength, shear strength, impact strength, water absorption and soroptivity.Also the blocks are tested for heat insulation and sound insulation.

4.Experimental results :

This section deals with the experimental results on the production of green concrete interlocking wall blocks produced by using various industrial wastes. In this 20% of cement is replaced by fly ash and 30% natural sand is replaced by waste foundry sand. Also the natural aggregates are replaced by recycle aggregates in various percentages such as 0% ,10% ,20%,30%,40%,50%,60%,70%,80%,90%, 100%

4.1 Workability test result

Following table 1 give the workability test result of concrete produced by using various industrial wastes required for the production of interlocking wall blocks. The results are depicted in the form of graph as shown in figure 1,2 and 3

Table 1 Workability test results

Percentage replacement of natural aggregate by recycled aggregate	Slump (mm)	Compaction factor	Vee Bee degree (sec)
0%	300	0.988	9
10%	280	0.988	17
20%	270	0.987	18
30%	250	0.980	25
40%	250	0.975	26
50%	240	0.970	26
60%	240	0.967	26
70%	230	0.963	30
80%	230	0.957	36

90%	200	0.953	40
100%	200	0.950	46

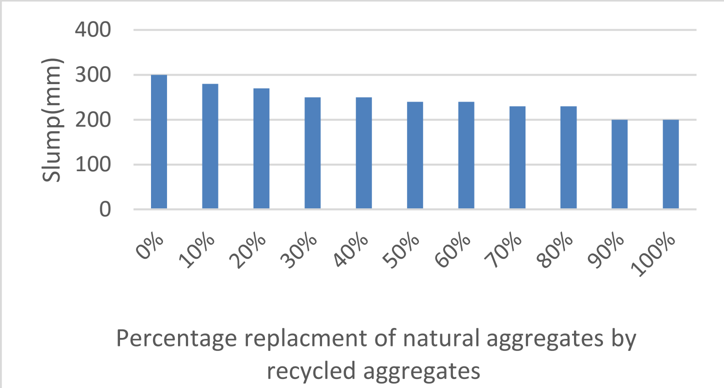

Fig 1 Variation of slump.

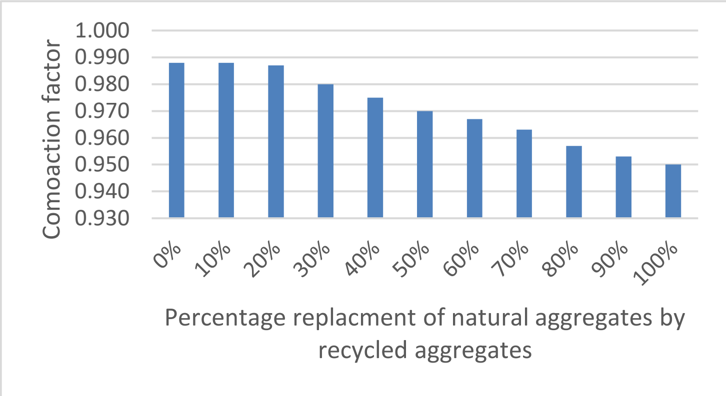

Fig 2 Variation of compaction factor.

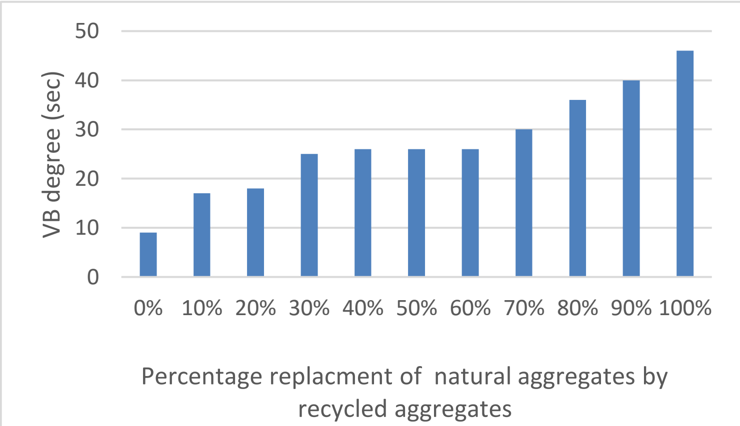

Fig 3 Variation of vee bee degree.

