Pretreatment of Sawdust for Producing Sawdust Concrete

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ABSTRACT

Sawdust concrete has some shortcomings due to the harmful effects of some organic soluble components existing in the sawdust which affects setting and strength of sawdust concrete. Also, volume changes of sawdust as an aggregate due to variation of moisture content, cause large volume changes in the sawdust concrete. In this work, sawdust was treated before using as an aggregate for making sawdust concrete. The treatment included boiling the sawdust in water containing hydrated lime in order to dissolve all soluble organic components. To reduce water absorption of sawdust, it was dried and treated with waterproofing material. Two types of waterproofing materials were used (cutback asphalt and classic varnish). The properties of sawdust concrete were highly improved using pretreated sawdust. The increase of compressive strength was up to 50% for moderate sawdust ratios. Flexural strength is also increased, water absorption and thermal conductivity were highly reduced, while the basic advantages of sawdust concrete such as lightness of weight, sawability and nailability were not affected.

Keywords: pretreatment, sawdust, concrete, lightweight, lime, cutback, asphalt, varnish.

المعالجة المسبقة للنشارة في انتاج خرسانة نشارة الخشب

الخلاصة

خرسانة نشارة الخشب لها بعض السلبيات بسبب احتواء النشارة على بعض المواد الضارة ذات الطبيعة العضوية و القابلة للذوبان في الماء والتي تؤثر على تصلب و مقاومة خرسانة نشارة الخشب. كما ان التغيرات الحجمية للنشارة الناجمة عن تغير محتوى الرطوبة فيها تسبب تغيرات حجمية في الخرسانة التي تحتوي على هذه النشارة. في هذا البحث تمت معالجة نشارة الخشب قبل استخدامها كركام في الخرسانة. تضمنت عملية المعالجة غلي النشارة في ماء يحتوي على الجير المطفأ لغرض اذابة و التخلص من كل المواد الضارة الموجودة في النشارة. ولغرض تقليل امتصاص النشارة للماء, تمت معالجة النشارة بعد تجفيفها بمواد مانعة للرطوبة. تم استخدام نوعين من المواد المانعة للرطوبة وهما الزفت القيري و الورنيش التقليدي. و من خلال البحث وجد ان خواص خرسانة نشارة الخشب تحسنت بشكل كبير باستخدام نشارة معالجة حيث ارتفعت مقاومة

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الانضـغاط بحـدود ٥٠% بخلـط نسـب متوسـطة مـن النشـارة. كـذلك فـان نسـبة امتصـاص المـاء والتغيرات الحجمية قلت بشكل ملحوظ, بينمـا لـم تتـأثر الايجابيـات و الميزات الاساسية لخرسـانة نشارة الخشب - كخفة الوزن و امكانية قصها بالمنشار و دق المسامير فيها- بالمعالجة.

INTRODUCTION

Sawdust has been used in concrete for at least 40 years, but not widely. Although seriously limited by its low compressive strength, sawdust concrete can be made to perform well in certain floor and wall applications. Dry sawdust concrete weighs only 30% as much as normal weight concrete, and its insulating properties approximate those of wood [1].

Sawdust concrete consists of Portland cement, sand and sawdust, with water to give a slump of 25-50 mm. Sawdust concrete is also called nailing concrete because nails and screws can be driven into which and are firmly held. Also, it can be sawed and drilled as wood. With proper cement to sawdust ratios, it is not flammable. Therefore, it can be used for manufacturing precast units for use in certain floor and wall applications. However, due to the organic nature of sawdust, and the presence of harmful soluble carbohydrates, tannins, waxes and resins in wood, hydration of cement is affected [2,3]. The main inhibitors of cement hydration are wood fiber soluble sugars and part of hemicellulose, which under certain conditions can be resolved into sugars [2, 3]. Sugars in concentrations as low as 0.03 – 0.15% in cement retard the setting time and affect strength of the cement [3]. It has been found that Alkali medium dissolves much more (about 5-10 times) wood's extractives than water [2]. Under the influence of Alkali medium hemicellulose disintegrates to the soluble sugars[4]. It has also been found that along with sugars, starches and tannins can inhibit cement setting [3,5,6,7]. Therefore, pretreating sawdust by soaking in water and washing it without addition of Alkali material will not extract all the harmful materials, which will be extracted lately in sawdust concrete by the Alkali medium of cement paste. Concentrations of soluble wood materials in extract depends on extraction time and temperature (2). The longer extraction time and the higher temperature afford to higher concentration of soluble materials. In this work, sawdust was pretreated by boiling it for an hour in water containing hydrated lime.

