ENVIRONMENTAL GREENING THROUGH UTILIZATION OF SAWDUST FOR PRODUCTION OF BRICKS

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Abstract: South Africa and the rest of the world are saddled with challenges of appropriately using the enormous amount of waste that have negative impact on the environment. The investigation of sawdust as a waste material has been conducted in many countries over many years; and received positive attention as partial component for masonry units in building construction. Owing to the availability of sawdust and its inexpensiveness in Pretoria, South Africa, the research sought to investigate the utilization of sawdust for the partial replacement of crusher sand for the production of bricks in order to enhance the greening of the environment. The sawdust used in the research was generated from the laboratory of the Department of Mechanical Engineering, Tshwane University of Technology, Pretoria, South Africa, as a waste of the timber processing. While the source of the crusher sand was Hoicim-Ferro, Weltevredenpark, Pretoria, South Africa; the cement used was CEM IV/B [V] 32,5R. The methodology involved the conduct of gradation analysis on the sawdust and crusher sand used for the production of bricks. Thereafter, sawdust was used as a partial replacement of crusher sand at 1, 3 and 5 percent by volume to produce bricks at a productive site in Malelodi, Pretoria as well as cubes at the laboratory of the Department of Civil Engineering, Tshwane University of Technology. The compressive strengths of the produced bricks were determined at 7 and 28 days in line with the South African standards on masonry units. The compressive strength of the bricks showed a steady increase from the values at 7th day to that at the 28th day. Though, it was observed that there was a reduction in compressive strength with the increase of sawdust by volume. However, the compressive strength values of the bricks produced on site was less than the minimum specified in the standard; while those produced at the laboratory had satisfactory strength values that satisfied the minimum standards. The results may be due to better quality control practices in the laboratory. Therefore, the quality of the bricks produced on site may be improved. The research showed the potential of sawdust being used as a partial replacement for crusher sand in the production of bricks. Thus heaps of sawdust that would have constituted environmental nuisance could be gainfully utilized by providing solution for the waste management problems of sawdust waste and also contribution towards maximizing the strength of the bricks utilized in the building industry.

Keywords: Environmental greening; Compressive strength; Bricks, Sawdust; and Crusher sand.

INTRODUCTION

Developing countries are faced with the challenge of adequate provision of shelter for the populace. Therefore, there is need to develop strategies that would encourage the use of low cost building materials. Waste materials are generated from industrial and agricultural activities. These can be used as substitutes for conventional materials by recycling them into new building materials [1]. The increase in the popularity of using environmentally friendly, low-cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting the environment as well as maintaining the material requirements in the standards [2]. Sawdust as waste material has received some attention as a lightweight concrete building construction for a number of years and has been investigated in many countries. Since sawdust is available in abundance and is relatively inexpensive, attempts have been made to investigate the suitability of the material for a possible use in building construction [3].

Subsequent upon the assessment of masonry units in order to enhance the indigenous production capacity in Mamelodi East in a previous study, the present research sought to utilize sawdust, a waste material in the production of bricks at one of the sites used for the production of bricks in Mamelodi, South Africa. In addition, cubes of bricks using sawdust as partial replacement of crusher sand at 1, 3 and 5 percent were produced at the laboratory of the Department of Civil Engineering, Tshwane University of Technology, Pretoria. The research ensured, in the long run, effective collaboration and extension services and knowledge sharing between research institutions and industry, thereby enhancing the greening of the environment as well as improving the quality of building materials through sustainable research and development.

MATERIALS AND METHODS

The research involved production of bricks in a selected site of the township that dealt with brick production using two standard mixes peculiar to the producer; and other mix proportions with 1, 3 and 5 percentages of sawdust by volume as replacement for crusher sand used in the production unit. Cubes of bricks using the same materials and sawdust at the same percentage replacement were produced at the laboratory of the Department of Civil Engineering, Tshwane University of Technology, Pretoria. The methodology provided appropriate basis for informed decisions on viable extension of research based knowledge transfer to producers of bricks in addition to greening the environment.

Sample collection

The research ensured that all the materials used were the same as that used at the selected site in Mamelodi. The sawdust was collected from the laboratory of the Department of Mechanical Engineering, Tshwane University of Technology. The other materials used and sampled consisted of: (a) crusher sand whose source was at Hoicim-Ferro, Weltevredenpark, Pretoria, South Africa; (b) cement (CEM IV/B [V] 32,5R. and Fly ash percentage of 40 to 45%); (c) an admixture which was a cement accelerator and hardener diluted 1:9 with clean water capable of facilitating the rapid increase in setting time and strength of bricks made with the type of cement used; and (d) water, which in line with [4], was found to be clean and acceptably free from impurities that may impair the strength or durability (or both) of the bricks.

