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Recycling of industrial solid waste to produce cement units

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Introduction

The priority in a waste management policy is to reduce the amount of waste. The reduction or elimination of wastes at source, usually within a process is an established waste minimization technique. Waste minimization approach has been seen as the only suitable means of dealing with the waste problem. Recycling / reuse; is the use or reuse of a waste as an effective substitute for a commercial product or as an ingredient or feedstock in an industrial process. Recycling / reuse include “reclamation of useful constituent fractions within a waste material, removal of contaminants from waste to allow (reuse).

Life cycle assessment is a developing environmental management technique. At every stage of an industry there can be material, energy and labor inputs. At every stage there may be waste that is treated or untreated before disposed to the environment. In sugar industry sugar beet fibers is a major fraction of solid waste , it is the residue remaining after the extraction of the juice and drying it by hot air then cool air then drawing it. These natural fibers could be reused in concrete industry to produce fiber reinforced concrete (FRC). Many natural fibers can be obtained at low levels of cost and energy using locally available manpower and technical know-how. Such fibers are used in the manufacture of thin sheet high fiber content FRC. These fibers are typically referred to as unprocessed natural fibers; they are available in reasonably large quantities in many countries and represent a continuously renewable resource. Types of natural fibers used in concrete production is ; Coconut , Sisal , Sugar can bagasse ,Bamboo , Jute , Flax , Elephont grass , Water reed , Plantain , Musamba , and Wood fiber (Kraft pulp) (R.Brown , A .Shukla and K.R. Natarajan 2002) . No announcement was seen about using beet fibers in the literature.

Fiber reinforced concrete is a concrete made primarily of hydraulic cements, aggregates, and discrete reinforcing fibers. The principal reason for incorporating fibers into a cement matrix is to increase the toughness , tensile strength and improve the cracking deformation characteristics of the resultant composite (ACI 544.2R 89) . The use of shredded wood (wood wool) as reinforcement for inorganic binders dates back to the beginning of 19th century. Gypsum and magnetite- bonded excelsior boards were manufactured in 1905 and 1915 respectively (Kossatz et al. 1983). The first commercial production of wood wool cement boards (WWCBs) started and was patented in Austria in 1927. In philippines , research to explore the suitability of indigenous wood species for the manufacture of WWCBs began almost half a century later by the forest products Research and Development Institute (FPRDI) ,WWCBs of commercial size were manufactured using the pilot plant and

were used to construct a 36-square metre model house in the FPRDI compound in 1986 .The industry has expanded to its current number of 14 WWCB plants , The raw material they process depend on their availability and accessibility ;rattan waste , wood / sugarcane bagasse and Yamane [Rico Jariel cabangon ,2000]

In Iraq an investigation was done to study the effect of reinforcing concrete with wild can fiber on its properties , a decrease in compressive strength were seen but an increase in the flexural and splitting strengths with no sudden failure at all [sabeH H. Muhoder 1996].

The target of this research is to reuse the sugar beet fibers which are the main part of solid waste of sugar beet industry in Mosul to produce fiber cement building units. I think it's the first approach of using beet fibers in concrete industry in both concrete and environment literature.

(2) Materials and procedure

(2-1) Materials used.

- a) Cement: - The cement used is ordinary Portland cement from <sugar factory> corresponding to Iraq standards no.5 1980.
- b) Lime: - hydrated lime produced in the same factory <Mosul sugar factory> was used. here is its specifications:-
Heat of incineration 1000-1200 °c
 - Active Calcium oxide CaO not less than 80%
 - Aluminum and ferrious oxides not more than 3.5%
 - Magnesium oxides Mgo not more than 3% SiO_2 and other materials unsolved in acid not more than 2%
 - Sulphate (based on SO_3) not more than 1%
 - Fineness of lime: - passing 74Msieves. 80%
- c) Beet fiber (dried beet solid waste) .It's the solid matter remaining from beet extraction after compressing and drying by hot air form burning room then cool air then drawing and separation of beet fibers
- d) Calcium chloride cacle. used as an admixture to the mix to accelerate the hardening of cement pieces.
- e) Copper nitrate or sulphate : It is added to the cement mix for incorriging resistance to oxidation, bacteria, fungies and alga .copper powder passing sieve size 0.053mm one percentage ot cement weight could be used instade of nitrate & sulphate mentioned.

