TECHNICAL ASSISTANCE MISSION FOR IROKO PROJECT

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CIRAD-Forest Department – Forest Products Program

Final Report of Technical Assistance Mission

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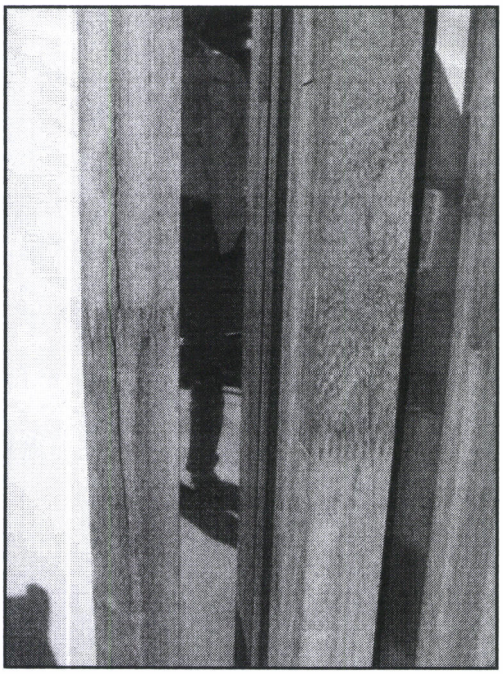
1 - PRESENTATION AND ORGANIZATION OF THE MISSION

11 - GENERAL OBJECTIVE

Bring technical assistance to SAMSUNG Corporation for Iroko project in the framework of the SAMOO "*S project*".

12 - CONTEXT OF THE PROJECT

The project consists of a building with a double façade (inside-outside) made of 7.3m long vertical Iroko boards (glued-laminated boards inside, massive wood outside), 60x100 mm in section (see technical sheet for Iroko in annex).
These Iroko boards have a brise-soleil function, without structural function.
First prototypes of glued-laminated boards with finger-joints have been manufactured then exposed to bad weather.
After 3 weeks exposure period, important damages occurred on the prototypes; in particular, more or less opened splits appeared at the end of the fingers (see photos below).



Because of the slightly rounded shape of the beam at the level of the finger-joint, it seems that the damage has been induced by a wood-swelling phenomenon at the level of the glue joints.

13 – PLACE AND DURATION OF THE MISSION IN KOREA

The three days mission has taken place in Korea from Wednesday 5 of January 2005 to Friday 7 of January 2005 (arrival in Korea on January 5 morning, departure on January 8).

14 - ORGANIZATION AND CONTENT OF THE MISSION

Date	
January 5	*Morning* • Arrival at Seoul Intcheon • First work/presentation meeting at Samsung Corporation – Cheil Communication Building [Mr Kim Jai Soo (Arch. Manager – *Samsung Corporation*), Mr Yun Seong Whan (Assistant Manager – *Samsung Corporation*), Mr Hee-Ho Choi and Mr Byeong-Soo Kim (Architects in Design Team H-Project – *Samoo Architects & Engineers*), Mr Song Byung Han (Representative Director - *Poongjun Lumber Co. Ltd*), Mr Kim Pil-Ki (Director Construction Division - *Heehoon Design & Global*)]. *Afternoon* • Visit of the *S Project* site • Visit and work meeting in *Kyungmin Industrial Co. Ltd – Kmbeam* (Mr Jeong JaeHong, Director) • Visit and work meeting in *Poongjun Lumber Co. Ltd* (Mr Song Byung Han)
January 6	• Wood Drying Laboratory - Faculty of Forest Science in Chonbuk National University (Chonju): Visit and work meeting with Pr. Lee Nam-Ho (Research Director of the Laboratory), the Director of HDG, Mr Kim Pil-Ki, Mr Seong Whan Yun, Mr Byung Han Song.
January 7	• Final work meeting / results of the mission (Cheil Communication Building) with Mr Kim Jai Soo, Mr Yun Seong Whan, Mr Hee-Ho Choi, Mr Kim Pil-Ki.
January 8	• Departure to Paris

2 - THE SUCCESSIVE STEPS OF THE PROCESS AND RELATED RECOMMENDATIONS

21 - IROKO LOGS STORAGE AND SAWING

At the moment of the mission in Korea at the beginning of 2005 January, logs of Iroko were stored in the yard of the sawmill, among the general logs stock owned by the enterprise.

A part of these logs[1] has been inspected: they are generally of good quality, suitable for sawing.
Two kinds of logs defects appear for some of them: defects of shape (flattened sections) and grain (logs with general spiral grain).
These defects must be taken into account during sawing (adjustment of the sawing pattern and appropriated log orientation and position in the carriage) in order to obtain good quality sawn products and to limit wastes.
Mr. Song (Representative Director of Poongjun Lumber Co. ltd) has specified that 300m^3 of Iroko logs to be sawn + 50m^3 Iroko sawn woods will be available for the Iroko project. These quantities will allow to supply the necessary wood volumes for the construction, i.e. 74m^3 of finished products: glued-laminated beam (37m^3) + massive wood for exterior façade (37m^3).

RECOMMENDATIONS

* A first wood quality control (QC1) must be organized just after sawing: boards with too much important defects (steep slope of grain all along the board length, large wood decayed areas...)[2] must be eliminated.
This control must be carried out taking into consideration and balancing the two following facts:
- unusable boards with too much important defects have not to follow the manufacturing process (in particular further drying operation),
but
- for some boards, localized wood defects can be later eliminated when machining just before glue-laminating; therefore, these boards must be kept for drying.
* When sawing, boards width and thickness adjustment must take into account both the higher value of drying shrinkage (5% to 6% according to the tangential direction of wood[3]) and dimensions decrease when planning (dried wood with 4 to 6 mm "overthickness" in order to have a smooth planning without unevenness afterwards).

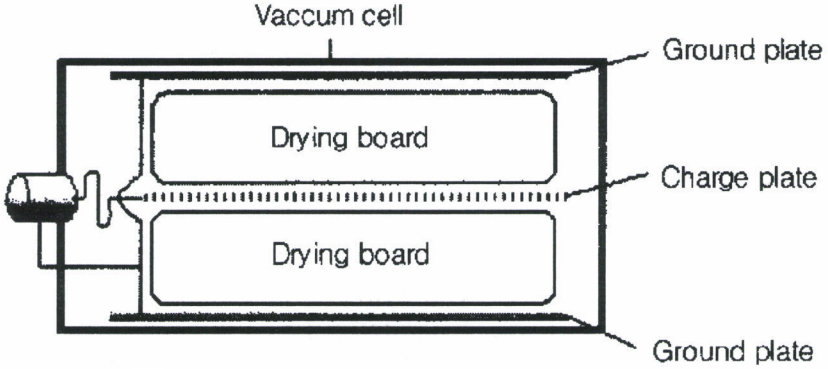
22 - DRYING

221 - Drying technique presentation

Drying of Iroko boards is the key stage of the process, the stability of the final glued-laminated products and massive wood for exterior use directly depending on the quality and efficiency of this operation.
Radio-frequency/vacuum drying technique has been chosen in order to shorten drying time and insure a good drying quality of the Iroko boards.

[1] The ones accessible in the logs yard.
[2] Complete specifications are given in the part relating to wood quality control after machining and before gluing.
[3] Radial shrinkage of Iroko is lower, between 4% and 5%.

Iroko will be dried using such a technique in the Wood Drying Laboratory of the Faculty of Forest Science in Chonbuk National University (Pr. Lee Nam-Ho team).
The drying principle and the drier characteristics[4] are given in the Pr. Lee's study report entitled "The quality Improvement of the Radio Frequency/Vacuum Drying and the Service for the Internal and External Wall Boards of Iroko" (December 2004)[5].
During drying, wood is heated and his temperature depends on Radio-Frequency control.
Vacuum cycles speed up and increase water extraction from wood, water boiling point decreasing with pressure (vacuum pressure between 50 and 80 torr, i.e. 67 to 107 millibars).
Possible boards distortions during drying are blocked by the pressure[6] applied by the upper layer cover made of flexible elastic rubber sheet coupled with a more rigid aluminum sheet.



