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DEVELOPMENT OF MODULAR WOODEN BRIDGES

SI/CHI/84/803

CHILE

Terminal Report*

Prepared for the Government of Chile
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of Christopher Mettem,
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BACKGROUND

The Bio-Bio region is well forested and has well-developed forest industries based on plantations of Pinus radiata. The University of Bio-Bio has considerable experience in many aspects of wood technology and has a well equipped carpentry and metal workshop. Its programme includes the mandate to search for new uses for timber and to act as a catalysing agent for development in this field. However, it lacks experience with the system of prefabricated modular wooden bridges, which have been developed by UNIDO.

On the other hand, a programming mission of UNIDO reported that, in Bio-Bio alone, there were some 1300 public road bridges (in an area of 50000 km^2), of which 60 percent have a length of 18-21m - the ideal span for UNIDO's system. Also, about 150 bridges must be erected each year on private roads. Very often floods and landslides destroy bridges, which naturally must be replaced. Thus the government's Road Department engineers considered that UNIDO's system offered a means of helping to solve their perennial problems of bridge construction and replacement. Two engineers from the University of Bio-Bio were awarded one-month fellowships to investigate the system in Honduras, where UNIDO helped to introduce these bridges under its project DA/DC/HON/81/002.

Their reports were promising, and the guidance of international experts was requested to ensure full transfer of the technology, and to advise on development of other wood structures.

The University stated that it was particularly anxious to build up its timber strength testing facilities, and to become able to provide advice and training to industry on this subject. This was appropriate owing to its proximity to and good relations with the sawmilling industry of the Bio-Bio region.

TERMS OF REFERENCE

The expert was required to take part in the project which emanated from the background explained above. The overall objective of the project was to introduce into the country a new use for timber and to contribute to improving the road network, especially in rural and forest areas. He was to advise on the establishment of the University of Bio-Bio (UBB) as a Timber Engineering development centre for the region.

An initial mission took place from 4-29th August 1986, and a report was issued (1) (SI/CHI/84/803/11-02 (31.7.A)).

This final report culminates a split mission under a Special Service Agreement. The second and final stage took place from 7th to 28th March 1988.

The duties defined in the job description were as follows:-

The expert will work with counterpart engineers of the University of Bio-Bio, Division of Scientific and Technical Investigation (DICITE) to improve the timber and timber component strength testing facilities and assist in introduction of UNIDO's modular wooden bridge system. In particular, he will:

1) Install and commission the specially designed bridge panel test rig ordered as part of the project, following the detailed plans developed during the Honduras bridge project DA/HON/81/002 and using the frame built by the University.

2) Initiate a suitable test programme for bridge timbers, bearing in mind the plans/programme of testing intended by the sawmilling industry, but also with a view to training counterpart staff in test methods.

3) Initiate a test programme for bridge panels.

4) Conduct a short training course on stress grading to the grading rules contained in UNIDO's 'Bridge Manual' (UNIDO/IO/R.162).

5) Present a lecture (or lectures) to University staff and students and industry representatives on stress grading and the current state of the art of visual and mechanical means used, including the newest types of scanning devices.

6) Assist in promoting timber engineering and construction and especially the bridge system as possible.

7) Prepare a short technical report on the activities carried out with recommendations for futher development in this field.

GENERAL DESCRIPTION OF THE CURRENT STATUS OF THE SUBJECTS OF TIMBER ENGINEERING AND TIMBER CONSTRUCTION IN UBB

As part of its broader plans to expand its activities in the field of timber construction, the UBB completed a large canopy structure late in 1987, which was to be devoted to these activities. The structure is known as the 'Pabellon de Tecnologia de la Madera', which does not translate directly into English, and which will therefore be referred to in this report as the 'timber technology laboratory'. Figure 1 is a reproduction of a sketch showing the scale of the building, which has a clear span of 15m and which measures 570m^2 in floor area.

Annex 1 provides a free translation of a paper produced for internal UBB planning purposes by Arq. Roberto Goycoolea I. one of the staff of DICITE. It explains the DICITE view of the objectives of the overall Timber Technology Project (PTM); in other words it covers the total range of activities in the timber technology laboratory. It contains sections on personnel requirements, and gives budgetary indications.

Thus, a good start has been made in UBB's aims of better being able to service the needs of the private sector, and in being able to relate to the forest industries of the region by becoming more involved in the construction field. The completion of the timber technology laboratory represents the accomplishment of a major investment, and provides an excellent physical base for the planned activities.

This report will conclude by pointing out that further steps still need to be taken to reach the real needs of industry, particularly in the field of construction. Construction activities in general, and especially house-building, are areas in which UBB has a less strong tradition and experience than in primary timber sawmilling and conversion.