Because of its very large moisture movement, sawdust concrete is not recommended for use where water accumulates or where water is constantly present[7]. To minimize water absorption of sawdust and reduce the adverse effects on properties of the resulting concrete, sawdust was also pretreated with waterproofing materials. The aim of the present work was to study the properties of sawdust concrete made with pretreated sawdust and comparing these properties with concrete made with untreated sawdust.

MATERIALS AND METHODS

The materials used in this investigation were ordinary Portland cement, river sand of gradation M according to BS EN 12620 and pine sawdust passing 6.3mm sieve. Pretreatment of sawdust consisted of two phases. Phase 1 was done to eliminate or reduce the retarding effect of the extractable substances in sawdust on setting and hardening of concrete. This phase was done by boiling the sawdust in water containing 20% hydrated lime for an hour. Another treatment used by other researchers [7] was to boil in water to which ferrous sulphate has been added. The sawdust was then washed from residues of extracts and lime by alternate soaking and removing from water. The sawdust was then dried. The calculated amount of extracted materials was 8.6% of wood weight.

Phase 2 was done to reduce moisture movement and prevent sawdust rotting by treating the sawdust with waterproofing materials. Two types of waterproofing materials were used which are medium curing cutback asphalt type MC-70 and classic varnish. Each of the two waterproofing materials was added with a ratio of 25% of dry sawdust weight, which is intended to replace the extracted soluble substances and coating the sawdust fibers without changing its unit weight a lot. Waterproofing materials were diluted with Kerosene before addition to dry sawdust which is thoroughly mixed and let to dry again under sun. Fig.(1) shows a close picture taken for treated and untreated sawdust fibers.

Figure(1): Close picture taken for sawdust fibers. (A) Untreated sawdust (Group1). (B) Washed sawdust (Group2). (C) Sawdust washed and treated with cutback asphalt (Group3). (D) sawdust washed and treated with classic varnish (Group4).

Cement, sand and sawdust were mixed thoroughly in dry condition, cement/sand ratio by weight was 1:1 in all mixes. The sawdust ratio was 0, 5, 10, 15, 20, 25, 30 and 35% by weight of cement. Water was added to produce a mix that can be finished satisfactorily under vigorous tamping and troweling. As it is believed that too much or too little water will impair the strength of concrete, the mix should never be wet enough to compact itself after placement [8]. The best mix will have the consistency of moist earth and give a slump of 25 to 50mm[5]. Therefore, water/cement ratio varied between 0.4 and 0.7 depending on sawdust ratio and whether the sawdust is treated or not. The fresh concrete mixes were molded in 100x100x100mm steel cubes for compressive strength, unit weight, and water absorption tests. Specimen preparation was according to ASTM C192 specifications. Flexural strength tests were conducted on 100x100x500mm prisms. Concrete was tamped and troweled vigorously. The specimens were demolded after 24 hours and cured under water for 28 days at 25 ^{0}C. The specimens were then tested for compressive strength and flexural strength. Two point load method was used to determine flexural strength in accordance with ASTM C78 specifications. Other specimens were oven dried by heating for 72 hours in 95 ^{0}C oven for water absorption determination. Water absorption property of sawdust concrete were determined by comparing wet and dry conditions. Heat conductivity was tested on air dry conditions of specimens with dimensions 200x100x50mm using a guarded hot plate apparatus according to ASTM C177 specifications.