The RFV Drier (from Pr. Lee's report)

[4] Sizes of the drier used for the first experiments

[5] **Further information on the drying system**: The technology of drying wood under vacuum using radiofrequencies (RFV) is an excellent alternative to conventional wood drying methods because it dries more rapidly and causes less damage to the wood. When wood is dried using RFV, it is essential to control its internal temperature in order to keep the heat from getting too intense. Among all the drying methods, RFV is the one that offers the best drying time as well as minimal wood degradation. The RFV system automatically optimizes drying for the type of wood being treated. The result is wood that is uniformly dry, of an exceptional quality, even if it is stained.
A typical RFV wood drying oven consists in a large vacuum chamber equipped with radiofrequency electrodes. In an environment where the pressure is low, as is the case in a vacuum chamber, the temperature at which water evaporates is much lower than the atmospheric pressure. Moreover, high frequency heating is known as internal heating because the object undergoing this wave field generates heat itself. The energy penetrates the wood and acts directly on the water molecules to facilitate evaporation: the wood is therefore heated in a very short lapse of time.
The result is a more uniform drying at temperatures lower than with conventional drying methods, which causes much less damage to the wood.
Temperature monitoring is the most important aspect of the RFV system: controlling the wood's internal temperature is essential throughout the entire drying process for a better quality of finished product.

[6] 10,000 kgf/m² for the drier used for the first experiments

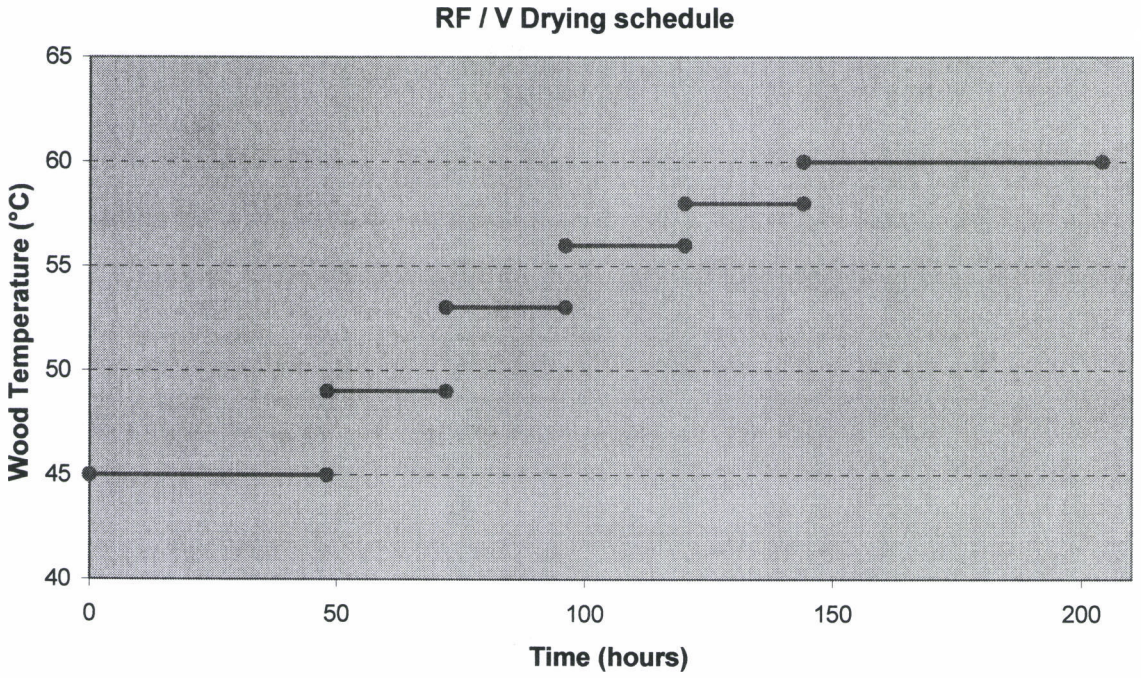
Pr. Lee has specified that 3 RFV driers will run for the Iroko project, with a total useful volume[7] of 13m^3 (3m^3 + 5m^3 + 5m^3). The third 5m^3- drier should be ready for use at the end of 2004 January.

222 - Drying schedule

The drying schedule to be used for 40mm and 70mm thick Iroko boards is the following (tested and checked during the first experiments in Chonbuk):

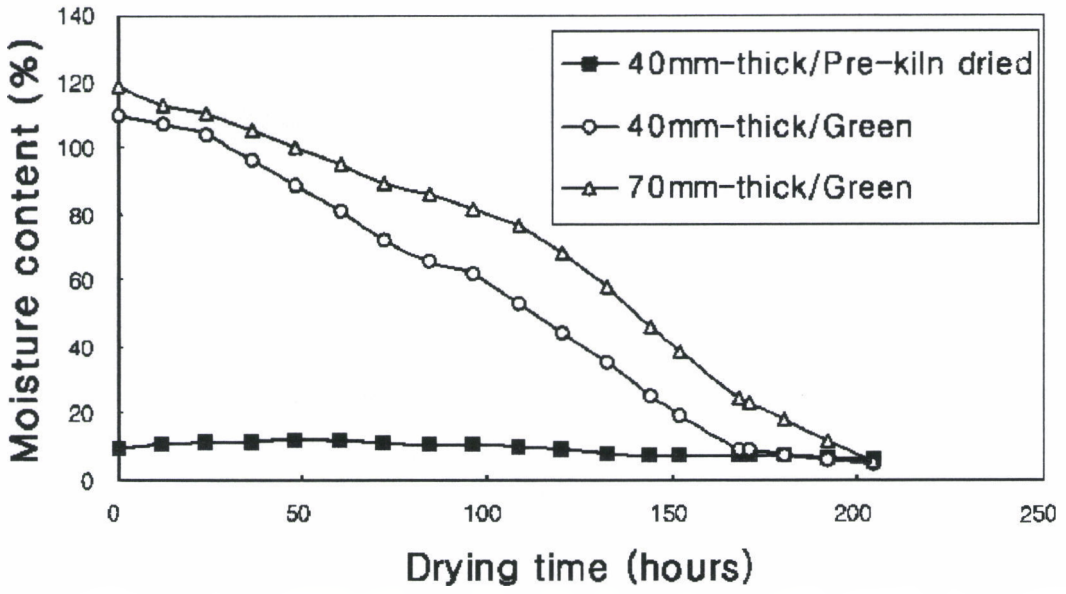
Drying time (hours)	0-48	48-72	72-96	96-120	120-144	144-204
Wood temperature (°C)	45	49	53	56	58	60

This schedule corresponds to the following chart



The drying kinetics obtained during tests is hereafter presented (from Pr. Lee's report):

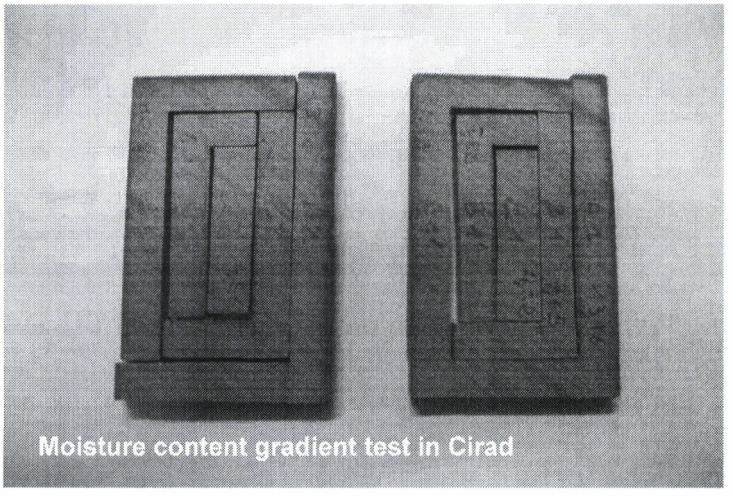
[7] Volume of boards to be dried.



The chart shows that both 400mm thick and 70 mm thick Iroko boards dried from green to around 6% in 8 to 9 days.

223 - Moisture content (MC) gradient across the section

Considering such a rapid drying process, it is of first importance to check the homogeneousness of the residual moisture content inside wood: high moisture content gradient across the section could lead to further damage in the construction caused by moisture content variations inside wood at the level of the final products.


Moisture content gradient test in Cirad

Moisture content distribution tests performed after drying experiments have shown that difference of moisture between outside part ("shell") and core is 0.8% for 40mm thick boards and 2.2% for 70mm thick boards.

It shows that an equilibrium step is necessary after drying in order to make moisture content more homogeneous across the section.