(3) Mix preparation & testing

(3-1) method

fibers are added to the concrete in several different forms and by using various techniques. The fibers can be incorporated into concrete as short discrete chopped fibers , as continuous network of fibrillated film , or as a woven mesh (Daniel, J.I.,et al ,1998).A hand lay-up technique may be used to produce composites with continuous networks, woven mesh can be incorporated into a cement matrix using a hand lay-up technique . High volume percentage of fibers cup to 12% in the cement matrix can be obtained by using this technique [Hannant,D.J.1978]

The method used in preparing mixes in this research is; firstly take off organic , sugar ,and acids matter form beet fibers by soaking , cleaning with water each six hours for two days extraction excess water form fibers then adding cement, lime (if used) copper sulphate (3-5% solution) , caliciun chloride , clean water mixing properly . Two types of mixes were tried to obtain the best mix that gives Highly compressive strength , modulus of rupture ,and toughness .The mixes used was :-

Mix A:-(Beet fibers + cement)

In this mix the proportions used was 1 cement to 1.5 beet fibers by weight .The amount of water needed to give agood workability to the mix was 0.7 water to cement ratio by weight .

Mix B :- (Beet fibers +cement +lime)

In this mix the proportions used was I cement :
0.5 lime : 1.5 Beet fibers (by weight) .The amount of water needed to give a good workability to the mix was 0.45water to cement ratio by weight.

(3-2) Casting Molds

For compressive strength testing steal molds (10x10x10 cm) were used after lubricating by metallic oil . Each mold casted in two compacted layers . Leaved 24-28 hrs in air then opened put it in shadow covering by cloth spraying water on it for three days then immersed in water . [AcI,1980,1986] For modulus of rupture steel molds (30x30x5cm) were used after lubricating by metallic oil casting the mix in it then covering by its metallic cover , then applying 200 kg/cm² pressure on it for 24 hrs , then removing the cover and pressure leave 24-48 hrs then the specimen kept in shadow covered with cloth spraying water on it for three days and immersed in water .[Rico Jariel cabango,2000]

(3-3) Laboratory testing

The testing methods used on specimens was according to American standards(ASTM)

- 1- Density at age 28 days.
- 2- Compressive strength at age 7,28 days
- 3- Modulus of rupture strength at age 7,28 days .
- 4- About toughness and atmospheric condition resistance the specimens was staid in atmosphere with direct use under sun light and rain for about seven months .

4. Results and discussion :

portland cement concrete is considered to be a relatively brittle material which are considered to have no significant post –cracking ductility . Fibrous composites have been and are being developed to provide improved mechanical properties to otherwise brittle materials . When fiber reinforcing is added to the concrete mix , it too can add to toughness , tensile strength , modulus of rupture , and improve the cracking deformation characteristics of the resultant composite . Unprocessed natural fibers are available in reasonably large quantities in many countries . UNFs require relatively small amounts of energy . So recycling of fibrous solid waste to produce building material gains the production of high specification of building units and the environment protection ofm large amounts of fibrous solid waste . The main properties influencing toughness and maximum loading of fiber reinforced concrete are :-

- Type of fibers used
- Volume percent of fiber
- Aspect ratio (the length of a fiber divided by its diameter)
- Orientation of the fibers in the matrix

The specification of Beet fibers used is :-

- Dry density of beet fibers $\approx 340 \text{ kg / m}^3$
- Wet density of beet fibers $\approx 700 \text{ kg / m}^3$
- Tensile resistance of fibers $\approx 19 \text{ Mpa}$.
- Solid materials not less than 90 %

The length of fibers may vary from (5cm to 50cm) because fibers are natural materials . they are not uniform in diameter and length . Typical values of natural fibers diameters vary from (0.1 to 0.75 mm).

After cleaning of beet fiber solid waste of sugar industry it was added to the cement matrix with calcium chloride 1% of cement waste to accelerate the setting

(hardening) of cement to avoid the retardness affect of trace organic matter remained on fibers . [Taylor ,1977,Cubango 2000] . Then Copper sulphate 3-5% of cement weight were added to the matrix to avoid corosion and growth of bacteria , fungies , and alga .

