Manufacture of Low-Cost Building Boards from Immature Gamar Wood

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Immature gamar (*Gmelina arborea*, Linn.) plants at about the age of 10 to 12 years become infested with loranthus, a parasitic plant, and ultimately die if a heavy infestation occurs. Gamar of 8, 12, 16 and 20 years age groups, having little timber value, have been studied for the manufacture of exterior grade hardboards. Fibre analysis and solvent extractibility show that the wood will be suitable for the purpose. Fibre length, flexibility coefficient, fibre diameter, relative fibre length and other related factors are better than those of many other tropical wood and grass species. The presence of high percentages of waxes, fats and resins makes the fibres naturally moisture resistant.

Pulps have been made by Cold Soda and Steaming processes. Both soaking and pressure impregnation methods have been tried in the Soda process. Steaming for one hour at 140 psi steam pressure has been found to be the optimum in the other process.

Additive chemicals have been used in the slurry for imparting water resistance to the boards. Fire retardant and insect repellent chemicals have been sprayed on the damp-dry mat or on the formed boards. Heat treatment and oil wax tempering were followed by applying protective coating with urea-formaldehyde glue and enamel paint.

Accelerated aging tests have been conducted according to ASTM procedures. Board specimens have been tested for physical strength, water resistance and fire retardance. For charring tests, a device has been developed at the Forest Research Institute. Modulus of rupture values, as high as 7000 psi, have been obtained. Tempered boards absored as low as 4% by weight and 1% by volume of moisture. Even after aging tests the boards were quite water resistant, though moderate in strength.

অপরিণত বয়সের গামার গাছ সাধারণতঃ দশ হইতে বার বৎসর বয়সে লোরেনথাস্ নামক এক প্রকার পরগাছা দ্বারা আক্রান্ত হয় এবং আক্রমণের তীব্রতা বেশী হইলে শেষ পর্যন্ত মারা যায়। বাহিরে ব্যবহারোপযোগী শক্ত তক্তি নির্মাণের জন্য কাঠ হিসাবে ব্যবহারের প্রায় অযোগ্য আট, বার, ষোল, এবং বিশ বৎসর বয়সের গামার গাছ লইয়া সমীক্ষা চালানো হয়। তন্তু ও রাসায়নিক বিশ্লেষণ হইতে আভাস পাওয়া যায় যে ইহা এতদুদ্দেশ্যে উপযোগী হইবে। ইহার তন্তুদৈর্ঘ্য, নম্যতাঙ্ক, তন্তুর ব্যাস, আপেক্ষিক তন্তু দৈর্ঘ্য এবং প্রাসঙ্গিক উপাত্তসমূহ অন্যান্য গ্রীষ্ম মণ্ডলীয় বৃক্ষ প্রজাতির ঐ সকল গুণাগুণ হইতে উৎকৃষ্ট; মোম, তৈল ও আঠা জাতীয় পদার্থের আধিক্য স্বভাবতঃই গামার তন্তুকে পানি প্রতিরোধী করে।

কোল্ডসোডা ও স্টীমিং পদ্ধতিতে মন্ড তৈয়ার করা হইয়াছে। প্রথমোক্ত পদ্ধতিতে স্বাভাবিক ও উচ্চচাপে রাসায়নিক বিশ্লেষণ করানো হয়। দ্বিতীয় পদ্ধতিতে ১৪০ পাউণ্ড চাপে এক ঘন্টার জন্য বাষ্প প্রয়োগই প্রকৃষ্ট বলিয়া প্রমাণিত হয়।

বোর্ডগুলিকে পানি প্রতিরোধী করার জন্য তৈয়ারীর সময়েই রাসায়নিক দ্রব্য প্রয়োগ করা হয়। তৈয়ারী বোর্ডে অথবা তাপ প্রয়োগের পূর্বে ভিজা বোর্ডে অগ্নি ও পোকামাকড় প্রতিরোধী রাসায়নিক দ্রব্য প্রয়োগ করা হয়। বোর্ডগুলিকে হিট-ট্রিটমেন্ট এবং অয়েল ও ওয়াক্স টেম্পারিং করিয়া এনামেল পেইন্ট অথবা ইউরিয়া ফরমালডিহাইড গ্লুর রক্ষণাবরন দেওয়া হয়।