Complementary similar tests performed in CIRAD after the mission on specimens obtained from the sawmill (see photo above) have given the following results:

Average MC (%) across the section (60x100mm)	Outside part	Intermediate	Inside part	$\Delta_{tot.}$ MC
Specimen 1	7.3	8.4	9.1	1.8
Specimen 2	7.6	8.2	8.8	1.2

The specimens collected in the sawmill have been more stabilized that the ones tested just after drying tests in Korea. That can explain the lower moisture content difference from inside to outside.

224 - Comments on the drying technique selected for the Iroko project

The drying technique selected for the project is well known, well tried and tested, and generally allows to obtain good quality results: homogeneous drying, low level of drying stresses, good stability of the boards.
This technique is the most often used by secondary processing wood firms for the manufacturing of high added-value interior products (upmarket furniture, flooring, cabinetwork items) when wood moisture content in service must be low.
Generally, this technique is not used for sawn wood because it is very expensive.

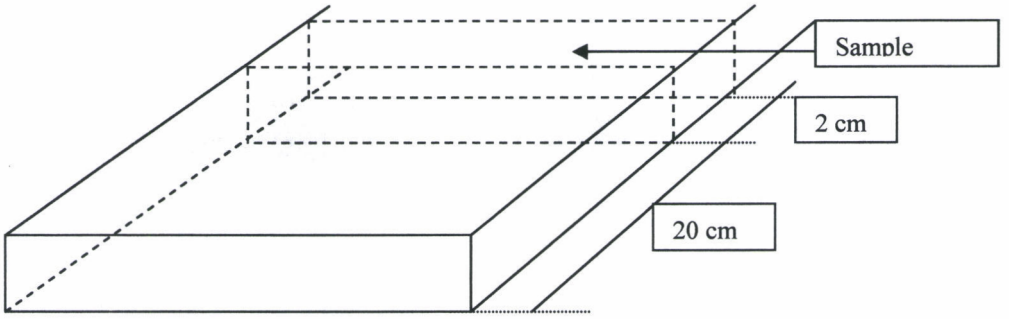
RECOMMENDATIONS

* Even if the Wood Drying Laboratory in charge of the drying process for Iroko well masters the RFV technique, a Wood Quality Control (QC2) must be set up after drying so that drying quality is checked; the following parameters must be measured:

- average moisture content,
- moisture content variations between boards,
- moisture content gradients across the section.

These drying quality parameters will be measured on samples removed from Iroko boards or with the help of a hygrometer.
The first technique takes up more time than the second one but is more reliable.
Hygrometer must be well calibrated according to the tested wood species (Iroko) (Hygrometer specifications supplied with the hygrometer must be taken into account).
These two test methods can be simultaneously used: hygrometer for more systematic measurements, laboratory tests on samples to regularly check hygrometer measurements (see scheme hereafter)[8].

[8] Wood sampling procedure for moisture content measurements:
- Samples must be taken in one or two boards inside a batch of boards, at least at 20cm from the ends of the board.
- Each sample corresponds to a 2 cm thick cross-section of the board (see scheme hereafter).
- After crosscutting, the samples must be quickly weighed with the help of precision scales (with an accuracy to within 0.1 gram).
- If immediate weighing is not possible, sample must be plastic film-wrapped in order to avoid evaporation before weighing.



Sampling procedure

* For interior glued-laminated products, the moisture content to obtain depends on glue manufacturer specifications (see complete specifications given by the glues manufacturers in annex):
10 +/- 3% for Koyo Bond KR-134,
8 to 12% for PI-111 Oshika (conditions applied during reference tests),
5 to 10% for TV-2L Oshika (conditions applied during reference tests).

* The variation of moisture content between boards to be bounded must be as low as possible. As a rule, **the moisture content of two adjoining strips should not differ by more 2 %.**

23 - MACHINING (PLANNING AND SIZING)

These operations included in the general process of glued-laminated boards manufacturing are carried out in the workshop of Kyungmin Industrial Co, Ltd (Kmbeam).

RECOMMENDATIONS

* As previously specified in the paragraph concerning sawing, dried boards must have a 4 to 6 mm "overthickness" in order to have a smooth planning without unevenness afterwards

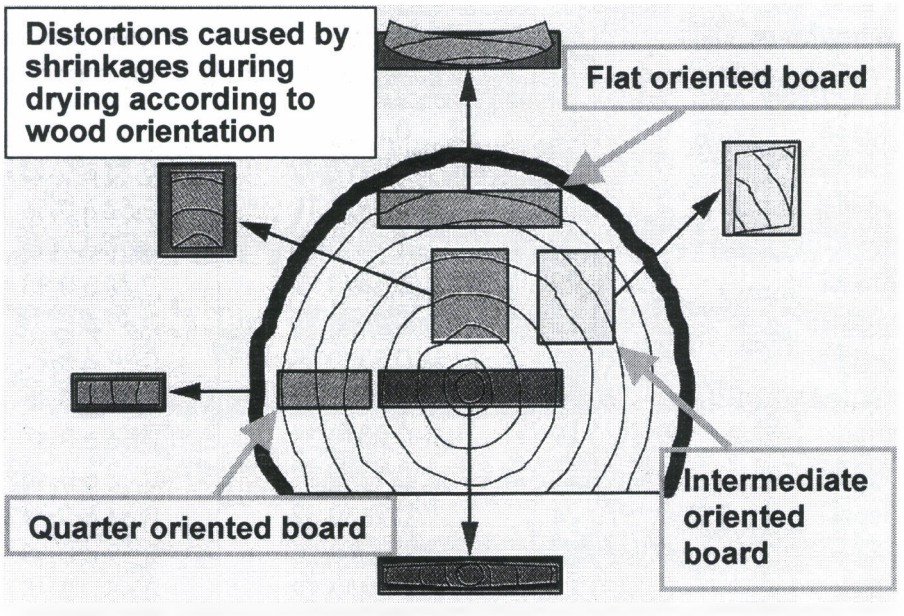
* The surfaces of the boards must be smooth; the unevenness value must be less than half of the capacity of the glue line thickness.
The unevenness comprises the wave effect of the rotating tools as well as the thickness tolerances within a board.
The surfaces must also be flat: the pressure applied by the press machine must set off the bow and warp of the boards; this can be achieved if the thickness of the boards is suitable.

- After weighing when green, samples are put into an oven at 103°C (European standard) during 48 hours so that wood is oven dried (0% MC).
- MC = [(green weigh) – (oven dried weigh)] / [oven dried weigh]

* Every time planning tools are changed, and at every shift rotation, the boards thickness must be measured all along their length with the help of a calliper rule.
A necessary adjustment must be made (complete setting of the tools and rejection of the non-complying lots of test pieces). The section of each piece must be perfectly rectangular to insure good quality gluing.

* For best results and optimum bounding strength, **planning should take place within 24 hours before gluing**.
During this time, the boards must be kept in a dry place **(dust free and wet free)**. In practice, pieces of timber (boards) must be kept in independent premises for bounding operations. In the case of Kmbeam, precautions must be especially taken in this matter.

*** Wood strips orientation before finger jointing**
As far as it is possible, due to wood shrinkage difference between radial direction and tangential direction[9], two strips to be jointed should have similar orientation (see scheme below):
flat oriented strip + flat oriented strip
or
intermediate oriented strip + intermediate oriented strip
or
quarter oriented strip + quarter oriented strip



Such a match of the strips is not easy to organize at an industrial processing level; however, it will need to strive for this way to do; at least, it is needed to avoid jointing fully opposite oriented strips, i.e. flat oriented strip + quarter oriented strip.

[9] For Iroko: average radial shrinkage: 3.5% - average tangential shrinkage: 5.4%

* After machining and before gluing, a continuous and rigorous Wood Quality Control (QC3) must be performed; all wood defects should be eliminated during machining operations and only clear wood must be used for glued-laminated products manufacturing:
In particular, the pieces of wood with the following defects must be rejected:

- Knots
- Slope of grain > 3%
- Sapwood
- Wane and other sawing defects
- Insect holes and decay
- Shakes and splits
- Wrap: spring, cup, and twist (slight bow can be accepted because recovered during flat pressing)

24 - GLUED LAMINATED BOARDS MANUFACTURING

241 - Selection of the adhesive

The glues selected by the manufacturer are Koyo bond KR-134 (Aqueous Polymer Isocyanate resin) for laminating and Oshika Corporation TV-2L or PI-111 (Polyvinylacetate PVA resin, without hardener) for finger jointing. Further to demand of complementary information to Koyo Sangyo Co Ltd, this firm mentioned the possible use of "*KR-7800 + AJ-1 because this glue type is to laminate for construction beams or difficulty bonding wood... KR-134 is for general bonding use and KR-7800 is basically same directions for use as KR-134*" (see full text in annex).
As mentioned at the end of this chapter (page 16), technical connections between the glued-laminated products manufacturer and the glues manufacturers (or suppliers) are highly recommended.