RESULTS AND DISCUSSION

Table (1) shows the relationship between sawdust ratio and air dry density of sawdust concrete. The results are shown for four groups of concrete specimens. These groups are:

Group1: concrete containing untreated sawdust, Groupe2: concrete containing sawdust boiled in water containing hydrated lime and then dried. Group3: concrete treated as in Group2 above and treated with cutback asphalt, and Group4: concrete treated as in Groupe2 above and treated with classic varnish. The table shows a small increase in density in coated sawdust groups (Group3 and Group4) in comparison with uncoated sawdust groups (Group1 and Group2) for the same sawdust ratio due to increase of sawdust unit weight by treatment.

Table (1): Relationship between sawdust ratio and air dry density for different sawdust concrete groups.

Sawdust ratio% of cement weight	Air dry density kN/m^3			
	Group1	Group2	Group3	Group4
0	22.17	22.17	22.17	22.17
5	20.05	20.09	20.20	20.32
10	18.63	18.45	18.50	18.73
15	17.78	17.46	17.91	17.80
20	16.10	16.25	16.37	16.52
25	14.87	14.79	14.87	14.94
30	13.49	13.30	13.61	13.83
35	12.11	12.24	12.44	12.19

Figure(2) shows the influence of sawdust ratio on compressive strength of sawdust concrete cubes at age of 28 days. The figure shows that compressive strength is drastically reduced as the percentage of sawdust is increased in all groups. This is due to weakness of sawdust as an aggregate and, increase of water/cement ratio with increasing sawdust content.

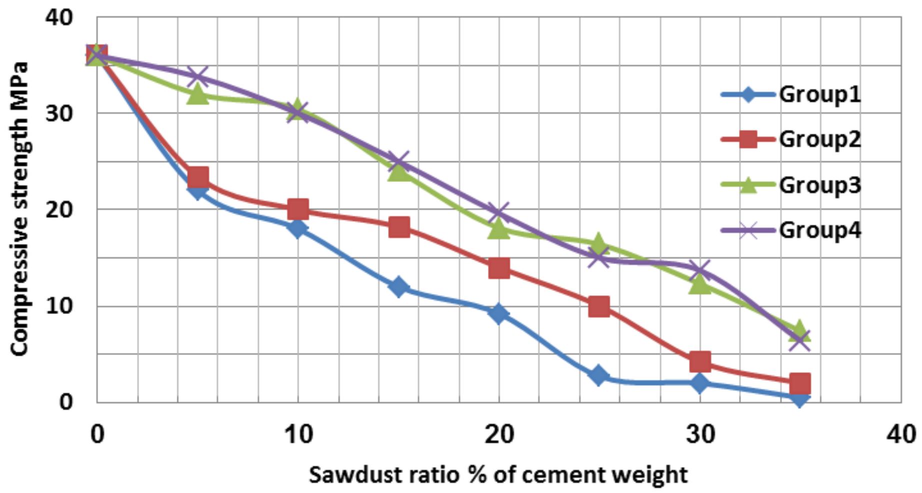
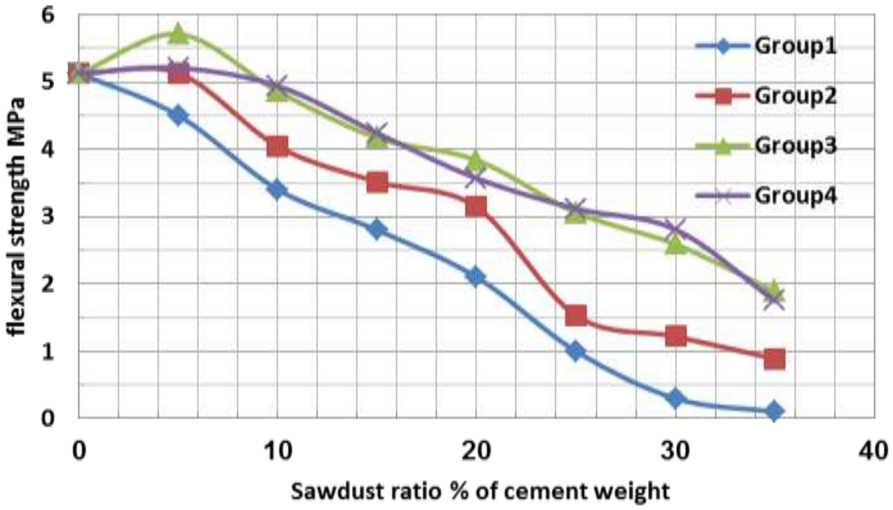