Production units

The selected site and the laboratory of the Department of Civil Engineering were the scheduled locations for the production of the bricks and cubes of bricks respectively using the prescribed percentages of replacement of sawdust for the crusher sand. The research also ensured adequate compliance with the existing quality control practices in both locations of experimental production.

Laboratory tests

The tests were conducted at the laboratories of the Department of Civil Engineering and SOILLAB (PTY) Ltd located in Lynnwood Ridge, Pretoria. The tests included sieve analysis of the sawdust and crusher sand in line with [5]; and compressive strength on the bricks and cubes of bricks at 7 and 28 days. The results were then compared with the specified values in the standard.

Preparation of bricks in Mamelodi

Mix proportions were used for the production of bricks based on the one used by the producer. The research mixes included: (a) Standard Mix 1; (b) Standard Mix 2; (c) Mix with 1% (by volume) of Sawdust; (d) Mix with 3% (by volume) of Sawdust; and (e) Mix with 5% (by volume) of Sawdust.

A total of 20 bricks were manufactured in the site as shown in Table 1 (a) to (e).

Compressive tests

Capping

The capping of the samples preparatory to the test was carried out according to [6] at the laboratory of the Department of Civil Engineering of the institution hosting the research.

Cubes manufactured in laboratory of the Department of Civil Engineering

According to [7], three cubes were needed for each test and required to be tested at 7 and 28 days, therefore six cubes were prepared for each mix.

Table 1: Mix design

(a) Standard Mix (cm) 1 (5 bricks)

Material	Shovels	Litres [L]	Weight [kg]	Volume [m^3]	Percentage [%]
Cement	1	2,4	2.4	0.0024	9
Crusher Sand	10	24	36.65	0.024	86
Hardener	-	0.5		0.0005	2
Water	-	1.1	1.1	0.0011	4
Tot		28		0.028	100
W/C	0.46				

(b) Standard Mix 2 (4 bricks)

Material	Shovels	Litres [L]	Weight [kg]	Volume [m^3]	Percentage [%]
Cement 32,5R	1	2.4	2.4	0.0024	8
Crusher Sand	10	24	36.65	0.024	84
Hardener	-	0.5		0.0005	2
Water	-	1.7	1.7	0.0017	6
Tot		28.6		0.028	100
W/C	0.71				

(c) Mix with 1% of Sawdust (5 bricks)

Material	Shovels	Litres [L]	Weight [kg]	Volume [m^3]	Percentage [%]
Cement	1	2.4	2.4	0.0024	8
Crusher Sand	9.88	23.712	36.21	0.02371	83
Hardener	-	0.5		0.0005	2
Water	-	1.7	1.7	0.0017	6
Sawdust	0.1		0.055	0.00024	1
Tot		28		0.028	100
W/C	0.79				

(d) Mix with 3% of Sawdust (6 bricks)

Material	Shovels	Litres [L]	Weight [kg]	Volume [m^3]	Percentage [%]
Cement	1	2.4	2.4	0.0024	8
Crusher Sand	9.6	23.097	35.27	0.02309	77
Hardener	-	0.45		0.00045	1
Water	-	3.2	3.2	0.0032	11
Sawdust	0.3		0.165	0.00072	3
Tot		29.147		0.02914	100
W/C	1.33				

(e) Mix with 5% of Sawdust (5 bricks)

Material	Shovels	Litres [L]	Weight [kg]	Volume [m^3]	Percentage [%]
Cement	1	2.4	2.4	0.0024	8
Crusher Sand	9.3	22.39	34.19	0.02239	70
Hardener	-	0.45		0.00045	1
Water	-	5.3	5.3	0.0053	16
Sawdust	0.5		0.275	0.0012	5
Tot		30.54		0.03054	100
W/C	2.21				

Table 2: Mix proportions of cubes of bricks

(a) Standard Mix 2

4 CUBES	L	kg	Vol [m^3]	%
water	0.9		0.0009	13.8
hardener	0.1		0.0001	1.5
cement		0.5	0.0005	7.7
sand		7.69	0.0050	77
TOT			0.0065	100
w/c	1.8			