Initially, technical specifications (technical report) have been supplied for KR-134, and only chemical compositions were available for Oshika Corporation glues. **Complementary data (gluing parameters) have been asked to the glues manufacturers[10]. This parameters later supplied by the glues manufacturers are given in the following paragraphs. Full specifications are given in annex.**

[10] ambient temperature, maximum/minimum acceptable wood moisture content, mixing ratio, spread rate (single or double spreading? In the second case, rate on each side?), open assembly time / closed assembly time and consequently total assembly time, pressure (kg/cm²) and pressure time, curing time.

242 - Preparation of the mix

The resin and the hardener shall be mixed in accordance with the specifications of the glue manufacturer.
The mix shall be homogeneous and the viscosity shall comply with the specifications of the glue manufacturer.
Mixing proportions for both KR-134 glue and KR-7800 glue are:

- resin: 100 parts by weight
- hardener: 15 parts by weight

243 - Production of mix

*** Pot life**

KR-134: about 60 minutes for an ambient temperature of 25°C.
PI – 111: 60 minutes (at 20°C) after hardener is added.

*** Amount of glue to apply (spread rate)**

The amount of glue per area unit shall comply with the glue manufacturer's specifications.
For KR-134 : 250-280 g/m^2 (single spreading) and 125-140 g/m² on each side when double spreading.

*** Open assembly time and closed assembly time**

Open assembly time: time between application of the glue and contact of boards.
Closed assembly time: time between application of the glue and application of the pressure.
This time shall not exceed the glue manufacturer's recommendations.
KR-134:
- open assembly time: within 1 minute
- closed assembly time : 15 minutes at 10°C, 10 minutes at 20°C, 7 minutes at 30°C.

PI-111:
- closed assembly time: within 10 minutes

*** Pressure**

The pressure to be applied shall not be less than the level specified by the glue manufacturer (see annex):
15 kg/cm² for KR-134,
0.8 to 1.5 MPa (i.e. 8 to 15 kg/cm²) for PI-111.
Pressing time for KR-134:
Less than 20°C: more than 4 hours.

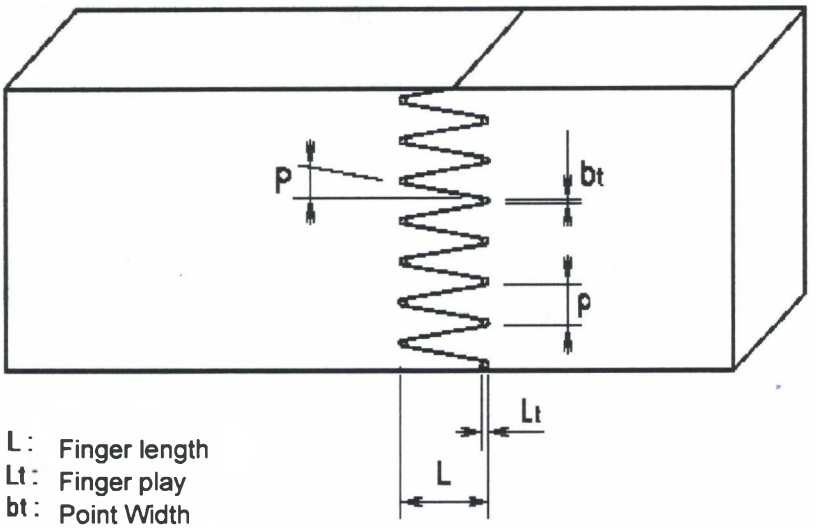
Over 20°C: more than 2 hours.
Pressing time for PI-111: more than 30 minutes at 20°C.
Note: Koyo Sangyo specifies that manufacturing tests must be performed because the pressing time is a very important gluing parameter to take into account (see page 2 in Koyo Sangyo annex).

RECOMMENDATIONS

Finger joint profile

For high hardness and high specific gravity wood species such as Iroko, it is recommended to use not too much long "fingers" (of the finger-joints) in order to improve gluing performance.
A finger length close to 15mm is appropriated, but 20mm is suitable too (finally proposed by the glued-laminated products manufacturer). Considering a classic finger-joint profile as presented on the chart below, its geometrical parameters are as follows (see parameters explanations on the chart hereafter):

Finger Length L (mm)	Finger Thread P (mm)	Point Width bt (mm)
10	3.7	0.6
15	**3.8**	**0.6**
20	6.2	1
32	6.2	1



L : Finger length
Lt : Finger play
bt : Point Width
P : Slope
p : Finger Thread

Quality control

During all the gluing process, a Quality Control (QC4) must be performed:

*** Wood moisture content control**
Moisture content of all the test pieces should be measured prior to the gluing operation; and the ones varying from the fixed average by more (or less) 2% should be rejected. These pieces should be dried again if MC too high, wet or re-conditioned if MC too low.
The glues manufacturer must supply data on optimum wood moisture content.

*** Temperature of the glue-laminating workshop**
Usually, workshop temperature during gluing must be maintained between 18°C and 20°C.
The information supplied by the glues manufacturers is as follow:
KR-134:
- ambient temperature: 5 to 35°C
PI-111:
- lumber temperature: 10 to 30°C
- work area temperature: 10 to 35°C

*** Gluing process**

- ***Mix manufacturing***

In case of discontinuous gluing, the relative proportion of the resin and the hardener (mixing ratio) should be measured either by mass or by volume and regularly checked; special care is required for this operation in order to keep gluing quality all along the manufacturing process period.

- Application of the glue

The amount of glue to be applied on the longitudinal faces must be measured on a regular basis, within a shift period (control by measurement of the mass of boards before and after glue application, or by measurement of thickness by means of special gauge).

- Cure of the glue

The pressure applied on the glue line must be controlled on the press machine (pressure dials properly calibrated for hydraulic-cylinders). The process must comply with the curing time specified by the glue manufacturer: more than 3 days at 20°C (or over) ambient temperature for KR-134.

*** Registration of the results of the quality control**

All the results of the quality control must be written down in a specific register.

*** Technical connection with the glues manufacturers (or glues suppliers)**

Beyond complementary technical information on gluing parameters CIRAD asked to the glues manufacturers, which will be supplied (when available) in parallel to this report, it is recommended that the glued-laminated boards manufacturer set up technical connection with the Japanese glues manufacturers (or suppliers). Such connections will be highly beneficial in order to take advantage of their specific know-how and experience on the glues to be used for Iroko.

*** Mechanical tests**

Even if glued-laminated boards have no structural function, gluing/manufacturing quality has to be checked through standard mechanical tests:

- bending tests to qualify finger-joints mechanical resistance,
- delaminating and shearing tests to qualify and check strips longitudinal gluing.

These tests can be performed in Wood Mechanics Laboratory – Chonbuk University (or other Mechanics Laboratory) using Korean standards.