স্বীকৃত পদ্ধতিতে ত্বরান্বিত প্রাচীনিকরণ করা হয়। বোর্ডের ভৌত গুণাগুণ জল-নিরোধণ এবং অগ্নি প্রতিরোধ ক্ষমতা নিরীক্ষণ করা হয়। অংগারীকরণের জন্য বন গবেষণাগারে একটি বিশেষ প্রক্রিয়া উদ্ভাবন করা হয়। মডিউলাস অফ রাপচারের মান প্রতি বর্গ ইঞ্চিতে ৭০০ পাউণ্ড পর্যন্ত পাওয়া যায়। টেম্পারড্ বোর্ডগুলি সর্বনিম্ন নিজ ওজনের ৪% ও আয়তনের ১% উদ্গ্রহণ করে। এমন কি, প্রাচীনিকরণের পরেও বোর্ডগুলি যথেষ্ট পানি প্রতিরোধী থাকে। অবশ্য ভৌত শক্তি বেশ হ্রাস প্রাপ্ত হয়।

INTRODUCTION AND MATERIAL

Gamar (*Gmelina arborea* Linn.) wood is extensively used by the furniture and construction industries. The ease with which it can be carved and worked makes it especially suitable for furniture making. It has a considerable demand as door and window panel and frame. Due to varied use and great demand, the species is planted by the Forest Department in large scale. The plants grow rather rapidly and mature in about 40 years' time. The immature plants, however, are attacked by loranthus, a type of parasitic plant which grows rapidly often enshrouding the entire plant and smothering it. The gamar plant usually dies after a heavy infestation. These infested plants, having little timber value are either used as fire-wood or allowed to perish in the forests, where felling and transportation are not economic.

On the suggestion of Bangladesh FIDC a project was taken up to manufacture hardboards with a view to utilise the loranthus-attacked immature plants. A number of cords of the species of four age groups, namely, 8, 12, 16 and 20 years, were obtained through the courtesy of the Karnaphuli Paper Mills Ltd. The bolts were straight and fairly free of knots.

Gamar is a medium to large-sized deciduous tree with board leaves. The bark is light grey, smooth and corky. The wood is yellowish white, soft and even-grained. It is rather light, about 45 lbs/cft green weight. In favourable conditions the tree grows to a maximum height of 100 feet and a girth of 15 feet. It is distributed generally throughout most of India and Burma. It is available in the Chittagong and Chittagong Hill Tracts forests of Bangladesh.

Fibre dimension studies (Table 11) indicate that no appreciable difference exists among the different age groups. So, instead of making boards separately for each age group, boards were made from mixtures of the groups in equal proportion.

Preliminary works indicate that unlike most other hardwood species of Bangladesh, gamar wood yields hardboards which are remarkably water-resistant. Chemical analysis shows that the alcohol-benzene solubility and other-solubility of the wood is quite high, indicating natural water resistivity (Table 2). This, as well as the dearth of low cost housing material in Bangladesh prompted the authors to modify the project to manufacture of hardboards suitable for exterior use and cheaper than most other conventional housing material. Necessary insect-repellent and fire-retardant properties were also imparted to the boards as are pertinent to an exterior grade hardboard.

EXPERIMENTAL WORK

The gamar bolts, after being sawn to 3″ x 3″ size, were chipped to approximately 1″ x 1/2″ x1/8″ size in a laboratory model chipper machine. The chips, about 67% dry, were cooked in 0.8 cubic feet stainless steel laboratory-model rotary digesters by applying direct steam under various steam pressures and for various lengths of time. The optimum cooking condition was established at 140 psi steam pressure for one hour. At the end of the cooks, the softened chips were fiberised in a disc mill to various freeness values. The optimum freeness value was between 50 and 70 seconds. An 86% average yield was obtained.

Some cooks were made by impregnating the chips in soda solutions of various concentrations in various liquor to wood ratios. The freeness values of the resulting pulps were very high. In some charges, the impregnation was effected under 60 psi pressure for half an hour, thereby considerably lowering the freeness values of the pulps produced from these chips.