4.2 Water absorption and sorptivity test results

Following table 2 give the water absorption and sorptivity test results of concrete produced by using various industrial wastes required for the production of interlocking wall blocks. The results are depicted in the form of graph as shown in figure 4, 5

Table 2 Water absorption and soropitivity test result

Percentage replacement of natural aggregate by recycled aggregate	Water absorption (%)	Soropitivity (mm/min)
0%	1.26	2.54
10%	1.02	2.30

20%	0.96	2.00
30%	1.15	2.10
40%	1.33	2.22
50%	1.49	2.51
60%	1.60	2.76
70%	1.79	2.82
80%	1.96	2.96
90%	2.05	3.00
100%	2.20	3.10

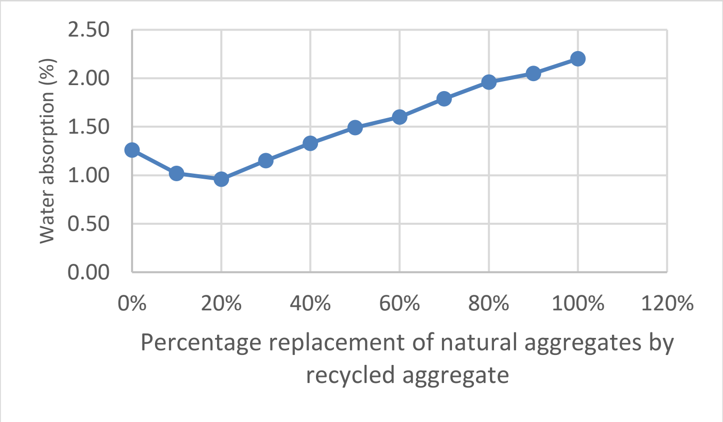

Fig 4 Variation of water absorption

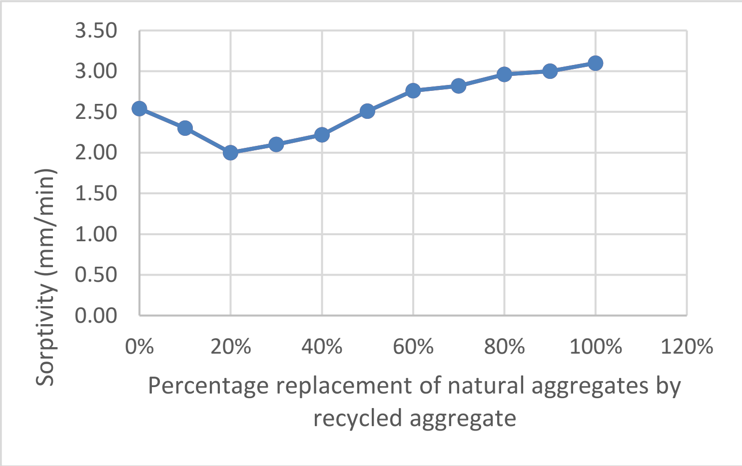

Fig 5 Variation of soroptivity

4.3 Compressive strength test results

Following table 3 give the compressive strength test results of concrete produced by using various industrial wastes required for the production of interlocking wall blocks. The results are depicted in the form of graph as shown in figure 6.

Table 3 Compressive strength test results

Percentage replacement of natural aggregate by recyled aggregate	Weight of the specimen(N)	Density (N/Cum)	Average density(N/Cum)	Failure load (kN)	Compressive strength (MPa)	Average compressive strength (MPa)	Percentage increase or decrease of compressive strength w.r.t refrence mix
0% (Ref. mix)	75.75	22444.44	22388.15	510	22.67	23.04	0.00
	75.58	22394.07		520	23.11		
	75.35	22325.93		525	23.33		

10%	83.22	24657.78	24726.91	520	23.11	23.48	1.93
	83.69	24797.04		535	23.78		
	83.45	24725.93		530	23.56		
20%	76.85	22770.37	22763.46	528	23.47	23.70	0.95
	76.65	22711.11		542	24.09		
	76.98	22808.89		530	23.56		
30%	79.53	23564.44	23559.51	395	17.56	18.15	-23.44
	79.36	23514.07		410	18.22		
	79.65	23600.00		420	18.67		
40%	79.48	23549.63	23547.65	405	18.00	18.07	-0.41
	79.36	23514.07		400	17.78		
	79.58	23579.26		415	18.44		
50%	79.20	23466.67	23487.41	400	17.78	17.90	-0.98
	79.26	23484.44		405	18.00		
	79.35	23511.11		403	17.91		
60%	80.26	23780.74	23863.70	400	17.78	17.85	-0.25
	80.69	23908.15		395	17.56		
	80.67	23902.22		410	18.22		
70%	81.81	24240.00	24221.23	395	17.56	17.67	-1.00
	81.67	24198.52		398	17.69		
	81.76	24225.19		400	17.78		
80%	80.18	23757.04	23807.41	398	17.69	17.63	-0.25
	80.36	23810.37		391	17.38		
	80.51	23854.81		401	17.82		
90%	81.91	24269.63	24246.91	392	17.42	17.54	-0.50
	81.76	24225.19		390	17.33		
	81.83	24245.93		402	17.87		
100%	81.30	24088.89	24113.58	385	17.11	17.36	-1.01
	81.37	24109.63		387	17.20		
	81.48	24142.22		400	17.78		