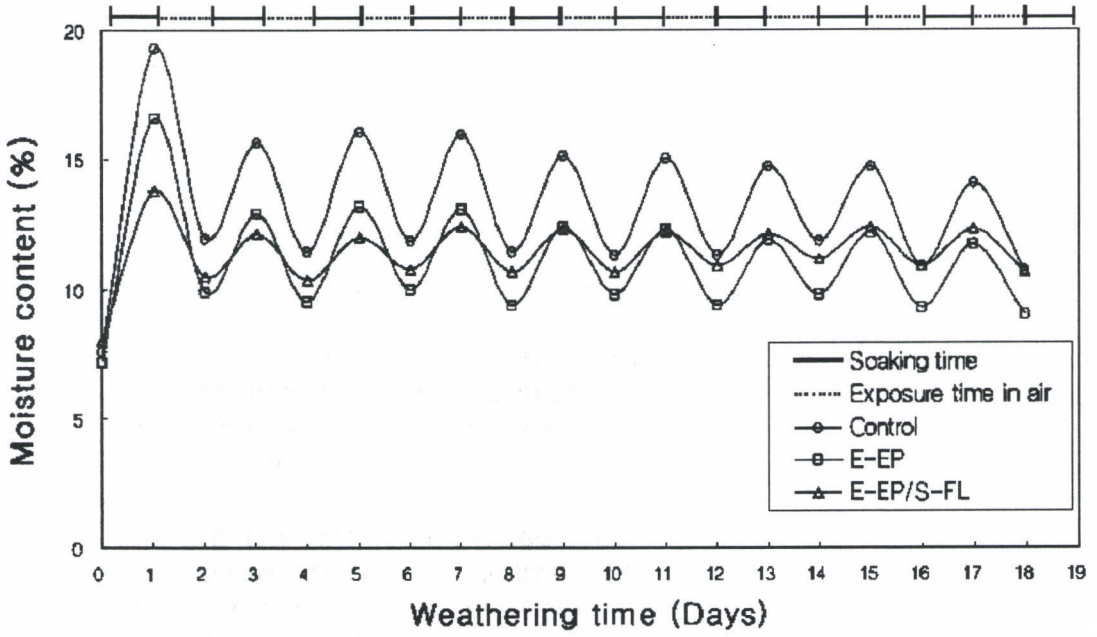
They have to be performed twice or three times during the glued-laminated boards manufacturing period (including one series when manufacturing is finished).

CIRAD proposes to complement these tests carried out in Korea by a series (on a few samples) to be carried out in the CIRAD's Mechanics Laboratory in Montpellier-France (for free) according to procedures defined in European standards (NF EN 385: Joint fingers bending test - NF EN 391: Delaminating test - NF EN 392: Shearing test).

25 - COATING, END-COATING AND AGING

Water surface treatment tests have been carried out in Chonbuk University in order to determine the treatment effect on wood hygroscopicity, water absorption and aging[11].
Tests procedures follow the Korean standards.
Surface coating and end-coating have been simultaneously tested by comparison with control samples.
All tests results are available in the Pr. Lee's report.
They show the positive effect of the treatment on :

- water absorption: significantly below the level observed for control samples,
- level of drying defects during accelerated aging test[12] (these tests: soaking period alternately with air drying period): no end-checks, no surface-checks and no warps on the treated specimens while these defects are frequent on control samples



The following chart gives a relevant representation of the positive effect of the tested treatment on water exchanges between wood and surrounding atmosphere.

COMMENTS AND RECOMMENDATIONS

*** Aging effect on wood color for exterior use**

At the end of the accelerated aging test (19 days), no wood discoloration is observed on the tested samples, neither on the control samples, nor on treated samples.

[11] Iroko has a good natural durability (resistance to decay, insects and termites, see Iroko technical sheet). Thus, it does not need any specific preservative treatment.
[12] During this test, wood samples are submitted to soaking periods alternately with air-drying periods.

The test duration is too short to lead to any significant and observable discoloration.
It must be specified that the color of any wood species used for exterior purpose will necessary change.
This phenomenon will take more or less time, the most often some months.
The phenomenon speed will depend on many factors: air humidity, sunshine (ultraviolet rays exposure is the main cause of wood color change), air pollution, and wood species.
In the present state of the knowledge on wood surface treatments, no finishing product avoiding permanently wood color change exists. For exterior uses, wood color change must be considered as a natural phenomenon, which is part of wood characteristics to be appreciated as such.

*** End-coating**

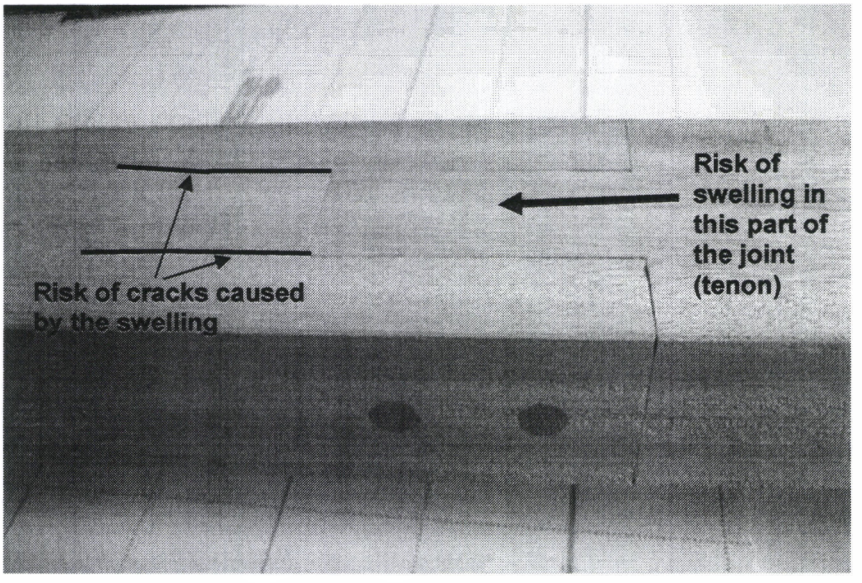
End-coating utilized for the test is an epoxy coating. Its effect on protection against water absorption is very significant because it constitutes a real waterproof film. However, its aging performance is limited because it is sensitive to ultraviolet rays.
Another end-coating product (more plastic) suited for end-coating wood beams can be recommended: Polyurethane Mastic: Componex WR, manufactured by Sikkens

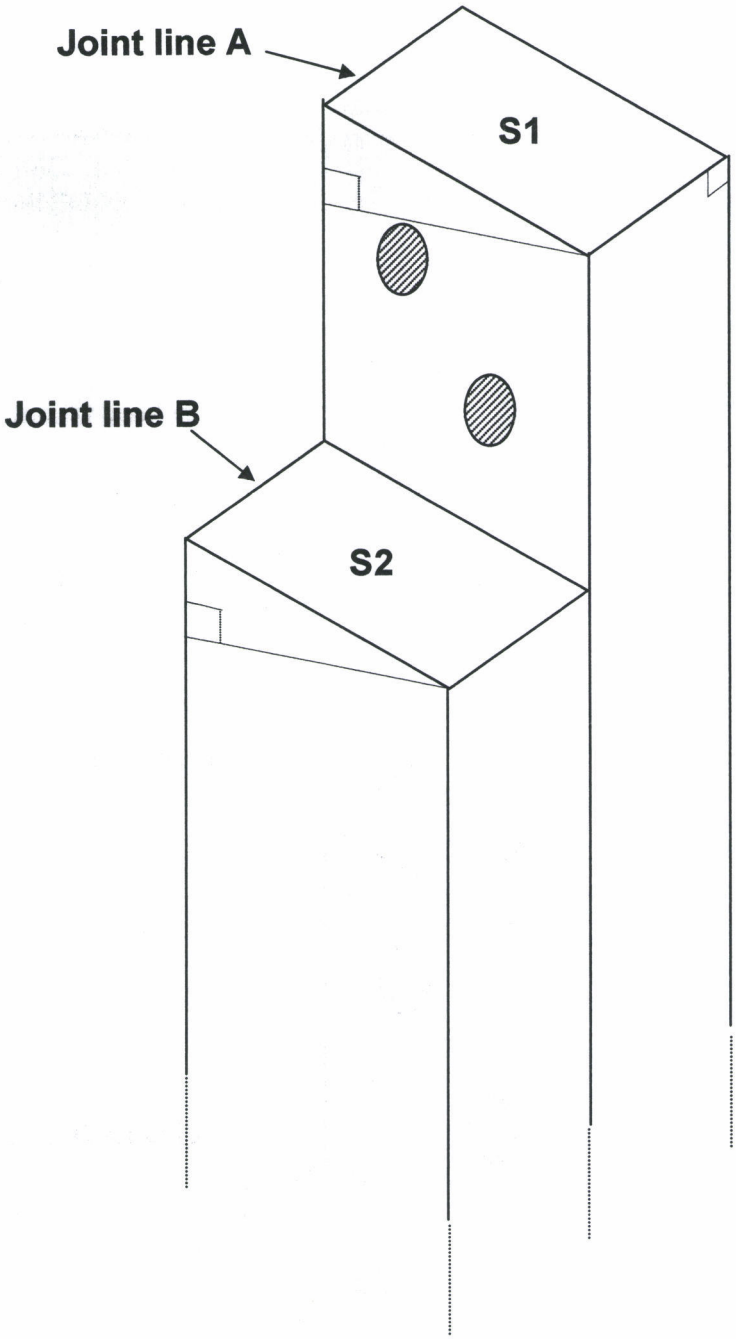
26 - BEAM FASTENING ALONG THE FAÇADE AND LONGITUDINAL JOINT PROFILE FOR EXTERIOR USE

The Iroko beams (7.3 m long) must be well fastened along the façade in order to avoid any possible distortion problems due to their long length. It is recommended to make an adequate number of fastening points: One fastening point each linear meter will allow to perfectly hold the beams against the façade.