The pulp was damp-dried in a hand press, shredded and sampled for moisture content. Boards were made from these pulps. Requisite amount of pulp was taken for 9 1/2″ dia round or 16″ square and 1/8″ nominal boards and stirred mechanically to make a 2% slurry. The slurry, further diluted to 1.3% consistency, was poured in the board former. Through a vacuum suction the water was drained and the same amount of air as the water was also, allowed to pass through the mat. The mat thus formed was cold-pressed to damp-dryness. These pulp mats were then pressed in a hot hydraulic press under 500 pounds per square inch pressure for six minutes, using a breather for one minute under 50 pounds per square inch pressure. Screens of 18 to 20 mesh put below the mats to ease the escape of steam, resulted in smooth faced screen backed boards.

Chemically treated boards were made by adding chemicals to the slurry before formation of the boards. Two percent alum, two percent ferrous sulphate and two percent resin size were used in various combinations. The pH was taken to the region of four to four and a half by the addition of sulphuric acid. 2.5% resin size and 0.5% ferrous sulphate was used in one cook. After the manufacture of the boards, a tempering experiment was carried out both on the control and chemical boards. Some boards were subjected to heat treatment in a force draft oven for one hour at 165°C temperature. Others were tempered with a minimum amount of paraffin wax or linseed oil. These, in their, turn were again heat treated. A number of these boards were again enamel-painceted or treated with urea-formaldehyde glue.

Some boards were treated with one to two percent boliden salt and penta-chlorophenol solutions in combination with other chemicals and additives for imparting insect-repellent properties to them. In some cases, formed boards were dip-treated and oven dried. In other cases, the mats were sprayed with the chemicals and press-dried.

For increasing the fire-resistance of the boards various percentages of diammonium hydrogen phosphate, ammonium dihydrogen phosphate, ammonium sulphate, ammonium phosphate, boric acid and borax were used in the slurry, mats or in the formed boards. In the slurry, the chemicals were stirred in. These were sprayed on the mats and the formed boards were dip-treated and oven-dried.

Specimens from all these boards were soaked in one inch deep water at 21 ± 2°C for 24 hours. The percentage change of volume as well as weight of the boards were recorded. Specimens were also treated for modulus of rupture values by static bending tests. The specimens for these tests were 5" x 2" in size. The span for the static-bending test was 3". The modulus of rupture values were adjusted for specific gravity by dividing the observed modulus of rupture by the square of the specific gravity.

Accelerated aging tests were conducted on the board specimens treated with wax, wax and paint, oil, oil and paint, and only paint. All the specimens were subjected to six complete cycles of accelerated aging, each cycle consisting of :

1. Immersion in water at 120° ± 3°F for I hour,
2. Spraying with steam and water vapour at 200 ± 5°F for 3 hours.
3. Storing at 10 ± 5°F for 20 hours,
4. Heating at 210 ± 3°F in dry air for 3 hours,
5. Spraying again with steam and water vapour at 200 ± 5°F for 3 hours.
6. Heated in dry air at 210° ± 3°F for 18 hours.

After completion of six cycles of exposure the specimens were further conditioned at 72° ± 30°F and a relative humidity of 50 ± 5% for at least 48 hours. The conditioned specimens as well as the control boards without aging were tested for water resistance and static bending properties.

Fire resistance tests were conducted in a flue, designed at an angle of 45° with the horizon, by applying direct flame of equivalent intensity and candle power and measuring the time taken to char a given area. The degree and extent of charring in a given time by weight loss was not used, as the proportional loss of weight due to the presence of volatile matter could not be determined accurately. The results have been adjusted on the basis of 0.125 inch thickness of the boards.

RESULTS AND DISCUSSION

Fibre analysis

The fibre length of 1.2 mm is quite good compared to other tropical hardwood species (3). Runkel ratio, obtained by dividing double cell wall thickness by lumen diameter, of less than unity, indicates the possibility of good sheet and board making qualities.