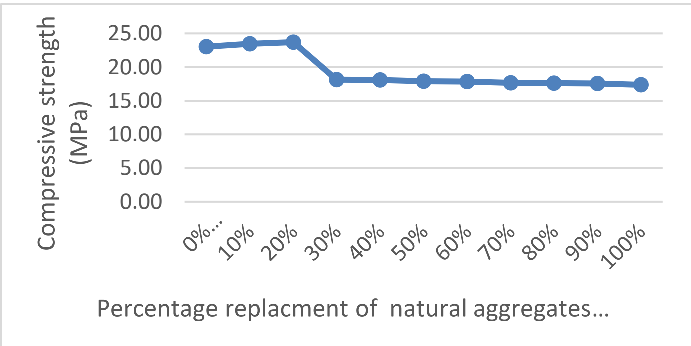

Fig 6 Variation of compressive strength

4.4 – Shear strength test results

Following table 4 give the shear strength test results of concrete produced by using various industrial wastes required for the production of interlocking wall blocks. The results are depicted in the form of graph as shown in figure 7

Table 4 Shear strength test results

Percentage replacement of natural aggregate by recycled aggregate	Failure load (kN)	Shear strength (MPa)	Average shear strength (MPa)	Percentage increase or decrease of shear strength w.r.t reference mix
0% (Ref. mix)	214	12.51	12.96	0.00
	230	13.45		
	221	12.92		
10%	216	12.63	13.18	1.65
	235	13.74		

	225	13.16		
20%	220	12.87	13.74	4.29
	245	14.33		
	240	14.04		
30%	150	8.77	7.99	-41.84
	135	7.89		
	125	7.31		
40%	140	8.19	7.89	-1.22
	130	7.60		
	135	7.89		
50%	138	8.07	7.66	-2.96
	130	7.60		
	125	7.31		
60%	135	7.89	7.47	-2.54
	125	7.31		
	123	7.19		
70%	130	7.60	7.25	-2.87
	122	7.13		
	120	7.02		
80%	125	7.31	7.17	-1.08
	128	7.49		
	115	6.73		
90%	120	7.02	7.02	-2.17
	130	7.60		
	110	6.43		
100%	115	6.73	6.73	-4.17
	120	7.02		
	110	6.43		

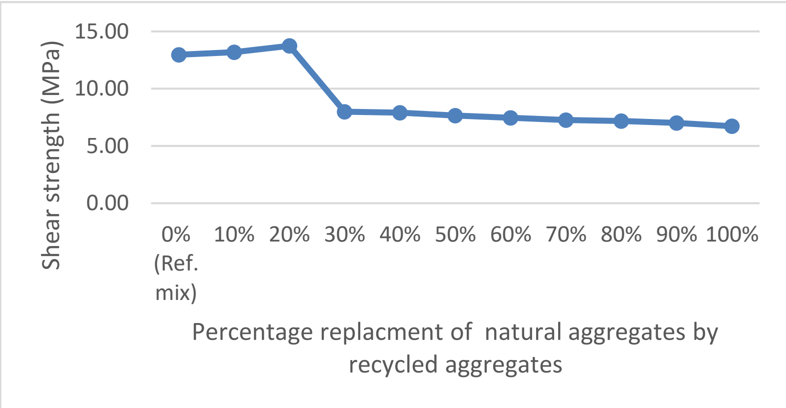

Fig 7 Variation of shear strength

4.5 – Impact strength test results

Following table 5 give the impact strength test results of concrete produced by using various industrial wastes required for the production of interlocking wall blocks . The results are depicted in the form of graph as shown in figure 8 and 9

