Information paper for the indurite process for the adding of density to UK grown timber species

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Information paper: The use of the Indurite solution and its effects on a range of mechanical and physical properties of treated timber.

Summary

The Indurite process of adding density to timber by impregnation with a starch solution that is cross linked by heat to solidify the material has real possibilities for the UK timber industry. With large volumes of low density material being produced and the likelihood of this increasing in the future, a process that could add value to the resource was worthy of investigation. The results observed with Radiata pine had not only proved impressive put profitable making highly durable and colour fast flooring out of a low density, fast grown material.

This information paper sets out the findings of the evaluation work carried out at BRE on the use of the Indurite solution with UK species and the resultant effects on a range of mechanical and physical properties, and addresses potential end use applications for treated material.

Since the work described in this information paper has been completed Osomose UK now hold the UK licence for the manufacture and distribution of the Indurite solution. Osomes will be working together with Indurite on licensing timber treatments.

Back ground.

The process came from New Zealand where it had been developed especially for use with Radiata pine. Radiata pine is one of the most abundant plantation grown species in New Zealand and therefore uses for the resource are constantly being sort. Experience has shown that radiate pine is a most amenable species to all kinds of processes that do not always work with the same degree of success when transfer to other timbers. Therefore, BRE in co-operation with Indurite (NuWood at the time), the Forestry Commission and Scottish Enterprise and a number of UK saw millers (BSW and James Jones) undertook a two year project in ascertaining the potential for the Indurite process with UK timbers.

Due to commercial sensitivities BRE carried out the treatments as directed by Indurite with no investigation of the underlying chemistry, therefore it was treated as a black box process.

Investigation in to treatment potential.

The method of treatment was to all intents and purposes the same as that used for the preservative impregnation of timber. The impregnation process was carried out using the BRE preservative plant with the timber species to be treated placed in tanks of Indurite solution that were load into the pressure vessel. A vacuum was drawn for an hour before release and then a pressure of 13kg/cm^2 was applied for two hours, at the end of which the specimens were removed and dried. The drying process was an hour at 40^{0}C followed by 12 hours at 60^{o}C. The initial trails demonstrated clearly that the treatment could be carried out using the BRE plant and that an effective loading in Radiata pine could be achieved, the reference timber for the initial trials.

What was also discovered at this early stage was that viscosity and temperature of the Indurite solution were critical factors for effective treatment. As the solution ages it becomes more viscose and shows great resistance to being forced into the timber. An optimum plant temperature of 20 ^{o}C was found appropriate for the solution.

Trials with UK timber species

A range of timber species were tested, most with little existing commercial value, the hope being that the process, by adding density, could also value add to the timber, though commercial important species were included such as Sitka spruce and British grown pines (a mix of Scots and Corsican). Unfortunately most species proved difficult to teat or treat effectively, Sitka spruce was amongst this group of timbers.

From the initial trials it became apparent that only species that are classified as permeable for preservative treatments showed suitability for treatment, even with fresh solution of 25 centipoises (viscosity at delivery) and at optimum temperature. The criteria for selection was gross increase in density over the initial starting density at 12% moisture content and a marked improvement in hardness as determined by the Janka's hardness test, both based on end matched samples. Only two of the species suggested for investigation by the project partners showed improvements to both density and hardness that were considered worthy of further investigation. These were Scots pine, particularly the sapwood (in fact it was a mix of Scots and Corsican) and poplar. These species were selected for the second stage of the work; to demonstrate the effects on the mechanical and physical properties that resulted from treatment.

Demonstrable changes to mechanical and physical properties.

The aim throughout this project was to achieve the maximum loading possible, therefore, the results explained in this section should be seen in that context. However, it is recognised that there is potential to vary the loading and that there are certain applications where a maximum loading is neither needed nor desirable to meet the end use criteria. The main timber used for this work was British grown pines but some poplar was also used in some of the test work.