The fibre length, fibre diameter, lumen diameter and cell wall thickness of the fibres from different age groups do not show appreciable difference. The pulps of various age groups would yield sheets of comparable tensile strength. The flexibility coefficient, lumen diameter divided by fibre diameter, predicts that the tensile strength would be quite good. The relative fibre length, expressed as the ratio of fibre length and fibre diameter, is an indication of tearing resistance properties of fibres. Tear values are rather low. These, however, seem to be improving with the increase in age. Probability is that better tear values would be obtained with fibres from mature trees (Table 1).

Chemical analysis

Chemical analysis shows that the alcohol benzene and ether solubility of gamar wood is 11.36% and 3.54% respectively. This is higher than those of most other tropical hardwood and grass species (4, 5, 6). This means the presence of higher percentages of wax and other solvent-extractible oil and resinous materials. These materials may form a protective coating on the individual fibres or fibre bundles. This may explain the natural water resistance of the boards. The degree of saturation of the cell walls of the fibres may also be responsible for the same.

Cold soda boards

In the cold soda process four different cooks were made. In the cook Nos. GCI amd GC2, the chips were soaked in 15 g/l cold soda solution for 18 hours. Chips of cook No. GCI was pulped to a freeness of approximately 50 seconds. The pulps were coarse with fibre bundles but there were lots of fines, which passed through the screen (Table 2). Milling the soaked chips further produced a pulp of approximately 300 seconds freeness (Cook No. GC2). The strength properties of the boards showed appreciable improvement over those of the boards of cook GCI, but the water absorption properties remained almost the same (Table 2). Heat treatment, however, improved the water resistance considerably. Decreasing the time of soaking of the chips to I hour in 15 g/l NaOH solution, deteriorated the physical properties (Table 2). In cook No. GC4 impregnation was effected under 60 psi pressure for 1/2 hour, resulting in comparable figures. The freeness, however, could be taken to the region of 110 seconds vis-a-vis 300 seconds (approx.) in the case of cook No. GC3 (Table 2).

Boards made by steaming process

The freeness values of the boards made by this process are rather low, an advantage over the cold soda process. Static bending properties were obviously a little inferior to those of the cold soda boards. Addition of chemicals for imparting moisture resistance had no effect on the strength properties (Table 3). Moisture resistance of control boards without any treatment are exceptionally good. This makes this species especially suitable for making exterior grade boards. Additive chemicals for imparting water resistance improve the results further. Heat treatment of these boards improves the water repellency but little (Table 1). Heat treatment followed by enamel-painting of these boards improves the results appreciably. However, if the control or the additive boards are waxed and heat treated, still better results are obtained (Table 5). This, however, depends on the quality and quantity of paint applied. In case of the painted boards, the change in thickness was not recorded as the change in thickness of the fibres and paint is inseparable.

In cook No. GC5, using an enamel paint of different brand, improved results were obtained so far as the moisture absorption is concerned. Higher percentage of paint, upto a certain degree, improves the results. In this cook, attempts were made to dip or brush treat the specimens with a dilute solution of urea-formaldehyde glue. The glued boards, after drying, were subjected to water absorption tests. The results were good, but the process was not continued further due to the difficulty with which the glue could be made to adhere to the boards (Table 6). In Cook No. GS6 control boards were treated with six to seven percent of linseed oil and then heat treated. Four to six percent of absorption by weight and about six percent change in thickness were recorded. The modulus of rupture values were also good. Addition of 0.5% $FeSO_4$ and 3.5% rosin size did not alter the results (Table 7).

Attempts were made to manufacture some boards with insect repellent and fire retardant chemicals. The chemicals were added to the damp-dried mats by spraying. The formed boards were treated with paraffin wax or linseed oil, followed by heat-treatment. The results were similar. The strength properties were, however, lower than expected. Five to seven percent moisture by weight and three to ten percent by volume were absorbed (Table 8).

In an experiment conducted for determining the fire resistance properties of boards, it is seen that the boards made without any chemicals are quite fire retardant compared to the commercial specimen (Table 9). It is a well known fact that gamar wood is a comparatively fire resistant species. It seems that the hardboards made from the species maintain the inherent properties of the wood. Specimens prepared along with other water resistant and insect repellent chemicals did not show much improvement over the control. This is presumably due to the presence of these and other chemicals or their carriers which by their kindling properties offset the effect of the fire retardant chemicals. Specimens S33 and S34, however, without any such chemicals present better results.