(b) Standard Mix 2 (plus cement)

2 CUBES	L	kg	Vol [m^3]	%
water	0.5		0.0005	14
hardener	0.05		0.00005	2
cement		0,6	0.0006	17
sand		3.5	0.0022	67
TOT			0.0034	100
w/c	0.84			

(c) Mix with 1% (by volume) of sawdust

6 CUBES	L	kg	Vol [m^3]	%
water	1.39		0.0013	13
hardener	0.15		0.00015	2
cement		1.15	0.00115	11
sand		11.3	0.0074	73
sawdust		0.03	0.0001	1
TOT			0.0101	100
w/c	1.22			

(d) Mix with 3% (by volume) of sawdust

6 CUBES	L	kg	Vol [m^3]	%
water	1.4		0.00140	14
hardener	0.15		0.00015	2
cement		1.15	0.00115	11
sand		10.56	0.00692	70
sawdust		0.07	0.00031	3
TOT			0.00997	100
w/c	1.21			

(e) Mix with 5% (by volume) of sawdust

6 CUBES	L	kg	Vol	%
water	1.6		0.0016	17
hardener	0.15		0.00015	2
cement		1.15	0.00115	11
sand		9.57	0.00627	65
sawdust		0.12	0.00052	5
TOT			0.00974	100
w/c	1.39			

Table 3: Sieve analysis of sawdust

SIEVE SIZE [µm]	Mass [g]	Cum Mass	Retained Cum % of Total Mass	Cumulative % passing sieve
4750	1,5	1,5	1	99
2360	5,6	7,1	7	93
1180	3,8	10,9	11	89
600	10,5	21,4	21	79
300	54	75,4	73	27
150	22	97,4	95	5
75	4,5	101,9	99	1
0	0,8	102,7	100	0
TOT	102,7			

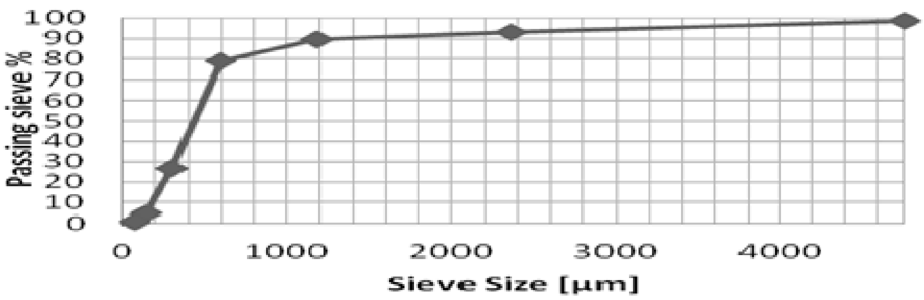

Figure 1: Gradation of sawdust

Table 4: Sieve analysis of crusher sand

SIEVE SIZE [µm]	Mass [g]	Cum Mass	Retained Cum % of Total Mass	Cumulative % passing sieve
4750	17,4	17,4	4	99
2360	119,2	136,6	28	74
1180	124,5	261,1	53	48
600	68,5	329,6	67	33
300	49,7	379,3	78	23
150	41,1	420,4	86	14
75	33,2	453,6	93	7
0	35	488,6	100	0
TOT	488,6			

Curing

According to [7], each mould was covered with impervious sheet and stored in a place free from vibration for 24 hours under a relative humidity of 90% and temperature of 22-25°C. Subsequently all the sides of the moulds were gently removed and the specimens were put into water under a temperature of 24°C.

Mixes

The mix proportions for the cubes of bricks are laid out in Table 2 (a) to (e).

Analytical and presentation technique

Calculations were carried out using established equations as specified in the relevant South African standards on brick on masonry.The research was reported through the use of charts, plates and figures with the conduct of basic analysis using [8].

RESULTS AND DISCUSSION

Sieve analysis of sawdust

The sieve analysis and pictorial representation of the gradation of the material that unique advantages such as lightness of weight, saw ability, nail ability and low thermal conductivity, according to [9] are shown in Table 3 and Figure 1..

Crusher Sand

The table that showed the sieve analysis and the graphical format of the gradation of the crusher sand are shown in Table 4 and Figure 2 respectively.