1. Addition to density

The work has clearly demonstrated that density can be enhanced significantly but the uptake is mainly within the sapwood portion of the timber. An increase to density of around 30% was achieved, but this did depend greatly on the ratio of sap to heartwood. An increase in density alone has little practical use other than adding mass. The main aim of determining density was to demonstrate and quantify the amount of uptake of the solution. It was hoped that as density increased so would the resistance to penetration – the hardness of the material. It was believed that as the solution resided within the lumen of the trachids, and once cross linked this would add to the hardness of the timber by preventing the crushing of the vascular tissue.

2. Effects on mechanical properties (Hardness, bending strength, stiffness, impact and dimensional movement.

In this section the testing of hardness, bending strength and impact strength were all carried out to BS: 373[(1)] - 1957.

2.1 Hardness

It was possible to demonstrate significant improvements to hardness on end matched samples of around 90% when the janka's hardness test was carried out. This measures the load required to drive a steel ball of known diameter a certain distance in to the timber. The greatest improvement to hardness was recorded at the ends and the edges of the treated boards; the hardness was not so enhanced at the mid section of the boards, though it was an improvement upon the matched controls.

2.2 Static bending (bending strength and stiffness)
On well treated material there was a significant increase in bending strength recorded over the control material. This was of the order of 28% but once again there was a difference between the material at the ends and edges compared with the mid portions of the boards, with the ends and edges showing a greater increase in strength.

Stiffness showed a remarkable increase as a result of treatment; the material underwent a 60% improvement over that recorded for the controls but yet again the ends and edges of the boards showed the greatest improvement.

2.3 Impact strength
Impact strength, also known as toughness, was also tested. It was believed that as bending strength had been improved then impact strength should be as well. However, there were slight concerns as there was some indication that at high solution loading embitterment could result and this would have had implications for impact strength. However, the testing showed these fears to be unfounded and there was a slight increase in impact strength over that recorded for the controls of 7% but this was within the natural variability of the material. Therefore, it can not be conclusively determined if impact strength is improved or not.

The embitterment, it is believed, may be linked to the conditions during the curing process that give rise to a high molecular weight polymer within wood rather than the degree of the loading.

2.4 Dimensional movement
The work on dimensional movement was based on BRE Technical Note 38[2] but the material was end matched rather than being truly radial or tangential, tests were was carried out on both Scots pine and poplar. The test is carried out by conditioning material at 25^{o}C and 90% RH until the dimensions and weight of the material was stable. Once stable the humidity was changed to 60% RH and held there until the dimensions and weight stabilised once more. The material was taken through several cycles of the regime. Both the treated Scots pine and poplar specimens showed markedly less dimensional change as a result of the changes in environmental conditions than did the controls. The Scots pine showed around 30% less overall movement and the poplar showed around 22% less movement than the controls. Therefore, the treatment is believed to reduced overall movement that the timber under goes as a result of changing environmental conditions.

3. Adhesive performance

Depending on the end use application of the treated material there is the possibility that the timber could be bonded with one of several types of adhesive from the common PVA type through to the structural EN301[3] adhesives or one of the polyurethane based adhesives, now gaining popularity. Treated timber was tested against the three adhesive types to determine if treated timber (Scots pine sapwood) performed differently to untreated timber.

The findings were clear and they indicated that regardless of adhesive type there was no determinable difference in performance when compared using the EN302: Part 1[4] lap shear test, see Figure 1.