Accelerated aging tests

Boards were manufactured for the accelerated aging tests, some with fire retardant and insect repellent chemicals and some without. Ultimate strength and moisture absorption properties were not influenced by this fact. The modulus of rupture values became considerably low after the boards passed through the rigorous cycles. But even then, in most cases, the values were from 2500 to 3000 psi (Table 10). This proves that the boards would last much longer than a ten year span if they are cared for at an interval of two to three years in exterior use. Water resistance properties of the boards after aging are remarkably well, comparable to or even better than S-1-S class I boards of the U. S. standard. This means that the boards with occasional paints would last for about 15 years. Due to little change in dimensional stability, the nail-withdrawal and lateral nail resistance properties would also be good.

Service tests

Board specimens kept for a service test in the form of a door facing outwardly on the southern wall of a public place remained in good condition for the last five years. Specimens kept for exposure test in the open deteriorated very much in the course of five years' time Specimens kept in contact with a termite mound resisted attack for four years. In the fifth year the chemicals washed away and termite attack started.

As has been mentioned, gamar is a fairly fast-growing species and becomes infested with loranthus when 10-12 years old. In many cases heavy infestation ultimately kills the plants. Use of these plants for the manufacture of hardboards would, in no way, damage the furniture or housing industry adversely. Generally, boards produced in Bangladesh at present entail a manufacturing expenditure of 50-56 paisa per square foot of board depending on the quality, which should cost the buying public about 65 paisa per square foot.

All the materials and chemicals suggested in this project for treatments and tempering of boards, excepting one or two, are locally available or can be manufactured indigenously. The total cost of these treatments would not increase the manufacturing expenditure by more 20 paisa per square foot. The common buyers can then obtain these at a fair price of 85 paisa per square foot. Considering the recurring expenditure of painting or asphalting the boards once in every 3 years, the cost would not exceed one taka per square foot in a span of 15 years, which it is expected to last. The present prices of all house building materials are much higher than this.

CONCLUSION

Chemical analysis shows the presence of large amounts of waxes, fats, resins, phytosterols, non-volatile hydrocarbons and gums. Presumably, these make the boards naturally water resistant. Fibre characteristics indicate that good quality boards could be made from immature gamar wood. Strong boards are obtained from cold soda pulps, but are slow draining. Pressure impregnation yields a comparatively free pulp. Boards made by steaming process are exceptionally water resistant. By means of additive chemicals and tempering, an exterior grade board can be made. Accelerated aging tests indicate that a superficial coating of enamel paint at reasonable intervals would make the boards last as long as 15 years. The price would also be within the reach of common man. Incorporation of fire retardant and insect repellent chemicals would make the boards more useful.

Table 1. Fibre analysis of immature gamar wood

Age group	8 years	12 years	16 years	20 years
Max. length (m m)	1.36	1.02	1.46	1.49
Min. length (m m)	0.52	0.49	0.80	0.73
Av. length (m m)	.96	0.81	1.03	1.20
Fibre Dia. (m m)	.028	0.028	0.028	.027
Lumen Dia. (m m) (Fibre dia.—2 CWT*	.017	.018	0.018	.017
Cell wall thichness (Fibre dia.—Lumen dia.)	.005	.005	.005	.005
Runkel Ratio (2 CWT/Lumen dia.)	.63	.55	.56	.62
Flexibility coefficient (Lumen dia./Fibre dia.)	.61	.64	.64	.60
Relative fibre length (Fibre length/Fibre dia.)	34.21	29.03	39.96	42.92