Figure (2): Effect of sawdust ratio on compressive strength for different sawdust concrete groups.

However, as expected, pretreated sawdust concrete has more compressive strength than untreated sawdust concrete for the same sawdust ratio, especially for high sawdust ratios. The improvement in compressive strength is larger for coated sawdust groups (Group3 and Group4) than other groups (Group1 and Group2). This can be explained by the reduced water/cement ratio required for coated sawdust mixes (Group3 and Group4) to acquire the same workability or (slump) of untreated sawdust (Group1), or boiled with lime sawdust (Group2). Also, coating the sawdust particles with waterproofing materials will reduce extraction of any residual soluble substances in the mix. No appreciable difference in compressive strength has been noted between Group3 and Group4 specimens in which, different types of waterproofing materials has been used. The properties on fresh state of the two mix groups of coated sawdust (Group3 and Group4) are also similar. The decrease in compressive strength with increasing of sawdust ratio is much more for untreated sawdust, which means that, larger pretreated sawdust content can be used to attain the same compressive strength of untreated sawdust concrete.

Therefore, lighter sawdust concrete can be produced with the same strength. The effect of sawdust ratio on flexural strength is shown in Fig.(3). Specimens were tested on air dry condition (tested 24 hours after removal from water). It can be seen that low sawdust ratios may increase the flexural strength of concrete due to the "fiber action" of sawdust. However, for higher sawdust ratios, flexural strength is reduced due to higher water/cement ratio and higher voids content.

Phase one of pretreatment of sawdust also improved flexural strength remarkably due to the better bond between pretreated sawdust and cement paste.



Figure(3): Effect of sawdust ratio on flexural strength for different sawdust concrete groups.

Bond between pretreated sawdust and cement paste is increased due to washing out harmful extractives in sawdust particles which inhabit setting and hardening of surrounding cement paste. Phase 2 of pretreatment (treating sawdust with waterproofing materials) increased flexural strength and bond between sawdust and cement paste much more due to the suppression of residual extractives which may exist on sawdust surface. Bond between sawdust particles and surrounding mortar is believed to be affected by volume changes in sawdust particles resulting from moisture movement which induce internal stresses in the surrounding matrix. Therefore, reducing volume changes by phase 2 of pretreatment , increased flexural strength by reducing internal stresses and better bond between sawdust particles and cement mortar. Numerical values for Figure.(2) and Figure.(3) are shown in table 2.

Table (2) Effect of sawdust ratio on compressive strength and flexural strength for different sawdust concrete groups.

Sawdust ratio% of cement wt.	Compressive strength MPa				Flexural strength MPa			
	Group1	Group2	Group3	Group4	Group1	Group2	Group3	Group4
0	36.1	36.1	36.1	36.1	5.13	5.13	5.13	5.13
5	22.0	23.4	32.0	33.8	4.49	5.13	5.71	5.21
10	17.9	20.0	30.4	30.0	3.40	4.04	4.86	4.94
15	12.1	18.2	24.0	25.0	2.80	3.52	4.17	4.24
20	9.2	14.0	18.1	19.6	2.12	3.14	3.84	3.57
25	2.7	10.1	16.4	14.9	1.01	1.53	3.06	3.12
30	2.1	4.2	12.3	13.7	0.31	1.22	2.59	2.81
35	0.5	1.9	7.4	6.4	0.10	0.89	1.89	1.75

Figure (4) shows the relationship between water absorption ratio and oven dry density of sawdust concrete for the four concrete groups. The high moisture absorption of Group1 and Group2 is expected especially for lower density (i.e. higher sawdust ratio). Group3 and Group4 concrete specimens with pretreated sawdust by waterproofing materials (phase 2 of pretreatment) have about 40% less water absorption than Group1 and Group2 specimens . No remarkable effect of the type of waterproofing material can be seen on water absorption ratio.