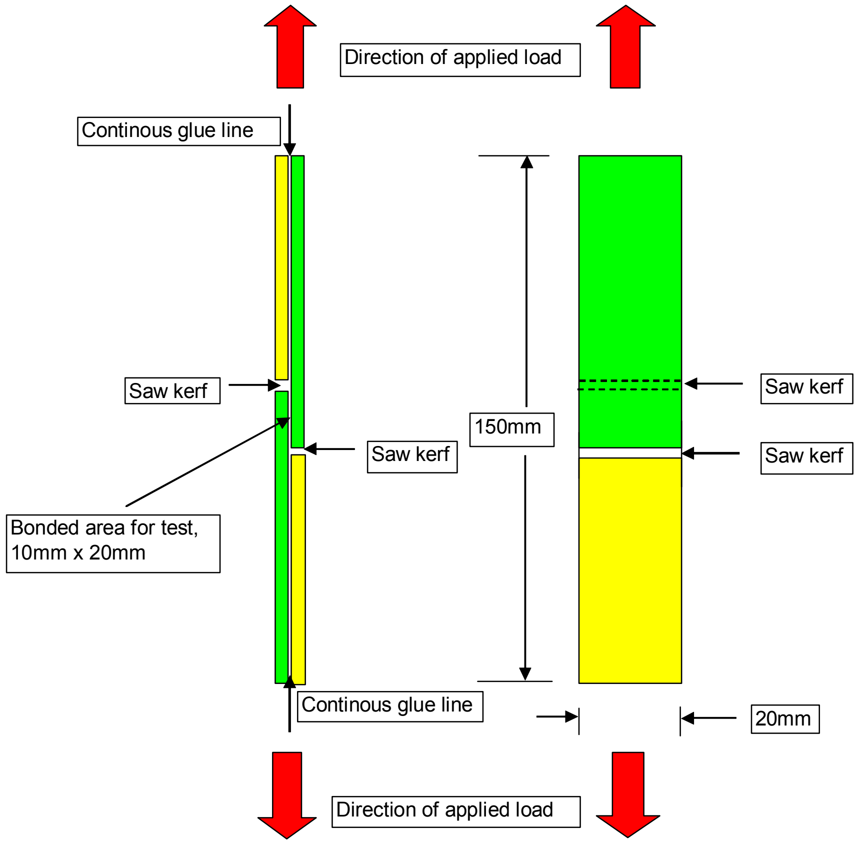

Figure 1. Shows the basic test specimen configuration.

The predominate mode of failure in all cases regardless of adhesive type or condition of the timber was failure within the wood rather than a failure of the adhesive to create an effective bond. Where there was separation at the bond line the exposed adhesive was covered in wood fibres, between 80 to 100% of the surface making this a failure of the wood. Any difference in the performance of the different adhesives could not be determined as all three out performed the timber, indicating more than adequate bond capacity.

4. Machining characteristics

There are many possible uses for the treated timber but joinery was considered a possible value added end use, therefore, the behaviour and performance of the timber during common machining processes was considered important and worthy of investigating.

4.1 Sawing (hand saws and band saw)

Timber treated with the indurite solution produces a crisp clean cut with good edge definition. The marks left by the saw teeth are not as pronounced as those left on untreated timber. There was reduced incidence of break out and splintering on the back edge of the cut as the blade progresses.

Due to the increase in density there may be a tendency to increase the rate of blunting of the teeth but this is unproven and a much higher quantity of material would need to be sawn to definitively demonstrate this.

Of importance was the nature of the sawdust; sawdust from the treated timber was finer than that from the untreated material and whilst extraction equipment designed to meet the expectations of current health and safety regulations should be able to accommodate the dust, where treated timber is being sawn in confined space without extraction all due care should be exercised.

4.2 Sanding

The treated material sands well and the presence of the treatment acts as a sanding sealer, improving both the quality of the finish and the rate at which the finish is attained. Saw marks are removed with greater rapidity from treated material compare to the controls.

The presence of the treatment, especially on the surface, can increase the rate at which sanding belts become clogged; this may lead to the requirement for more frequent belt cleaning.

As with sawing the dust produced is finer than for the untreated material which again may have implications when treated timber is being sanded in confined spaces without extraction equipment.

4.3 Planing

Treated material produces a clean smooth surface and appears to reduce the occurrence of tear-out of the grain; it significantly reduced tear-out when planing against the grain.

The dulling effect of the treatment on the planer blade was negligible and is not expected to reduce the life expectance of the blades.

