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Portland Cement Bonded Panel Products from Agricultural Wastes

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Agro-industrial wastes are normally used as fuel. Their appropriate use commensurate with their inherent properties has been a vital problem. The use of portland cement as a binder has been under investigation at the Central Building Research Institute, Roorkee. Particle boards from rice husk, groundnut husk, coconut pith and wood chips have been made under pressure. It is found that they do not exert inhibitory action on strength development in portland cement. Building panels of adequate strength are obtained when rice husk/coconut pith and cement are mixed in the ratio 1 : 2 by weight and consolidated to a density of 1100-1200 kg/m³. Groundnut husk and wood chips, however, require more cement.

AN important outcome of industrialization and increase in agricultural output in recent years has been the accumulation of huge amounts of agro-wastes from industrial crops. Rice husk, groundnut husk, coconut husk and pith, bagasse and jute sticks are obtained as agro-industrial wastes. Their appropriate use commensurate with their inherent properties has been a vital problem. So far, these are used mostly as fuel. The high silica content in rice husk ash has been found to be beneficial in the preparation of a good pozzolanic and cementitious material[1-3]. A few of these wastes have also been found suitable for the manufacture of particle boards[4,5]. In fact, conversion of these wastes into boards for use in prefab houses, partitions, etc. will help in saving the traditional building materials, such as wood and brick.

In view of their large surface area and porosity, it is rather uneconomical to use synthetic adhesives—phenolic resins—for the production of particle boards from them[5]. Inorganic binders such as magnesium oxychloride cement and gypsum have been used extensively for making wood-wool and plaster boards. But they exhibit poor resistance to water and are costly. Portland cement may be considered a cheap binder for these organic aggregates. Earlier attempts with portland cement were restricted to casting of building blocks and slabs without any pressure. It either resulted in poor strength or necessitated unusually high proportions of cement[6-8]. Investigations were, therefore, undertaken to make cement-bonded particle boards from rice husk, groundnut husk and coconut pith under pressure. Panels from wood chips were also prepared.

Materials and Methods

Rice husk—Twelve to fifteen million tonnes of rice husk are obtained in India every year. It is available mainly in three forms—completely burnt kernel, half brunt kernel and unburnt kernel. Rice husk is a tough brute because of the silica-cellulose structural arrangement. For this reason, it does not incinerate or even liberate heat in a manner resembling that from any other organic substance. It is light in weight (bulk density, 100-150 kg/m^3). It gives a short fibre (6-12 mm) and is friable. Rice husk is less hygroscopic than wood.

Groundnut husk—Its production is estimated at 8.5-10 million tonnes per year[9]. The husk obtained by decortication of groundnut pod constitutes 20-40% of the pod by weight. It is light (bulk density, 130 kg/m^3) and has high fibre and cellulose contents.

Coconut pith—It is a soft cork-like granular particle. Pith obtained by the retting process is dark grey, while that obtained by mechanical decortication is reddish brown in colour. The pith is made up mostly of pectins, tannins and other soluble substances and cellulose. However, the pith obtained by the retting process consists mainly of lignin and cellulose. The bulk density of air dried pith varies from 80 to 100 kg/m^3.

Bulk density, water absorption, ash content, water and alkali solubles and chemisorption of portland cement by rice husk, groundnut husk and coconut pith were determined. The results are given in Table 1.

Preparation of the board—The proportions of cement and husk for the preparation of boards are given in Tables 2 and 3. The husk was first soaked in 2% solution of calcium chloride in water. The free water was drained off. Dry portland cement was added to it and the mixture was mixed intimately. The whole mass was consolidated in a mould of 30×30×7.5 cm and pressed to a thickness of 2.5 cm. It was demoulded after 24 hr and cured under polyethylene cover for 6 days. It was then dried in shade.

Flexural strength, compressive strength, water absorption and linear and thickness swelling of the board were determined. The data obtained are given in Tables 2 and 3.

Discussion

The water soluble extractives in woody tissues, if present in considerable quantities, retard and sometimes inhibit the setting and strength development properties of portland cement[10-12]. Water soluble contents in groundnut husk and wood are more as compared to rice husk and coconut pith. However, inhibiting action is not noticeable (Tables 2 and 3). The content of alkali solubles is quite high. The extractives may be lignin, hemicelluloses, carbohydrates, etc. The chances of the presence of polyphenols in them are remote. In fact, the formation of polyphenols in a tree takes place during the conversion of sapwood into heart wood[13]. No such transformation seems to take place in these agro-wastes. The lower figures for the compressive and flexural strengths are mostly due to the lack of chemical affinity of these agro-wastes with cement. It follows that strength development depends largely on the close packing of the husk and the self-bonding of cement grains. For example, for the same proportion of cement to husk/pith, compressive strength increases with

Table 1—Physical characteristics of different wastes

Waste	Bulk density kg/m³	Water absorption %	Ash content %	Water solubles, %		Alkali solubles in 0.5 % NaOH, %	
				Cold	Hot	Cold	Hot
Rice husk	100-150	126-135	18-21	1.72	3.64	46.8	58.3
Groundnut husk	130-132	185-195	5-7	4.18	4.94	42.1	42.5
Coconut pith	80-110	630-640	14-16	1.06	1.95	28.3	30.7
Wood chips	220-230	180-190	0.2-0.4	3-5	4-6	41-42	42-44