Longitudinal joint profile for exterior beams

Glued-laminated technique will not be used for exterior façade. For the moment, mortise joint with swivel pins are planned (see photo of prototype opposite).
Such a mortise joint gives a good mechanical resistance to the beam, but risks of cracks exist due to the possible wood swelling phenomenon at the level of the central part of the joint where water could seep through without possible draining. Therefore, an other joint pattern is proposed as presented on the scheme below.





Advantages of this profile and comments:

- no risk of cracks due to damaging swelling because no "tenon" wedged between the two lateral parts of the joint as for the previous profile,
- the two cross-sections of the joint are not horizontal: if water seeps through at the level of joint line A or joint line B, draining towards outside is possible using gravity without any risk of water storage ("water trap") inside the joint (because the slopes of S1 and S2 are oriented from one (exterior) side to the opposite (exterior) side of the beam),

- the two swivel pins are not located on the same vertical line in order to avoid generating a low-resistance verticale line at the level of which splits and cracks could begin,
- wooden (Iroko) swivel pins or coach screw (possibly covered by wooden cap) can be equally used.

27 - GLUED-LAMINATED BEAMS STORAGE

Long lasting storage of the glued-laminated beams before fastening along the façade must be carrefully carried out in order to avoid:

- distortions caused by bad stacking up of the beams,
- humidity re-absorpion, especially at the level of the ends of the beams or close to the finger-joints.

During storage, Iroko glued-laminated beams can be protected by covers, but not perfectly airtight in order to avoid condensation phenomenon.

CONCLUSIONS / SYNTHESIS

The success of the project will depend on the good enforcement of the basic manufacturing specifications, the glues/gluing specifications, and the ***rule book*** at each step of the process:

SAWING

* For logs with specific defects (flattened section, general spiral grain), sawing pattern must be adjusted and log orientation / position in the carriage appropriated in order to obtain good quality sawn products.
* First wood quality control (QC1) must be performed after sawing to eliminate most important defects.
* Sawing must be performed with appropriate "overthickness" taking into account drying shrinkage and dimensions reductions during planning.

DRYING

* RFV drying technique will shorten drying time and insure a good drying quality of the boards.
* After drying, a second Wood Quality Control (QC2) must be performed to check average moisture content, moisture content variations between boards, moisture content gradient across the section.
* Optimum wood moisture content (depending on the glue) must be applied.
* The moisture content of two adjoining strips should not differ by more 2 %.

MACHINING (PLANNING AND SIZING)

* The surfaces of the boards must be smooth and flat; the unevenness value must be less than half of the capacity of the glue line thickness.
* Every time planning tools are changed, and at every shift rotation, the boards' thickness must be measured all along their length.
* The section of each piece must be perfectly rectangular to insure good quality gluing.
* Boards thickness must be regularly controlled (measurement made with the help of a calliper rule).
* For best results and for optimum bounding strength, planning should take place within 24 hours before gluing. During this time the boards must be kept in a dry place (dust-free and wet-free).
* As far as it is possible, two strips to be jointed should have similar orientation.
* After machining and before gluing, a third Wood Quality Control (QC3) must be performed in order to select only clear wood for glued-laminated products manufacturing.

GLUED LAMINATED BOARDS MANUFACTURING

* An appropriate finger joint profile must be used (not too much long finger).
* During the whole gluing process, a fourth Quality Control (QC4) must be performed for:
  - wood moisture content,
  - workshop temperature,
  - mix manufacturing (mixing ratio),
  - spread rate,
  - gluing pressure,
  - spread rate,
  - cure of the glue.
* Mechanical tests are recommended to check gluing and manufacturing quality.

COATING

* Coating will limit exchanges between wood and surrounding atmosphere.
* Appropriated long-life plastic end-coating must be applied at the end of the beams (exterior uses), such as the polyurethane mastic "Componex WR" manufactured by Sikkens.

BEAM FASTENING ALONG THE FAÇADE AND LONGITUDINAL JOINT PROFILE FOR EXTERIOR USE

* It is recommended to make an adequate number of fastening points: one fastening point each linear meter will allow to perfectly hold the beams against the façade.
* An appropriated joint profile must be selected for exterior beams, avoiding any risk of "water trap" inside wood (see proposed profile).

A key factor of the success of the project will be the good coordination between the different partners successively involved into the operation, and their synchronization. Sawing operation should take less than 3 weeks.

The longer operation will be drying: considering 13m^3 drying capacity and a 11 days drying cycle (including handling time), a basis of around 90 days must be considered for 100m^3 sawn wood drying.

Constraints of time are obviously of first importance for such an upmarket project. However, it would seem really judicious to give priority to manufacturing quality.
Any undue hurry or lack of respect of the rulebook in the manufacturing chain would risk leading to irreversible damages.

ANNEX

Iroko technical sheet (2 pages)

Koyo Sangyo Co ltd KR-134 glue specifications (2 pages)

Oshika PI-111 glue specifications (6 pages)

Oshika TV-2L glue specification (4 pages)

Common name:	IROKO
Family:	MORACEAE
Scientific name(s):	Milicia excelsa Milicia regia

LOG DESCRIPTION

Diameter:	from 80 to 100 cm
Thickness of sapwood:	from 5 to 10 cm
Floats:	no
Durability in forest :	Moderate (treatment recommended)
Note:	Yellow brown to more or less brown with golden glints. Ribbon like aspect on quartersawn, darker veins on slab. Possible presence of very hard white calcium carbonate deposits, sometimes surrounded by a darker colour.

WOOD DESCRIPTION

Colour:	Yellow brown
Sapwood:	Clearly demarcated
Texture:	Coarse
Grain:	Interlocked
Interlocked grain:	Slight

PHYSICAL PROPERTIES

Physical and mechanical properties are based on mature heartwood specimens. These properties can vary greatly depending on origin and growth conditions.

	mean	standard deviation
Density *:	0.64 g/cm3	0.06
Monnin hardness*:	4.1	0.9
Coef of volumetric shrinkage:	0.44 %	0.07
Total tangential shrinkage:	5.4 %	0.7
Total radial shrinkage:	3.5 %	0.4
Fibre saturation point:	23 %	
Stability:	Moderately stable	

MECHANICAL PROPERTIES

	mean	standard deviation
Crushing strength *:	54 MPa	6
Static bending strength *:	87 MPa	15
Modulus of elasticity *:	12840 MPa	2496

(* : at 12 % moisture content ; 1 MPa = 1 N/mm2)

NATURAL DURABILITY AND TREATABILITY

Fungi and termite resistance refers to end-uses under temperate climate.
Except for special comments on sapwood, natural durability is based on mature heartwood.
Sapwood must always be considered as non-durable against wood degrading agents.

Fungi:	Class 1-2 very durable to durable
Dry wood borers:	Durable; sapwood demarcated (risk limited to sapwood)
Termites:	Class D - Durable
Treatability:	4 - not permeable
Biological hazard class*:	3 - not in ground contact, outside exposed
Note:	This species is listed in the European standard NF EN 350-2. The heartwood does not cover the biological hazard class 4 required for end-uses in contact with permanent humidity (example: contact with ground). On the other hand, if the constructive system is well-drained, without water trap, this species can be used outside without any treatment. Heartwood is hardly permeable to preservative products.

* ensured by natural durability (according EN standards).