4.4 Drilling

The treated material drills well with all sizes of drill bits and all the common bit formats, twist drill (both normal conical point and precision point), flat bits and fostner / hinge bits. The treated timber also mortises well leaving a smooth well defined mortise. Treated timber takes a countersink well, giving a better finish to the countersunk hole with less tearing of the surface fibres on the periphery than does untreated timber.

4.5 Routing

The indurite treated timber routed swell, both with the grain and against it leaving a clean well defined profile that had reduced tear-out of the wood fibre than the untreated material. The dulling effect was difficult to assess as tungsten carbide tipped cutters were used. It is thought any dulling will not be significant.

Overall the machining characteristics of the treated timber were an improvement upon those of the untreated timber. All the machining processes gave a better finish and definition, though the fineness of the dust produced will need to be taken into consideration.

5. Mechanical fixings

The indurate treated timber performed more like a dense hardwood than a softwood and required treating in the same way. This in part may be due to the formation of high molecular weight polymer during the curing process, as mentioned previously under impact strength, and may be in part controllable. However, the results for nailing are that the timber will require to be predrilled to prevent splitting, this is of particular importance on the face of the boards near the ends and in to the end grain. The requirements for nailing at or around the mid portion of the boards, where treatment is not so fully effective, is less critical. The carpenters trick of blunting the end of the nails to break the wood fibres rather than part them also proved ineffective and the timber still split.

Screw fixings required the holes to be drilled in accordance with good woodworking practice. The pilot holes had to be of the correct proportion to the screw size being used otherwise splitting would occur. The increasing practice of using power driven self cutting screws, thereby negating the necessity to pre-drill should be avoided. Anchorage of the screws into the end grain was improved in the treated timber with reduced tendency for the wood fibres to pull out.

6. Biological Durability

Initial work carried out in New Zealand suggested that treated timber showed greater resistance to decay than untreated material. If this was the case then not only could the solution be used to improve a range of desirable properties for manufacturing purposes but it could also expand the range of locations and service conditions that the treated timber could be used in. This therefore had to be investigated as it would be a significant property of the material if it could be demonstrated.

The UK timbers that show best results with the Indurite solution will in the main contain predominantly sapwood and, in consequence, should be regarded as perishable. Therefore, the use of the indurite solution on such timber may confer a degree of durability, as once impregnated and cross-linked the presence of the treat may prevent the decaying causing organism recognising the timber as a food source.

Treated material was tested to BS EN113(5) against Poria placenta and Coniophora puteana and the evaluation of results based on EN350(6) principles. A cautious interpretation of the results was that Scots pine sapwood was very durable (class 1) for Poria placenta and moderately durable (class 3) to durable (class2) for Coniophora puteana. However, these results apply only to fully treated material, for cases where the material has not been fully treated the presence of low levels of the Indurite solution may enhance the rate of decay.

Though the results are promising and a fully optimised treatment regime may produce more uniformity in the material, more work needs to be done to confirm the initial durability ratings and on a greater range of wood destroying organisms appropriate to the end use classification of the material, before it can be recommended for external use. The nature of the indurite solution does allow the use of the solution as a carrier for other treatments that can impart a high degree of durability.

7. Fire performance

Again there was evidence from New Zealand that suggested treated timber showed a slower rate of uptake of fire than similar but untreated timber. This was considered an important property of the solution if it could be demonstrated as it would open a number of specific end uses applications where resistance to combustion is considered vital.

This was an initial investigation based on a single treated board tested against an end matched control specimen. The treated material had received a 25% increase in density, though not the highest it was about average for a processed timber. The specimens were given to BRE's Fire and Risk Science (FRS) Division to carry out the test. This was a "match" or single point ignition source on the surface of the specimens; this is a standard test, BS EN 11925 -2(7).

The overall result showed the there was no difference between the time taken for the flame to spread the measured distance for the treated and control specimen, though the treated material did show a slower initial uptake of flame and more initial charring of the surface.