*CWT = Cell Wall Thickness

Table 2. Physical properties of gamar cold soda boards

Sp. No.	Freeness	Treatment	Sp. Gr.	Water soaking: % change in weight.	Water soaking: % change in thickness	Adj. M of R psi
GC1—2	54	Heat treatment	.96	22	23	5900
GC1—3	47	Heat treatment	.98	26	26	5700
GC1—4	48	Heat treatment	.93	23	25	5500
GC2—2	330	nil	.96	76	62	6500
GC2—3	330	nil	.97	75	62	6500
GC2—4	285	nil	.97	71	60	7000
GC2—2	330	Heat treatment	.96	24	25	6500
GC2—3	330	-do-	.96	23	24	6500
GC2—4	205	-do-	.97	22	24	7000
GC3—3	310	-do-	.97	41	27	4500
GC3—4	314	-do-	.96	31	28	4700
GC3—5	276	-do-	.95	33	28	4600
GC3—3	310	nil	.97	88	68	4500
GC3—4	314	nil	.96	78	70	4700
GC3—5	276	nil	.95	79	59	4600
GC4—3	120	nil	.93	delaminated		4500
GC4—4	112	nil	.93	78	59	4800
GC4—5	110	nil	.94	delaminated		4400
GC4—3	120	Heat treatment	.93	30	32	4500
GC4—4	112	-do-	.93	32	33	4800
GC4—5	110	-do-	.94	33	34	4400

Note—In case of cook GC1 & 2 the chips were soaked for 18 hours and in GC3 for 1 hour, whereas in GC4 the chips were pressure inpregrated for 1/2 hour under 60 psi

Table 3. Strength properties of steamed control and additive boards.

Sp. No.	Freeness (sec.)	Chemicals	Sp. Gr.	Adj. M of R
GS3 -1	65	nil	1.04	5000
-2	61	nil	1.02	4300
-3	61	nil	1.01	4600
-6	53	2% $FeSO_4$	1.0	4500
-7	54	2% $FeSO_4$	1.0	5200
-9	85	2% Rosin size.	0.98	4500
-10	85	2% Rosin size	.98	4400
-12	46	2% alum	1.01	4800
-13	45	2% alum	0.98	4400
-16	52	2% alum	1.03	4600
-17	50	2% Rosin size	1.0	4800
-19	51	2% alum	1.02	4800
-20	50	2% $FeSO_4$	1.0	4600

Table 4. Water-absorption tests of heat-treated & untreated steamed boards.

Sample No.	Chemicals.	Heat treated: % change in wt.	Heat treated: % change in Thickness.	Untreated: % change in wt.	Untreated: % change in Thickness.
GS3-1	nil	10.1	9.0	15.9	13.0
-2	nil	11.1	9.6	14.1	11.4
-3	nil	10.9	9.5	15.4	11.7
-6	2% $FeSO_4$ 2% alum	10.5	8.1	11.7	9.0
-7	-do-	11.1	8.5	10.0	7.5
-9	2% Rosin	11.5	9.3	14.3	10.3
-10	-do-	11.1	9.4	13.9	9.6
-12	2% Alum	10.4	9.1	10.7	7.2
-13	-do-	10.6	8.8	11.1	9.4
-19	2% Alum 2% $FeSO_4$	10.6	7.6	11.1	8.5
-20	-do-	10.3	8.2	12.3	10.3
-16	2% Alum 2% Rosin	7.9	7.1	11.1	9.3
-17	-do-	8.6	6.4	11.9	10.9

Table 5. Water absorption tests of heat-treated, enamel painted and waxed boards

Sp. No.	Freeness (sec.)	Chemicals (%)	Tempering (%)		change in wt. (%)	change in Thickness (%)
GS3-4	61	nil	10	paraffin wax	4.28	1.45
GS3-5	61	nil	10	-do-	4.41	1.35
GS4-9-3	42	2 alum	8.8	-do-	4.60	6.80
GS4-12-3	41	2 $FeSO_4$	8	-do-	7.40	9.70
GS4-15-3	40	2 alum 2 $FeSO_4$	8.8	-do-	3.80	8.10
GS4-18-3	60	2 alum 2 Rosin	8.3	-do-	4.90	8.80
GS4-2-2	50	nil	14	enamel paint	7.50	–
GS4-8-2	42	2 alum	13	-do-	6.00	–
GS4-11-2	42	2 $FeSO_4$	15	-do-	7.60	–
GS4-14-2	40	2 alum 2 $FeSO_4$	14	-do-	8.80	–
GS4-17-2	60	2 alum 2 Rosin	15	-do-	5.63	–