Bricks produced at site

Owing to the difference between the calculated and practical water requirement for the mix proportions, two standard mix proportions were prepared: the latter was used as a basis for the adjustment for the percentage addition of sawdust at 1, 3 and 5%. The machine used for the production of bricks in Mamelodi had a vibration feature; and usually managed by two trained work men. After the production, the bricks were left on the site for curing before being collected testing. However, at the moment of the collection, some bricks were so weak and damaged. Out of the 25 bricks produced, 7 were damaged. The main cause may be attributed to inadequate curing at the site and the rainfall that distorted the natural cycle of curing. It may also be necessary for provision of a form of covering for the fresh bricks during the natural process of curing. The qualities and proportioning of the materials may need to be enhanced

Brick cubes produced at the laboratory

Two control mix proportions were prepared for the production of the cubes of bricks. While the mix was similar to the mix proportion used for the bricks produced on the site, the other had a different mix proportion in order to determine the appropriate mix that will satisfy the minimum specification of compressive strength in line with the standard for a useful practical site application.

Compressive tests

Capping

According to [6], the capping operation was carried out at the laboratory of the institution.

Compressive Strength at 7 days

After 7 days, the compressive strength obtained according to [6], are shown in Table 5 (a) to (d).

Compressive strength at 28 days

The compressive strength of the bricks produced on site after 28 dats are shown in Table 6 (a) to (e). It was observed that there is a gradual reduction in the values of the compressive strength as the proportion of sawdust increased. On the other hand, the compressive strength at 28 days was greater than that obtained at 7 days in Table 5. However, the values were lower than the specified minimum values in the standard. It is worthy to note that there existed slight increase in the compressive strength of the bricks sampled before the commenncement of the research to that obtained during the research as shown in Table 7 (a) and (b). The latter showed that adequate colloraboration may bring about enhanced quality of housing units consequent upon use of materials that meet minimum specified standard.

Figures 4 to 7 showed the graphical representation of the compressive strength of the sample as ordinate to the percentage of sawdust added; water to cement ratio and age of the brick as abscissa respectively.

There was an increase of the ratio of water to cement as the percentage of sawdust increased as shown in Figures 5 and 6. It is clear from the results that sawdust absorbed water as the its percentage increased in the mix proportions.

Compressive tests for the cubes

The test procedure used for the cubes followed the procedures of [10].

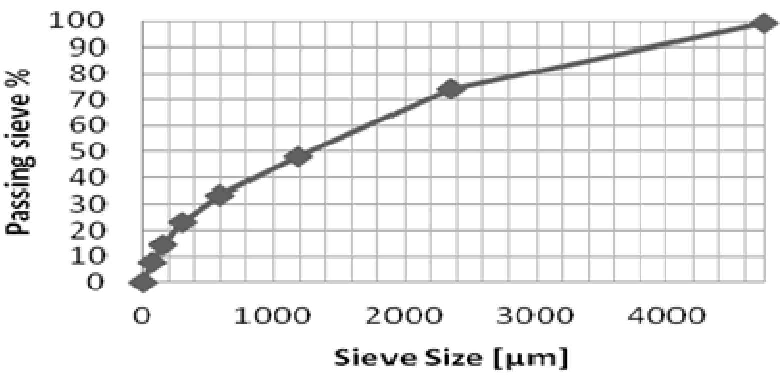

Figure 2: Gradation of crusher sand

Table 5: Compressive strength of produced bricks at 7 days

(a) Standard Mix 1

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm 1.4	290	150	90	43500	6.344	24	0.55
cm 1.5	290	150	90	43500	6.896	26	0.60

(b) Standard Mix 2

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm. 1	290	150	90	43500	7.300	29	0.67

(c) Mix with 1% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
1.1	290	150	90	43500	6.348	9	0.21
1.2	290	150	90	43500	7.271	13	0.30
1.4	290	150	90	43500	7.428	20	0.46

(d) Mix with 5% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
5.1	290	150	90	43500	6.295	3	0.07

Table 6: Compressive strength of produced bricks at 28 days

(a) Standard Mix 1

N°	Length [mm]	Width[mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm 1.1	290	150	90	43500	6.933	32	0.74
cm 1.2	290	150	90	43500	6.683	31	0.71
cm 1.3	290	150	90	43500	6.646	32	0.74

(b) Standard Mix 2

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm 2.2	290	150	90	43500	7.107	35	0.80
cm 2.3	290	150	90	43500	7.264	38	0.87
cm 2.4	290	150	90	43500	7.202	39	0.90