COUNTRIES - LOCAL NAMES

Countries	Local names
Angola	MOREIRA
Benin	LOKOTIN
Cameroon	ABANG
Congo	KAMBALA
Côte d'Ivoire	IROKO
Dem Rep of Congo	KAMBALA
Dem Rep of Congo	LUSANGA
Dem Rep of Congo	MOKONGO
Dem Rep of Congo	MOLOUNDOU
Equatorial Guinea	ABANG
Gabon	ABANG
Gabon	MANDJI
Ghana	ODOUM
Guinea	SIMME
Liberia	SEMLI
Mozambique	MUFULA
Mozambique	TULE
Nigeria	ROKKO
Sierra Leone	SEMLI
Belgium	KAMBALA

IROKO

REQUIREMENT OF A PRESERVATIVE TREATMENT

Against dry wood borer attacks:	Does not require any preservative treatment
In case of temporary humidification risk:	Does not require any preservative treatment
In case of permanent humidification risk:	Does not require any preservative treatment

DRYING

Drying rate:	Normal
Risk of distortion:	Slight risk
Risk of casehardening:	No
Risk of checking:	No risk or very slight risk
Risk of collapse:	No

Possible drying schedule

M.C. (%)	Temperature (°C) dry-bulb	wet-bulb	Air humidity (%)
Green	50	47	84
40	50	45	75
30	55	47	67
20	70	55	47
15	75	58	44

This shedule is given for information only and is applicable to thickness < 38 mm.
It must be used in compliance with the code of practice.
For thickness from 38 to 75 mm , the air relative humidity should be increased by 5 % at each step.
For thickness over 75 mm , a 10 % increase should be considered.

Note: Spacer sticks often leave marks. A vertical surface drying is recommended before stacking.

SAWING AND MACHINING

Blunting effect:	Fairly high
Sawteeth recommended:	Stellite-tipped
Cutting tools:	Tungsten carbide
Peeling:	Good
Slicing:	Good
Note:	The calcium carbonate deposits in some logs severely damage tools. Very irritant sawdust. Risks of tearing (irregular grain).

ASSEMBLING

Nailing / Screwing:	Good
Gluing:	Correct

END-USES

Main known end-uses; they must to be implemented according to the code of practice.
Important remark: some end-uses are mentionned for information (traditional, regional or ancient end-uses).

Note: Filling recommended. Wood sometimes resistant to wood finish product: IROKO contains a non-saturated phenolic compound, the chlorophorin, which is a powerful anti-oxidant. It is then necessary to use paints or varnishes without free siccative oil, it is to say, synthetic resin based paints or varnishes such as vynilic paints or polyurethane varnishes that can also be used as undercoat.

Exterior joinery
Interior joinery
Flooring
Sliced veneer
Ship building (planking and deck)
Interior panelling
Cabinetwork (high class furniture)
Turned goods
Current furniture or furniture components
Light carpentry
Cooperage
Glued laminated
Stairs (inside)
Veneer for interior of plywood
Veneer for back or face of plywood
Vehicle or container flooring
Bridges (parts not in contact with water or ground)

ISHIKAWA LK-BUILDING 1-9-9, KAJI-CHO,
CHIYODAKU-TOKYO 101, JAPAN

TEL: 81-3-3252-1701
FAX: 81-3-3252-1707
DATE: 1st. February, 2005

To : Forest Products Programme
Attn : Mr. Jean Gerard

+33-467-615-725 2 pages (including this sheet)

Thank you for your inquiry of fax.
Regarding your questions, you are considering our glue " KoyoBond KR-134 + AJ-1 ".
I am pleased to introduce our " KR-7800 + AJ-1 " because this glue type is to laminate for construction beams or difficulty bonding wood.
Our KR-134 is for general bonding use. And KR-7800 is basically same directions for use as KR-134.

These answers for your questions are as follows,

Q1. Ambient temperature(minimum/maximum acceptable temperatures in the gluing workshop)?

A1. 5～35℃

Q2. Minimum/maximum acceptable wood moisture content?

A2. 10±3% M.C.

Q3. Mixing ratio?
A3. KR-7800 / AJ-1 : 100 / 15 also KR-134 / AJ-1 : 100 / 15

Q4. Spread rate?

A4. 250～280 g/m2・・・single spreading,

Therefore double spreading, 125～140 g/m2 on each side.

Q5. Open assembly time? Closed assembly time?

A5. Open assembly time is within 1 minute.

Closed assembly time is

ambient temperature 10℃・・・ 15 minutes

20℃・・・ 10 minutes

30℃・・・ 7 minutes

Q6. Pressure and pressure time?

A6. Pressure is 1 5 kg/cm2

Pressure time is

ambient temperature 2 0℃ or less・・・ more than 4 hours

ambient temperature 2 0℃ or over・・・ more than 2 hours

This condition is most important. The case of such wood species as TEAK, it is difficult to laminate. Please trial manufacture according to your standard.

Q7. Curing time?

A7. ambient temperature 2 0℃ or over・・・ more than 3 days

If you have any questions, please contact me.

KOYO SANGYO CO., LTD.

MASAMITSU ITOH
KOYO BOND DIVISION

OSHIKA
Adhesives & Construction materials

TECHNICAL INFORMATION

P.I. BOND P I − 1 1 1

Water based polymer - isocyanate adhesive for wood

OSHIKA CORPORATION

1-4-21 FUNADO, ITABASHI-KU, TOKYO
174-0041, JAPAN

TEL. 81-3-5916-8845
FAX. 81-3-5916-8856

P.I. BOND P I − 1 1 1 is a water based polymers and isocyanate adhesive system that is suitable for manufacturing structural or non-structural laminated lumbers.

1. CHARACTERISTIC

(1) Easy to wash up due to its water-based property and easy workability.

(2) Offers superior initial bond and allows short pressing cycle.

(3) Offers high water durability and meets manufacturing structural laminated lumbers.

2. FIELDS OF APPLICATION

(1) Non-structural laminated lumber

(2) Soft wood structural laminated lumber

(3) Bonding wood materials

3. TYPICAL PHYSICAL PROPERTIES

Product	P.I. BOND PI-111	Hardener H-3M
Appearance	Milky white viscous liquid	Dark brown homogeneous liquid
Non-volatile Content (%)	60	-
Viscosity (Pa·s/25 ℃) *	10	0.17
pH	6.4	-

These are measured values, not criteria.
* Viscometer : Brookfield Model H (20 rpm)

4. INSTRUCTIONS FOR USE

(1) Glue mixing

PI Bond PI-111	: 100 parts by weight	) mixing ratio
Hardener H-3 M	: 15 parts by weight	)

Note)

- Weigh accurately by mass and mix thoroughly until the mixture becomes homogeneous cream-color.
- Glue should be mixed at a time to be used up within a pot life.

(2) Pot life

60 minutes (20 ℃), after Hardener added)

(3) Bonding conditions

Lumber temperature	: 10 to 30 ℃)
Work area temperature	: 10 to 35 ℃)
Glue spread rate	: 220 to 300 g/m²)
Closed assembly time	: Within 10 minutes)
Pressing pressure	: 0.8 to 1.5 MPa)
Pressing time	: More than 30 minutes at 20 ℃)

(4) Other information

- Trimming and second process must be done after the following day.
- It takes at least seven days to reach final bond strength (water durability).
- Mixed glue should be used at 10 to 35 ℃.
- For establishing gluing standard it is necessary to ensure by using actual materials which shall be adopted in the production.

5. PERFORMANCE DATA

5-1. Compression shear strength (JIS K 6806)

Testing method	Results
Original state	1991 [203] (93)
Warm water resistance	833 [85] (0)
Repitive boiling	628 [64] (0)

Shear strength : N/cm² [ ] : kgf/cm² ( ) : wood failure %

Bonding conditions

Material tested	: Birch ; density 0.76, moisture content 8 to 12 %)
Glue spread rate	: 270 g/m²
Pressing pressure	: 1.2 MPa
Pressing time	: 16 hours
Work area conditions	: 25 ℃, 63 % RH
Conditioning	: 5 days at 18 to 26 ℃

OSHIKA CORPORATION

5-2. Bond performance of structural laminated lumber

Testing method	Douglas fir	Red wood	Spruce
Immersion delamination test	0 %	0 %	0 %
Boiling water soak delamination test	0 %	0 %	0 %
Vacuum pressure treatment test	0 %	0 %	0 %
Block shear test	104 (100)	95 (100)	88 (100)

Soak test : % delamination
Shear strength : kgf/cm² ( ) : wood failure %

5-3. Bond performance of non-structural laminated lumber

Testing method	Oak	Elm	Ash
Immersion delamination test	0 %	0 %	0 %

Soak test : % delamination

5-4. Gluing conditions
Material tested

Lumber species	Thickness (mm)	No. of ply	Density	Moisture (%)
Douglas fir	21	5	0.50 ~ 0.58	7 ~ 9
Red wood	21.5	5	0.45 ~ 0.55	7 ~ 9
Spruce	21.5	5	0.40 ~ 0.52	6 ~ 8
Oak	24	5	0.63 ~ 0.72	6 ~ 8
Elm	27	5	0.51 ~ 0.58	6 ~ 8
Ash	27	5	0.60 ~ 0.70	6 ~ 8