Table 2—Composition and properties of cement bonded panels from rice husk and wood chips

Composition		Rice husk-cement panels (30×30×2.5 cm)				Wood chips-cement panels (30×30×2.5 cm)			
Waste g	Cement g	Flexural strength kg/cm²	Compressive strength kg/cm²	Linear swelling %	Water absorption %	Flexural strength kg/cm²	Compressive strength kg/cm²	Linear swelling %	Water absorption %
600	1200	17.0	30	0.375	29.5	14.8	46.0	0.38	47.3
700	1400	25.2	38	0.355	26.2	20.2	54.4	0.36	32.5
800	1600	34.0	88	0.36	23.4	28.3	66.0	0.325	20.0
900	1800	45.8	98	0.34	17.6	29.2	72.8	0.32	32.1
1000	2000	50.4	120	0.35	16.8	—	106.0	0.32	—
1200	1200	35.0	60	0.645	34.3	—	88.0	0.40	—
960	1440	36.1	78	0.395	29.8	18.3	68.2	0.36	40.0
800	1600	34.6	88	0.36	23.4	28.3	66.0	0.325	20.0
685	1715	31.5	76	0.345	24.3	39.5	80.6	0.32	14.3
600	1800	30.5	58	0.310	22.7	45.7	78.2	0.32	13.7
480	1920	28.0	54	0.205	—	32.1	68.0	0.29	15.2
800	1600*	23.5	66	0.305	31.3	26.2	58.0	0.46	22.8

*Without calcium chloride

Table 3—Composition and properties of cement-bonded panels from coconut pith and groundnut husk

Composition		Coconut-pith-cement panels (30×30×2.5 cm)				Groundnut husk-cement panels (30×30×2.5 cm)			
Waste g	Cement g	Flexural strength kg/cm²	Compressive strength kg/cm²	Linear swelling %	Water absorption %	Flexural strength kg/cm²	Compressive strength kg/cm²	Linear swelling %	Water absorption %
600	1200	5.4	20.0	0.58	38.0	6.3	10.6	0.22	38.0
700	1400	11.2	26.4	0.56	30.7	6.5	21.2	0.63	29.9
800	1600	26.8	32.8	0.52	19.6	16.2	30.6	0.85	29.0
900	1800	20.7	50.0	0.52	37.3	12.3	46.0	1.00	31.1
1000	2000	11.2	52.0	0.54	40.6	—	70.8	—	—
1200	1200	—	26.8	0.76	—	5.8	50.4	—	59.8
960	1440	18.5	29.3	0.62	43.4	12.0	—	1.7	31.2
800	1600	26.8	32.8	0.52	19.6	16.2	30.6	0.85	29.0
685	1715	22.0	28.8	0.42	19.0	16.7	34.0	0.73	27.3
600	1800	23.8	30.0	0.37	17.2	18.9	36.0	0.46	23.5
480	1920	21.3	30.2	0.30	15.6	16.8	29.2	0.16	21.0
800	1600*	—	20.0	0.56	—	10.9	22.2	—	45.6

*Without calcium chloride

increase in the density of the panel, i.e. the higher the density, the higher is the strength. Again, for the same density, increase in the concentration of cement causes increase in compressive strength. However, there appears an optimum level of cement concentration for the husk to achieve requisite consolidation and compactness and consequently good strength. Increase in the proportion of cement alone does not increase the strength when the ratio of husk to cement is 1 : 3 or more by weight.

On comparing the compressive and flexural strengths of different materials it is found that rice husk produces the strongest board, while groundnut husk gives the weakest board. This is due to the differences in their packing properties and compression recovery after the pressure is released. It may also be due to the high contents of water solubles in groundnut husk as compared to rice husk and coconut pith. With increase in the density of the panel, the flexural strengths of wood chips, coconut pith and groundnut husk increase. The flexural strength is maximum when the density is around 1100 kg/m^3. At a density of 1100 kg/m^3, rice husk and coconut pith require a quantity of cement twice their weight, while groundnut husk needs cement almost three times its weight.

The linear swelling of rice husk and wood chip panels is comparable to that of commercial resin-bonded boards[14]. Coconut pith and groundnut husk panels show slightly higher values. It appears that linear swelling is not appreciably affected by change in density, except for groundnut husk. It decreases as the proportion of cement increases and is minimum when the ratio of cement to husk is 4 : 1 by weight.

All the panels show high water absorption. With increase in density, rice husk panels absorb less water (Table 2). However, for wood chips, groundnut husk and coconut pith, there appears an optimum density. Water absorption is least when the density is 1100 kg/m^3. Again, for the same density, water absorption decreases with increase in the proportion of cement.

Economics

The cost of raw materials for the production of 2 m × 0.5 m × 2.5 cm board of density 1100 kg/m^3 is estimated at Rs 9.25.

Conclusions

(1) Rice husk, coconut pith and groundnut husk do not exhibit inhibitory action on strength development in portland cement.

(2) Building panels of adequate strength are obtained when rice husk and coconut pith are mixed with cement in the ratio 1 : 2 by weight and consolidated to a density of 1100-1200 kg/m^3.

(3) Groundnut husk shows high compression recovery and possesses noticeable swelling characteristics.

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