Table 6. Water resistance properties of glued, enamel painted and heat treated boards

Sp. No.	Freeness (sec)	Chemicals	Glue (%)	Enamel paint (%)	Moisture taken wt.
GS5-2-1	120	nil	–	6.85	3.60
GS5-3-1	113	nil	11.7	–	8.60
GS5-7-1	90	2 alum	–	13.8	1.14
GS5-8-1	90	2 alum	13.2	–	8.10
GS5-22-1	100	2 + Alum 2 Rosin size	–	14.5	2.17
GS5-23-1	113	-do-	12.4	–	7.30

Table 7. Physical properties of heat and oil tempered steamed boards

Sp. No.	Freeness (sec.)	Chemicals (%)	Linseed oil (%)	Moisture (%) wt.	Absorbed thickness	M of R psi
GS6-1	80	nil	6.4	3.64	6.47	5700
GS6-4	84	nil	7.1	5.80	5.97	6000
GS6-7	176	$FeSO_4$ .5 Rosin size 2.5	6.3	6.82	8.70	6200
GS6-9	198	-do-	7.0	3.68	4.47	5300

Table 8. Water-resistance properties of insect repellent & fire-retardant boards tempered with oil or wax

Sp. No.	Freeness (Sec.)	Chemicals	Treatment	% wax or oil.	After water soaking % change in wt.	% change in thickness	Strength (psi)
GS7-1	61	nil	—	–	16	13.2	5200
GS7-1	61	nil	Linseed oil	6.95	7.31	9.77	5200
GS7-6	65	1% Boliden salt	—	–	13	14	–
GS7-6	65	-do-	oil	9.05	6.32	7.30	–
GS7-6	65	-do-	wax	7.26	5.97	7.36	–
GS7-14	55	1% B. salt 1% $(NH_4)_2SO_4$	oil	7.82	6.85	8.82	–
GS7-17	52	1% B. salt 1% $(NH_4)_3PO_4$	oil	9.77	6.88	5.67	–
GS7-20	75	1% $Na_2B_4O_7$	oil	7.60	7.06	5.36	–
GS7-23	55	$(NH_4)_3PO_4$	oil	9.74	6.17	3.35	–
GS7-26	53	$(NH_4)_2SO_4$	oil	7.96	6.55	4.54	–
GS7-29	71	H_3BO_3	oil	7.53	5.90	6.94	–

Table 9. Fire retardant tests of gamar boards

Sp. No.	Type of treatment	Av. Thickness (inch)	Time of charring (sec)	Adjusted time (Sec.)
S2	nil	.137	197	180
S24	Commercial	.151	150	124
S21	2% $NH_4H_2PO_4$ 2% Rosin size	.135	200	185
S22	2% $(NH_4)_2HPO_4$ 2% Rosin size	.136	205	188
S31	1% Boliden salt 1% $(NH_4)_2HPO_4$	.141	204	181
S33	2% $NH_4H_2PO_4$	.136	240	220
S34	2% $(NH_4)_2HPO_4$	.235	215	199

Table 10. Physical properties of boards subjected to accelerated aging tests

Sp. No.	Treatment.	Tempering	Moisture (%)	Absorption Thickness change (%)	Adj. M of R.
S29-1	–	wax	12.2	24.8	2700
- 4	–	wax + paint	8.8	25	3300
- 7	–	L. oil	12.5	23.9	1800
-10	–	L. oil + paint	6.25	11.8	2500
-13	–	Aging only	13.8	19.2	2600
-16	–	paint	6.8	24.5	3200
-19	–	nil	–	—	*
S30- 1	1% Boliden salt 1% $(NH_4)_2HPO_4$	wax	9.9	24.3	2200
- 4	-do-	wax + paint	5.9	11.1	2900
- 7	-do-	L. oil	10	17.4	1200
-10	-do-	oil + paint	5	14	2400
-13	-do-	aging only	11.1	14.8	2400
-16	-do-	paint	3.4	10.9	2500
-19	-do-	nil	–	–	*

*Control boards deteriorated beyond measurement.

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