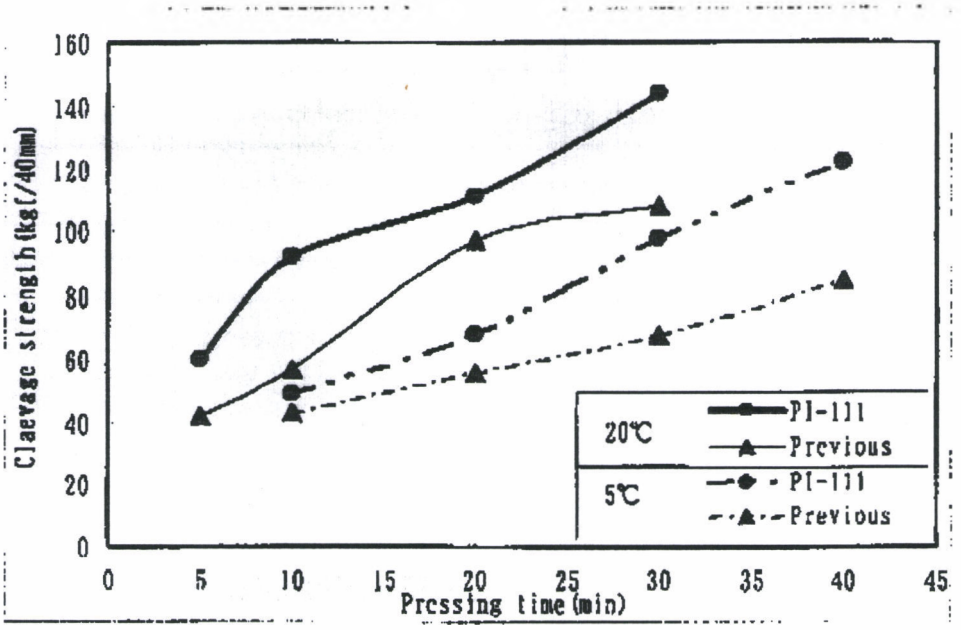
Glue mixing : P.I. BOND PI-111 100 parts / Hardener H-3 M 15 parts
Glue spread rate : 250 g/m²
Pressing pressure: 1.0 MPa (douglas fir, red wood, spruce)
: 1.2 MPa (oak-A & B, Ash)
Pressing time : 40 minutes (20 ℃)

5-5. Gluing conditions
All test were carried out in accordance with JAS (Japanese Agricultural Standard).

OSHIKA CORPORATION

6. INITIAL BONDING PROPERTY

Pressing time vs Cleavage strength



Gluing conditions

Materials bonded	: Birch and Rubber wood
Glue mixing	: P.I. BOND PI-111 100 parts / Hardener H-3 M 15 parts
Glue spread rate	: 250 g/m^2
Pressing pressure	: 1.0 MPa
Pressing time	: 5, 10, 20, 30, 40 minutes
Work area temp.	: 5, 20 ℃

Testing procedure

After pressed, apply a vertical load to specimen that is 40 mm wide, then record a load when ruptured.

OSHIKA CORPORATION

8. PRECAUTIONS

BASE RESIN

May cause irritation or inflammation to skin.

HARDENER

This material contains more than 1 % of 4, 4' - diphenylmethanediisocyanate (MDI).
Skin contact or inhalation may cause skin irritation or toxicosis.

Refer to MSDS in handling

1. Use with local exhaust ventilation when used inside room.
2. Handle the container carefully in order not to spill the material.
3. For spills, dike for further disposal and try to collect as much spills as possible. After collected, keep the material in container.
4. Wear adequate protective goggles and protective gloves ,and chemical cartridge respiratory if required.
5. If the material gets in eyes immediately wash eyes with copious amount of water for at least 15 minutes. Seek medical attention if irritation persist.
6. If the material contacts on skin immediately wash with copious amount of water and seek medical attention if irritation persist.
7. For vapor inhalation or ingestion, immediately seek medical attention.
8. If clothing is polluted immediately wash with copious amount of water. Launder clothing before reuse.
9. Keep the material at 5 to 35 ℃. Keep away from direct sunshine and other chemicals.
10. Tightly seal the container after use.
11. Keep out of reach of children.
12. Do not use this material for other purpose besides bonding.
13. Follow the instruction in MSDS when disposing container.
14. Mix well before use since long term storage may cause separation or sedimentation.

NOTICE

The information given in this bulletin are based on our research and the recommendations and suggestions herein are made without guarantee or representation as to results.

Adequate tests have to be made in your laboratory or plant to determine if this product meets all of your requirements.

Consult OSHIKA SALES BRANCH for further applications.

OSHIKA
Adhesives & Construction materials

TECHNICAL INFORMATION

SHINKOBOND TV－2 L

High Performance Polyvinyl Acetate Emulsion Adhesive

OSHIKA CORPORATION

1-4-21 FUNADO, ITABASHI-KU, TOKYO
174-0041, JAPAN

TEL. 81-3-5916-8845
FAX. 81-3-5916-8856

Shinkobond TV-2L is a fast setting glue for finger-jointing.
Shinkobond TV-2L meets many applicators as this has low viscosity and has therefore excellent liquidity.

1. CHARACTERISTIC ADVANTAGES

(1) TV-2L has higher bond performance, higher heat resistance and higher water resistance than other general PVAc (polyvinyl acetate).

(2) TV-2L can be uniformly spread into all finger joints without starved glue due to good liquidity.

(3) TV-2L sets very quickly, providing shorter interval to further cutting process and is therefore suitable for automated production line. This leads to simplifying of machines and labor saving.

2. FIELDS OF APPLICATION

(1) Finger jointing for nonstructural laminated lumber.
Notice :
Ensure bond performance by preliminary testing since different materials will give different reults.

3. TYPICAL PHYSICAL PROPERTIES

Appearance	White emulsion
Viscosity (Pa·s/25 ℃) *	1.2
Non-volatile Content (%)	59
pH	5.5

These are measured values and not criteria.
* Viscosity was measured by Brookfield viscometer (20 rpm, spindle #3)

OSHIKA CORPORATION / R&D DEPARTMENT

4. INSTRUCTIONS FOR USE

TV-2L is a one-component glue, therefore any hardener or cross-linker is not required

5. PERFORMANCE DATA

Bond strength in shear by compression loading

Conditioning / Glue tested	1 day	2 day	6 day
TV-2L	586 (70)	527 (90)	672 (90)
PVAc (55% NV)	386 (10)	404 (20)	399 (10)

Labo-testing conditions

Material	: Ash (solid lumber)
Lumber thickness	: 28 mm
Moisture content	: 5 to 10 %
Finger length	: 11 mm
Finger pitch	: 4 mm
Spread rate	: Sufficient glue at finger joints
Assembly time	: Within 1 minute
Pressing pressure	: 70 kgf/cm^2
Pressing time	: 2 to 3 seconds
Conditioning	: at 20 ℃ & 65 % RH for 1, 2 and 6 days

OSHIKA CORPORATION / R&D DEPARTMENT

6. PRECAUTIONS

May causes irritation to skin

Refer to MSDS in handling

1. Use with local exhaust ventilation when used inside room.
2. Handle the container carefully in order not to spill the material.
3. For spills, dike for further disposal and try to collect as much spills as possible. After collected, keep the material in container.
4. Wear adequate protective goggles and protective gloves or chemical cartridge respiratory if required.
5. If the material gets in eyes immediately wash eyes with copious amount of water for at least 15 minutes. Seek medical attention if irritation persist.
6. If the material contacts on skin immediately wash with copious amount of water and seek medical attention if irritation persist.
7. For vapor inhalation or ingestion, immediately seek medical attention.
8. If clothing is polluted immediately wash with copious amount of water. Launder clothing before reuse.
9. Keep the material at 5 to 35 ℃. Keep away from direct sunshine and other chemicals.
10. Tightly seal the container after use.
11. Keep out of reach of children.
12. Do not use this material for other purpose besides bonding.
13. Follow the instruction in MSDS when disposing container.

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We recommend that adequate tests to be made in your laboratory or plant to determine if this product meets all of your requirements.

Consult OSHIKA R&D DEPARTMENT or SALES BRANCH for further applications.

OSHIKA CORPORATION / R&D DEPARTMENT