Table 5 Impact strength test result

Percentage replacement of natural aggregate by recyled aggregate	Number of blows for first crack	Impact strength for first crack (N-m)	Average impact strength for first crack (N-m)	Number of blows for final failure	Impact strength for final failure (N-m)	Average impact strength for final failure (N-m)	Percentage increase or decrease of impact strength for final failure w.r.t reference mix
	32	5.76	7.02	36	6.48	7.38	0

0% (Ref. mix)	37	6.66		38	6.84		
	48	8.64		49	8.82		
10%	34	6.12	7.32	36	6.48	7.56	2.44
	39	7.02		40	7.20		
	49	8.82		50	9.00		
20%	38	6.84	7.86	40	7.20	8.10	7.14
	51	9.18		52	9.36		
	42	7.56		43	7.74		
30%	28	5.04	6.78	29	5.22	6.96	-14.07
	45	8.10		46	8.28		
	40	7.20		41	7.38		
40%	26	4.68	6.36	27	4.86	6.54	-6.03
	42	7.56		43	7.74		
	38	6.84		39	7.02		
50%	37	6.66	6.12	40	7.20	6.48	-0.92
	41	7.38		42	7.56		
	24	4.32		26	4.68		
60%	35	6.30	5.88	36	6.48	6.06	-6.48
	40	7.20		41	7.38		
	23	4.14		24	4.32		
70%	34	6.12	5.52	35	6.30	5.70	-5.94
	20	3.60		21	3.78		
	38	6.84		39	7.02		
80%	33	5.94	5.22	34	6.12	5.40	-5.26
	19	3.42		20	3.60		
	35	6.30		36	6.48		
90%	31	5.58	4.86	32	5.76	5.04	-6.67
	32	5.76		33	5.94		
	18	3.24		19	3.42		
100%	29	5.22	4.44	30	5.40	4.62	-8.33
	30	5.40		31	5.58		
	15	2.70		16	2.88		