(c) Mix with 1% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
1.3	290	150	90	43500	6.426	31	0.71
1.5	290	150	90	43500	6.107	27	0.62
1.6	290	150	90	43500	7.27	33	0.76

(d) Mix with 3% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
3.1	290	150	90	43500	5.850	10	0.23

(e) Mix with 5% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
5.3	290	150	90	43500	6.549	9	0.21

Table 7: Compressive strength of producer's bricks at 28 days

(a) Bricks from the producer during research

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
P1	290	150	90	43500	7.760	66	1.52
P2	290	150	90	43500	7.852	74	1.70
P3	290	150	90	43500	7.979	84	1.93

(b) Bricks from the producer before research

	Dimension							Crushing Strength
No of sample	Length [mm]	Width - Average [mm]	Height [mm]	Area L x W [mm^2]	Volume [mm^3]	Mass [kg]	Failure Load [KN]	Compressive Strength [MPa]
3.1	292.97	154.10	103.00	45146.6770	4650107.731	7.617	66.55	1.5
3.2	293.80	147.44	96.78	43317.8720	4192303.652	7.290	52.59	1.2
3.3	296.15	148.45	98.10	43963.4675	4312816.162	7.370	76.16	1.7

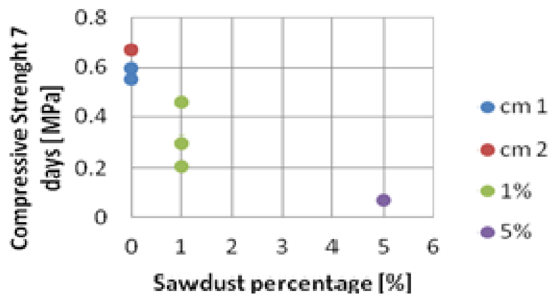

Figure 3: Compressive strength / sawdust percentage at 7 days

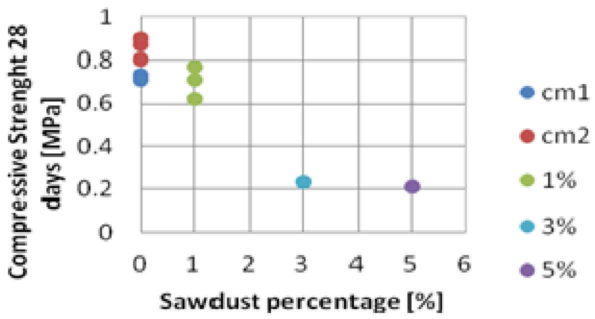

Figure 4: Compressive strength / sawdust percentage at 28 days

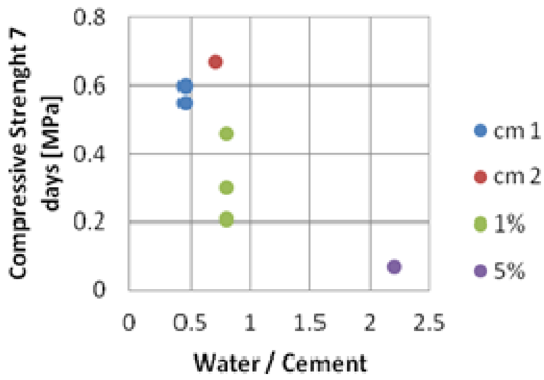

Figure 5: Compressive strength / w/c at 7 days

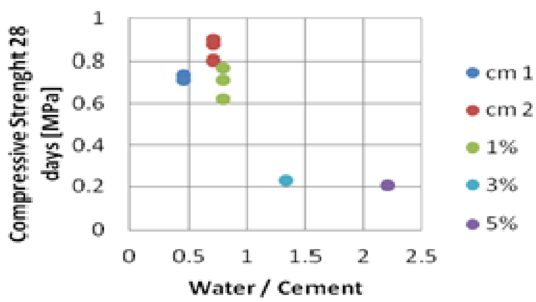

Figure 6: Compressive strength / w/c at 28 days

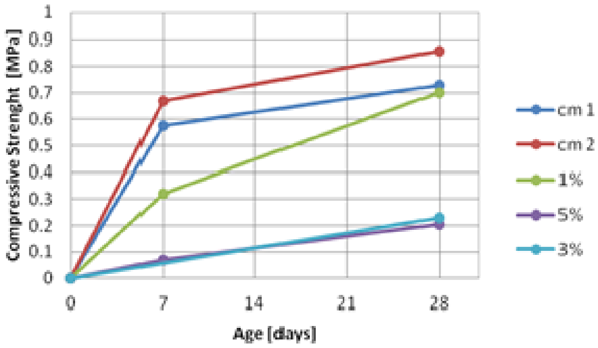

Figure 7: Compressive strength (average) / Age

Table 8: Compressive strength of cubes at 7 days

(a) Standard Mix 2

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm 1.1	100	100	100	10000	2,264	25	2,5
cm 1.2	100	100	100	10000	2,187	26	2,6