Mix A ; was made from cement and beet fibers without lime the proportions used was 1 cement : 1.5 beet fibers by weight with water cement ratio 0.7 of cement weight . The dry density of this mix was 1850 kg / m³ which is lighter than ordinary concrete (Table 1) . The compressive strength of specimens was 1.8 Mp at age of 7 days and 3.1 MP at age of 28 days (table 2) while Modulus of rupture for pieces of this mix was 0.5 MP at age of 7 days and 0.79 MP at age of 28 days . After exposing these specimens for direct uses under natural atmospheric conditions (cold and rain in winter –high temperature and direct sun light in summer)

For about 220 days losses were seen in compressive strength (becomes 2.9 MP) and Modulus of rupture (becomes 0.63 MP)

Mix B ; In order to make use of the byproducts of the factory ; lime was recycled also in producing the cement units under study .Hydrated lime from the same factory was used with cement and beet fibers in proportions (1 cement : 0.7 lime : 2 beet fibers) by weight , as lime improves the workability of the mix by increasing consistency and reducing air voids inside the concrete which leads to decrease the water needed to give the aproperate workability to 0.45 of cement weight . This is very good for the concrete produced because in concrete science the less the water cement ratio the more is the compressive strength , modulus of rupture , and toughness of pieces .

So the compressive strength of specimens of this mix was 5.7 MP at age of 7 days and 7.2 MP at age of 28 days . It is more than twice of that of mix A (without lime) . Also modulus of rupture of casted pieces was greater than that of mix A. It was 3.9 MP at age 7days and 4.5 MP at age of 28 days which is more than three time of that of mix A. In addition the dry density of pieces made from mix B was 1350 kg / m³ which is less than that of mix A (without lime, dry density 1850 kg / m³). This light weight obtained from mix B is very useful in increasing thermal insulation. More of that is when testing specimens of mix B after exposing to direct use in natural atmospheric conditions and for 220 day as made with mix A , no decreasing in compressive strength and modulus of rupture were seen . This is very useful from practical point of view. So mix B is much better and successful in producing cement units under study than mix A.

Worth mentioning is that these results obtained above is less than that expected , because the pressure used in casting these units was less than that needed 200 kg / cm² [Rico Jarid cabango 2000] because of the lake pressure device needed . If the casting pressure was adequate the results might be much better. Also the lime used (which is a byproduct of the same factory) was 80% in activity while the activity of lime used in structural object must be more than 90% in activity also its fineness was bad . If lime used had better activity than used, the compressive strength and modulus of rupture could be higher.

Finally about thermal insulation as we know from references that the low density of cement units the high is its thermal insulation. This means that the thermal insulation of casted units using cement with lime and beet fibers is about twice that of ordinary concrete units since its density are 1350 kg / m³ while the density of ordinary concrete is more than 2400 kg / m³.

Mix type	Proportions by weight	Density (unit weight) At age of 28 days
Mix A	1 cement : 1.5 beet fiber water cement ration 0.7	1850 kg / m ³
Mix B	1 cement : 0.5 lime : 1.5 beet fiber water cement ratio 0,45	1350 kg /m ³

Table 1. Density (unit weight) of cement units.

Mix type	Age (days)	Compressive strength Mpa
A Cement + beet fiber w/c 0.7	7 28 220	1.8 3.1 2.9
B Cement + lime + beet fiber W/c 0.45	7 28 220	5.7 7.2 7.3

Table 2 .Compressive strength of mixes used at different ages

Mix type	Age (days)	Modulus of rupture MP
A Cement + beet fiber W/c 0.7	7 28 220	0.5 0.79 0.63
B Cement + lime + beet fiber W/c 0.45	7 28 220	3.9 4.5 4.8

Table 3 .Modulus of rupture of mixes used at different ages

Conclusion:-

- 1) Beet fibers (sugar industry solid waste) could be recycled to produce cement units.
- 2) The units casted from cement with beet fibers using lime (by product from the same factory) which mentioned as mix B was much better than that casted from cement and beet fibers with out lime (mix A) in compressive strength , modulus of rupture and toughness .
- 3) The compressive strength of casted units was 7.2 MP at age of 28 days which means validity in using these units in buildings.
- 4) Modulus of rupture of casted units was 4.5 MP at age of 28 days which is higher than the standard needed for coating pieces in buildings.
- 5) Mix B casted units had thermal insulation twice as that of ordinary concrete units since it was light in unit weight (1350 kg /m³).

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