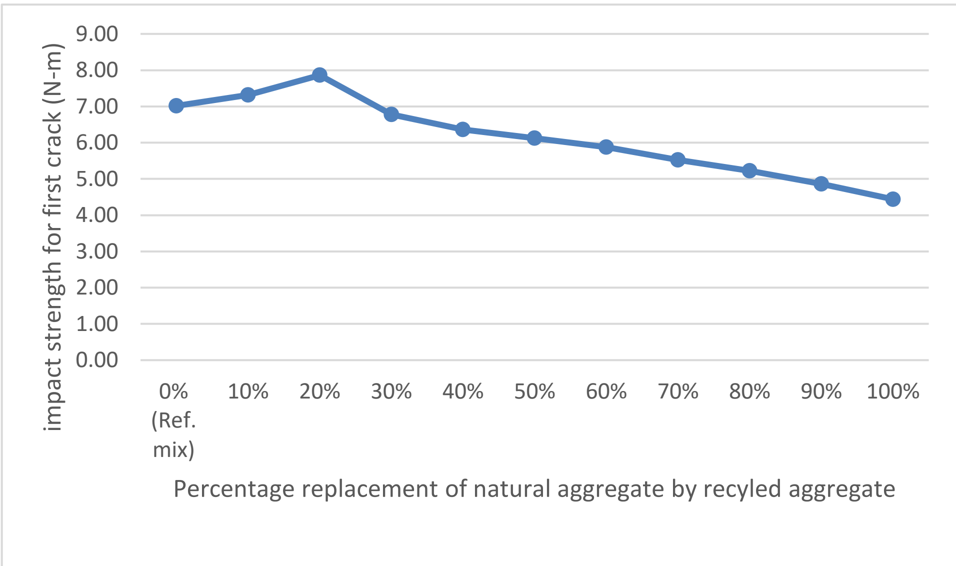

Fig 8 Variation of impact strength for first crack

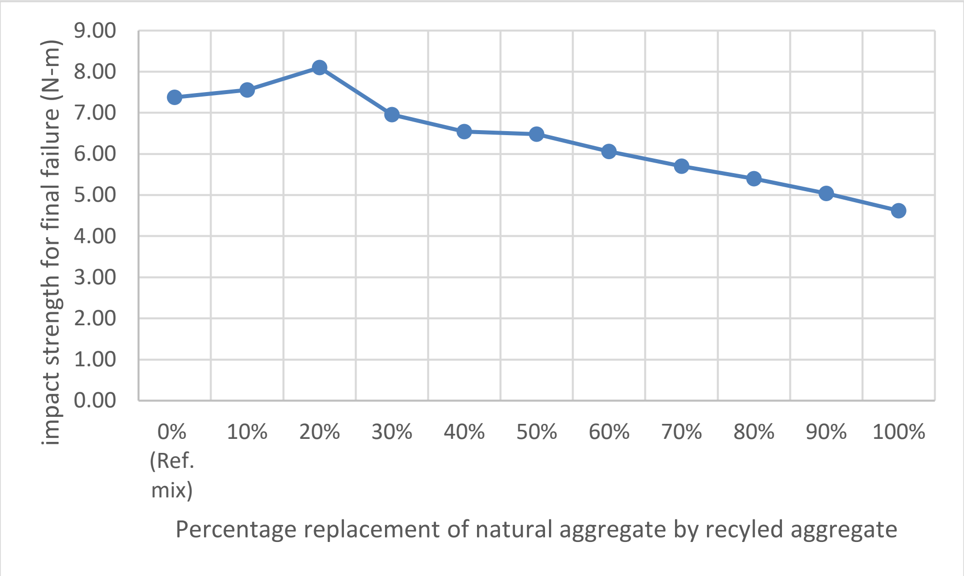

Fig 9 Variation of impact strength for final failure

4.6 – Heat insulation test results

Following table 6 give the heat insulation test results of concrete produced by using various industrial wastes required for the production of interlocking wall blocks. The results are depicted in the form of graph as shown in figure 10.

Table 6 Heat insulation test results

Percentage replacement of natural aggregate by recycled aggregate	Duration of heatinng (min)	Temperature of upper surface (°C)	Temperature of lower surface (°C)	Difference in temperature of lower surface and upper surface (°C)
0%	5	16	55	39
10%	5	11	62	51
20%	5	8	70	62
30%	5	12	69	57
40%	5	12	68	56
50%	5	20	75	55
60%	5	15	70	55
70%	5	12	65	53
80%	5	14	65	51
90%	5	10	60	50
100%	5	14	63	49

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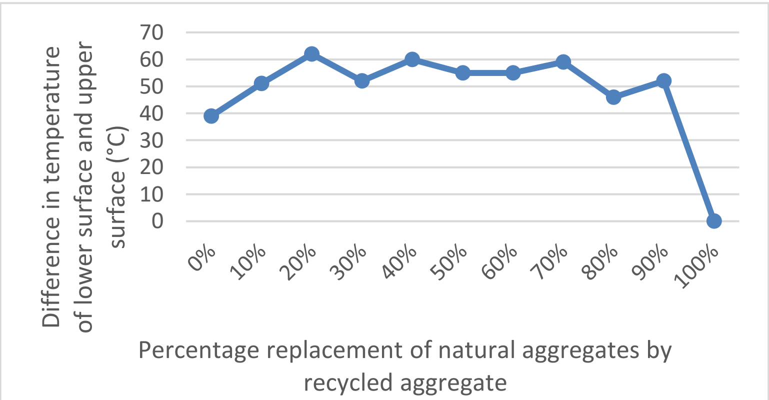

Fig 10 Variation of thermal conductivity

5. Observations and discussions :

The following observations are made based on experimentation conducted.

1. Table 1 gives the workability test results as measured from slump, compaction factor and VB degree. The graphical representation of workability is shown figure 1, 2 and 3. It is observed that the workability of concrete using industrial wastes and by replacing natural aggregates by recycled aggregates goes on decreasing as the percentage replacement of natural aggregates by recycled aggregates goes on increasing.

   This may be due to fact that as the percentage replacement of natural aggregates by recycled aggregates goes on increasing, the adhared cement particle to the recycled aggregates offer lot of friction to the concrete for the flow, thereby reducing workability.

   Thus it can be concluded that the workability in terms of slump, compaction factor and VB degree goes on decreasing as the percentage replacement of natural aggregates by recycled aggregates increases.

2. Table 2 gives the water absorption and sorptivity test results and graphical representation of the same is given in figure 4 and 5. It is observed that the water absorption and sorptivity goes on decreasing up to 20% replacement of natural aggregates by recycled aggregates. After 20% replacement, the water absorption and sorptivity starts increasing. At 20% replacement the water absorption and sorptivity are found to be 0.96% and 2.00mm/min

   This may be due to fact that at 20% replacement of natural aggregates by recycled aggregates, the pore structure may become minimum. Maximum voids will be filled at 20% replacement, there by decreasing the water absorption and sorptivity values.