(b) Mix with 1% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
1.1	100	100	100	10000	2,214	27	2,7
1.2	100	100	100	10000	2,199	26	2,6
1.3	100	100	100	10000	2,203	29	2,9

(c) Mix with 3% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
3.1	100	100	100	10000	2,177	23	2,3
3.2	100	100	100	10000	2,166	24	2,4
3.3	100	100	100	10000	2,179	23	2,3

(d) Mix with 5% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
5.1	100	100	100	10000	2,106	15	1,5
5.2	100	100	100	10000	2,11	15	1,5
5.3	100	100	100	10000	2,108	16	1,6

Table 9: Compressive strength of cubes at 28 days

(a) Standard Mix 2

N°	Length[mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm 1.3	100	100	100	10000	2,243	37	3,7
cm 1.4	100	100	100	10000	2,250	40	4

(b) Standard Mix 2 (plus)

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
cm p.1	100	100	100	10000	2,235	224	22,4
cm p.2	100	100	100	10000	2,274	176	17,6

(c) Mix with 1% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
1.4	100	100	100	10000	2,222	61	6,1
1.5	100	100	100	10000	2,207	62	6,2
1.6	100	100	100	10000	2,218	60	6

(d) Mix with 3% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
3.4	100	100	100	10000	2,228	55	5,5
3.5	100	100	100	10000	2,206	57	5,7
3.6	100	100	100	10000	2,218	60	6

(e) Mix with 5% (by volume) of sawdust

N°	Length [mm]	Width [mm]	Height [mm]	Area L x W [mm^2]	Mass [kg]	Failure Load [KN]	Compressive Strength [Mpa]
5.4	100	100	100	10000	2,150	42	4,2
5.5	100	100	100	10000	2,351	43	4,3
5.6	100	100	100	10000	2,112	31	3,1