On the advice of the FRS expert the test was repeated with a slightly large flame as this some times influences the overall rate of spread of the flame. The test was carried out on the reverse side of the two specimens. The results were exactly the same as the first test.

Whilst it had not been possible to show enhanced resistance to fire, what it did show was that the fire performance of the treated timber was not compromised by the presence of the indurate solution.

FRS experts suggested that future work should be carried out on 1m^2 square panels as this may yield different results but this fell outside the scope of the original brief. Therefore, there is still more work that is needed to demonstrate the potential for improved fire resistance of Indurite treated timber. However, as with the enhancement to durability the Indurite solution could be used as a carrier for more conventional fire retardant treatments as long as they do not significantly alter the viscosity of the solution.

Conclusions

The curing process, as used at BRE on the advice of Indurite, may not have been fully optimised and with a fully optimised curing process it is possible that better results for the range of tests carried out may have been achievable. But based on results that it was possible to achieve it can be said that the Indurite process shows considerable promise and with full optimisation can yield significant improvements to a range of mechanical and physical properties that have important characteristics for a range of possible end uses.

Whilst only British grown pines and poplar were shown to be suitable out of the range of species suggested for this study the investigation of other species should not be ruled out as it is possible other species not included in this study may prove suitable.

Low density timber can be valued added to by the use of the Indurite treatment to meet a number of potential end uses but most will require attracting a high value end use to off set the processing costs required to carryout the treatment. There are potential uses that do not fall in to the high value added category that could benefit from such a treatment but the economics may mitigate against its use. Some potential end users are:

- Flooring: Indurite is used in other areas of the world to improve the performance of low density radiate pine as a flooring product. The improvement in hardness enhances the surface performance of the material making it less prone to surface indentation and abrasion. What has been demonstrated with radiate pine but not as yet with UK timber species is the inclusion of a fixed colour through the bulk of the timber that unlike surface treatments can not been worn away with use.

- Internal furniture and joinery: The improvements that result from increased density to such properties as strength, stiffness and hardness can make low density timbers suitable for a range of internal furniture and joinery applications. The enhancement of the machining characteristics will increase its attractiveness as a resource and there is the possibility that end uses like turning blanks are possible that can directly compete with the highest quality material for decorative stair parts or other high value turned products.

- Window joinery, external doors and trims: The dimensional movement of treated timber is lower than untreated timber and this suggests that in applications where low dimensional movement in response to changing environmental conditions is required treated timbre would be suitable. Components made with treated timber should be less prone to sticking or gaping and can be machined to finer tolerances to achieve better performance.

- External furniture: With the potential for increased durability treated timber would be suitable for patio or garden furniture. The possibility is to replace naturally durable species of tropical origin giving an added incentive to the retailer knowing that the product they are selling comes from a sustainable resource yet has an accompanying degree of durability.

The involvement of Osomse can be seen as a positive development ensuring suitable market placement and appropriateness of treatments.

References:

1. British Standards Institution 1957, Methods of testing small clear specimens of timber, BS373: 1957, London

2. Building Research Establishment, Technical Note 38.

3. British Standards Institution 1992, Adhesives, phenloic, and aminoplastic, for load bearing timber structures, classification of performance requirements, 1992, London

4. British Standards Institution 2004, Adhesives for load bearing timber structures, test methods: Determination of bond strength in longitudinal shear strength

5. British Standards Institution1997, Wood preservatives. Test method for determining the protective effectiveness against wood destroying basidiomycetes. Determination of toxic values, BS EN113:1996, London

6. British Standards Institution 1994, Durability of wood and wood-based products – Natural durability of solid wood. Guide to natural durability and treatability of selected wood species of importance in Europe, BS EN 350: Part 2, 1997, London.

7. British Standards Institution 2002, Reaction to fire tests. Ignitability of building products subjected to direct impingement of flame, single flame source, BS EN ISO11925: Part 2. 2002, London