   Thus it can be concluded that the water absorption and sorptivity value are lower at 20% replacement of natural aggregates by recycled aggregates and water absorption and sorptivity values are found to be 0.96% and 2.00mm/min

3. Table 3 gives the compressive strength test results and graphical representation of the same is given in figure 6.It is observed that the compressive strength goes on increasing up to 20% replacement of natural aggregates by recycled aggregates. After 20% replacement the compressive strength starts decreasing. At 20% replacement the compressive strength is found to be 23.70MPa and percentage increase in compressive strength with respect to reference mix is found to be 0.95 percent.

   This may be due to fact that at 20% replacement of natural aggregates by recycled aggregates, the adhared cement particles may create a strong bond between the cement mixture, there by increasing the compressive strength of concrete required for green interlocking wall blocks.

   Thus it can be concluded that the compressive strength is higher at 20% replacement of natural aggregates by recycled aggregates and its compressive strength is found to be 23.70MPa MPa and it's percentage increase in compressive strength is found to be 0.95 % with respect to reference mix.

4. Table 4 gives the shear strength test results and graphical representation of the same is given in figure 7.It is observed that the shear strength goes on increasing up to 20% replacement of natural aggregates by recycled aggregates. After 20% replacement the shear strength starts decreasing. At 20% replacement the shear strength is found to be 13.74MPa and percentage increase in shear strength with respect to reference mix is found to be 4.29 percent.

   This may be due to fact that at 20% replacement of natural aggregates by recycled aggregates, the adhared cement particles may create a strong bond between the cement mixture, there by increasing the shear strength of concrete required for green interlocking wall blocks.

   Thus it can be concluded that the shear strength is higher at 20% replacement of natural aggregates by recycled aggregates and its shear strength is found to be 13.74MPa and it's percentage increase in shear strength is found to be 4.29 % with respect to reference mix.

5. Table 5 gives the impact strength test results and graphical representation of the same is given in figure 8 and 9.It is observed that the impact strength goes on increasing up to 20% replacement of natural aggregates by recycled aggregates. After 20% replacement the impact strength starts decreasing. At 20% replacement the impact strength is found to be 8.10N-m and percentage increase in impact strength with respect to reference mix is found to be 7.14 percent.

   This may be due to fact that at 20% replacement of natural aggregates by recycled aggregates, the adhared cement particles may create a strong bond between the cement mixture, there by increasing the impact strength of concrete required for green interlocking wall blocks.

   Thus it can be concluded that the impact strength is higher at 20% replacement of natural aggregates by recycled aggregates and its impact strength is found to be 8.10N-m and it's percentage increase in impact strength is found to be 7.14 % with respect to reference mix.

6. Table number 6 gives heat insulation test results and graphical representation of the same is given in figure 10.It is observed that the heat insulation goes on increasing up to 20% replacement of natural aggregates by recycled aggregates. After 20% replacement the heat insulation starts decreasing.

   This may be due to fact that at 20% replacement of natural aggregates by recycle aggregates, the pore structure becomes minimum. After 20% pore structure increases,there by decreasing the heat insulation.

   Thus, it can be concluded that the heat insulation is higher at 20% replacement of natural aggregates by recycled aggregates. After 20% replacement the heat insulation starts decreasing.

6 .Conclusions :

Following conclusions may be drawn from the tests conducted on concrete required for the production of green interlocking wall blocks.

1. The workability in terms of slump, compaction factor and VB degree goes on decreasing as the percentage replacement of natural aggregates by recycled aggregates increases.

2. The water absorption and sorptivity is lower at 20% replacement of natural aggregates by recycled aggregates and its water absorption and sorptivity are found to be 0.96% and 2.00mm/min

3. 3.The compressive strength is higher at 20% replacement of natural aggregates by recycled aggregates and its compressive strength is found to be 23.70MPa and it's percentage increase in compressive strength is found to be 0.95% with respect to reference mix.

4. The shear strength is higher at 20% replacement of natural aggregates by recycled aggregates and its shear strength is found to be 13.74MPa and it's percentage increase in shear strength is found to be 4.29% with respect to reference mix.

5. The impact strength is higher at 20% replacement of natural aggregates by recycled aggregates and its impact strength is found to be 8.10N-m and it's percentage increase in impact strength is found to be 7.14% with respect to reference mix.

6. The heat insulation is higher at 20% replacement of natural aggregates by recycled aggregates. After 20% replacement the heat insulation starts decreasing.

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