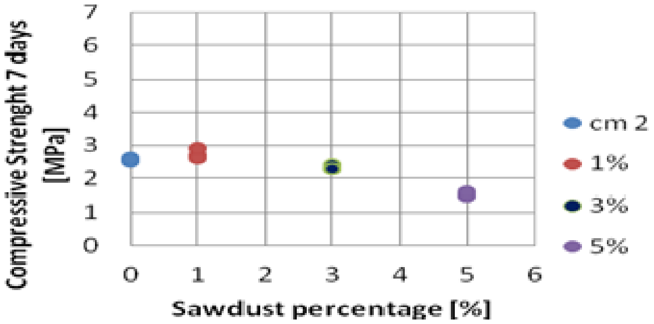

Figure 8: Compressive strength / sawdust percentage at 7

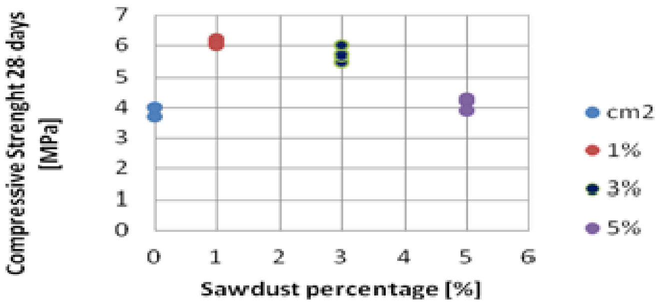

Figure 9: Compressive strength / sawdust percentage at 28

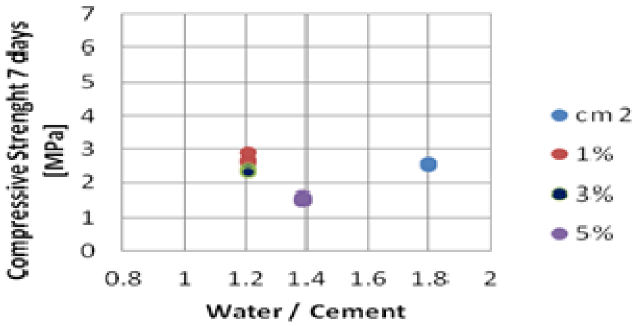

Figure 10: Compressive strength / w/c at 7 days

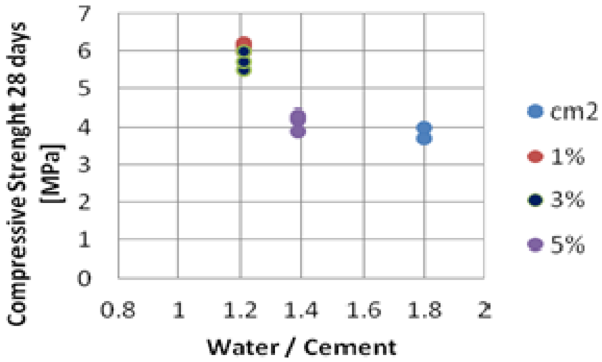

Figure 11: Compressive strength / w/c at 28 days

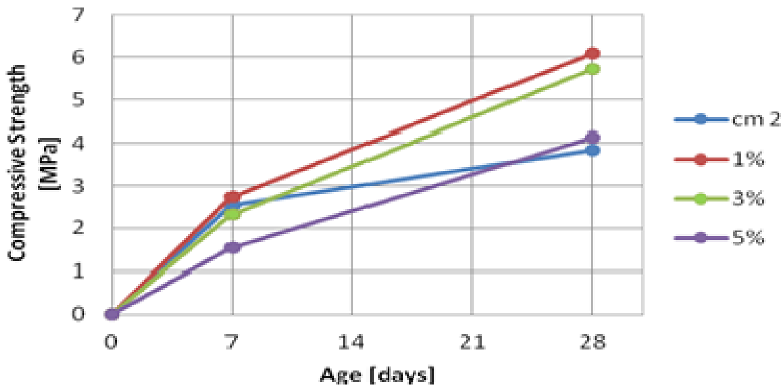

Figure 12: Compressive strength (average) / Age

Compressive strengths at 7 days

Table 8 showed the compressive strength of the cubes of bricks at 7 days. The strength increased with reduction in the percentage of sawdust as shown in Table 8 (a) to (d) and Figure 8.

Compressive strength at 28 days

Table 9 (a) to (e) gave an outlay of compressive strength of the cubes of bricks at 28 days. Also, Figure 9 showed its graphical representation. As the percentage of sawdust in the mix proportions increased, there was a decrease in the compressive strength of the cubes.

CONCLUSIONS

The research demonstrated the possibility of using sawdust as partial replacement for crusher sand for the production of bricks: thereby resulting in environmental greening. It also showed that appropriate collaboration between research and practice may enhance quality of building materials prerequisite to viable extension service. Though the results obtained from the samples produced at selected site in the township of Mamelodi, Pretoria showed lower compressive strength than the values in the specified standard, the slight increase in the strength of the bricks produced on the site during the research reflected the willingness of the producer to adapt meaningful knowledge to enhance productivity and involve in research collaboration at the use of relevant waste such as sawdust.

The results obtained from the compressive strength test of bricks and cubes have been rather conflicting. The difference in the results may be due to peculiarities of the production on site such as: (a) The additional of water to improve the workability of the mix; resulted in changed percentages calculated for each mix design and increased the ratio of water to cement. (b) The duration and quality of vibration of the machine depended on the proficiency of workers. (c) The curing of the bricks depended on weather conditions. (d) The quality of the crusher sand and the cement that had high percentage of fly ash. (e) The quality of capping, which depended mostly on the cement used.

The results obtained from compressive strength test on the cubes were more satisfactory possibly due to more controlled mixing and curing;, and through a mix design that included a slight increase in the percentage of cement. The change was made following the discovery that the amount calculated for 6 cubes starting from those used for bricks were not sufficient due to the greater compactness of the cubes. The latter may be responsible for low values of compressive strength of the second controlled mix at 7 and 28 days, than those obtained from cubes with different percentages of sawdust. Such a result ought not to have been obtained if the mix design were calculated directly for the cubes, in line with [3].

The research has clearly shown a need for a follow up study to ensure that sawdust is beneficially used by the producers of bricks through ensuring that adequate models are developed to mitigate the challenges identified during the study in order to provide housing for the needy in the township and enhance environmental friendliness..

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