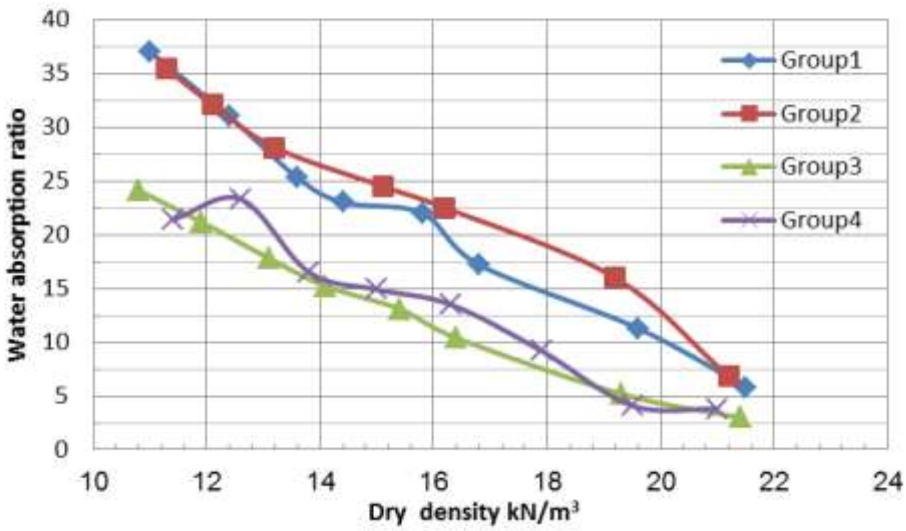


Figure (4): Effect of dry density on water absorption ratio for different sawdust concrete groups.

Table(3) shows thermal conductivity relationship with sawdust ratio of sawdust concrete. The four concrete groups have about similar properties in regard with thermal conductivity, because the effect of reducing water absorption capacity of pretreated sawdust with water proofing materials is compensated by the reduced mixing water (w/c) for such concrete. However, concrete made with pretreated sawdust with waterproofing material is expected to perform better in humid conditions due to the reduced water absorption capacity of such concrete.

Table(3) Effect of sawdust ratio on thermal conductivity of sawdust concrete.

Sawdust ratio	Thermal conductivity W/m K			
	Group1	Group2	Group3	Group4
0	2.03	2.03	2.03	2.03
5	1.43	1.52	1.45	1.48
10	0.65	0.62	0.56	0.60
15	0.51	0.55	0.51	0.52
25	0.35	0.38	0.39	0.36
30	0.32	0.33	0.34	0.33
35	0.30	0.33	0.33	0.31

Although rotting and fungal resistance is not investigated in this study, it is expected that pretreated sawdust will improve rotting and fungal resistance due to the reduced water absorption of such aggregates.

CONCLUSIONS

1- Pretreatment of sawdust is necessary for making sawdust concrete.
2- Phase 1 of pretreatment (boiling sawdust in water to which hydrated lime is added) stimulated extraction of harmful substances in sawdust and improved its properties as an aggregate.
3- Phase 2 of pretreatment (addition of waterproofing material diluted in Kerosene to sawdust) improved sawdust properties much more.
4- Compressive and flexural strength of sawdust concrete is increased by phase 1 of pretreatment of sawdust, and is increased more by phase 2 of pretreatment.
5- The high water absorption ratio which is the main disadvantage of sawdust concrete- is remarkably reduced by phase 2 of pretreatment.
6- The air dry thermal conductivity of sawdust concrete is not affected by treatment of sawdust.

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