Further changes of emphasis are required to translate the policies and activities of DICITE and the Timber Technology Project towards building construction. The aim should be to fuse the experience available in the teaching departments, particularly Architecture, with the skills and knowledge required for consultancy and testing services. It should also be mentioned that relative weaknesses in staff experience in the field of structural engineering have been exacerbated by the recent resignation from UBB of the civil engineer responsible for the modular wooden bridge programme. Thus responsibility for timber engineering in general, and including bridges, rests with the Forestry Engineer, who was one of the two original trainee Fellows in the project. This engineer has a good general appreciation of the bridge system and future timber engineering development needs, but lacks the qualifications to be able to make and approve calculations, and thus to submit the system to Ministry engineers and others.

PROGRESS OF MODULAR WOODEN BRIDGES

A progress report and recommendations concerning the development of modular wooden bridges in the region was produced by another UNIDO expert (2).

On the part of the counterparts, a report containing recommendations was issued in January 1987 (3) and a further report was made in September 1987

(4). A report explaining a computer program which was written to produce design tables for a range of Chilean species was also published in the same year (5).

The January 1987 report contained a description and the costs of fabrication of 42 modules, which were fabricated in the University at the rate of 2.5 per day. It also described the choice of timbers for the first bridge, the decision having been taken to build this at a location known as los Quillayes, about 14km north east of the town of Tome. In the opinion of the expert, this was a very good choice of site in terms of profile of crossing, class of road, and service provided by the bridge. Local participation in the project was also good. These features should be emphasized by DICITE in future, whenever presentations or promotions of the system are made.

On the decision of the national engineers, certain modifications were made to the design. These can be summarized as follows:

1) It was decided to use six trusses for this 15m span design, which was fabricated using the timber known in Chile as 'Roble' (Nothofagus obliqua). It was also decided to regroup these six trusses into three pairs, as shown in Figure 2, rather than to use two girders and two auxilliary lines of trusses, as shown in the UNIDO manuals prepared by TRADA.

2) The design of the lower steel chords was modified, involving the use of more material. Thicker and larger plates were welded on to the area of the chords around the spigot holes.

3) The steel anchor plate details were modified by including slots rather than holes at one end, to make allowance for seismic movement.

4) The thickness of the deck, fabricated in radiata pine, was increased from 120mm as indicated in the manuals, to 150mm.

The launching and construction of the bridge at los Quillayes is described in the other expert's report, and by all accounts it was in general a very successful operation. The report contains some comments on the discovery by experience of the need for substantial diagonally-applied temporary bracing to the girders during launching. This is in accordance with TRADA's more recent experience, and is a detail that should be explained more clearly in the existing manuals. The use of three paired girders undoubtedly facilitated the launch, and from this point of view it was certainly a good idea. Whether or not six trusses were strictly necessary for the span and loading of this site is more debatable. Doubts about the cost effectiveness of the designs in Chile are certainly being exacerbated by the tendency to overdesign, as exemplified by the points mentioned above.

Each of the 42 modules, manufactured for this first bridge (30 being actually required in the design), were proof tested at the University before use in the bridge. The procedure was to load each module up to a maximum value; release the load; then to reload in stages, taking five sets of deflection measurements, one at each stage. The maximum load applied was 186.4 kN. Considering that the whole procedure had a duration of about one hour, this seems to the writer to have been an excessive value to apply to the modules which were intended for subsequent use. A comment was made to this effect during the first visit, but the procedure had by then already been applied to the majority of the modules which were subsequently used in the bridge. The rig used for these provisional tests was a temporary arrangement, and it can now be replaced by the rig installed in the second stage of the project. Because of the provisional nature of the first rig and equipment, the load increments during the first tests were known to only a rather approximate accuracy. The values expressed to four figures in kilonewtons were in fact conversions of round numbers in imperial units.

At an early stage in the first set of tests, a failure occurred in the fillet weld which is located between the back of the longitudinal top chord spigot pin and the plate No. 10 which supports this pin. Because of this, it was decided to modify the design as shown in Figure 3, after which no more problems occurred with this connexion. At high load values, the top chord end lateral plates, which contain steel dowels used to connect the steel plates to the timber, exhibited a substantial tendency to rotate. The loading likely to be experienced by a module in use however was undoubtedly exceeded. In some cases, partial timber failures also occurred during these tests. They took the form of along-the-grain shear splits in the top chords, beginning in the region of the top chord steel side plates, at dowel hole locations.

Making some conservative assumptions about the maximum values of some of the module tests reported as 'failures' during this first series, it is calculated that the 42 modules tested achieved a mean maximum load during the proof tests of 180.2kN. BS 5268: Part 2: 1984, Section eight, 'Testing recommendations' states that 'where more than one structure of the same design is tested, the design should be regarded as satisfactory if the lowest ultimate load recorded is at least K_{73} times the design load'. The value of K_{73} for five or more similar structures is 2.0. The mean maximum load recorded during the module proof tests mentioned above is not really an average ultimate load, since the modules were not loaded to absolute destruction. However, in order to obtain a maximum design load resulting from these tests, it is obviously conservative to regard them as ultimates. Hence it can be concluded that the modules can be regarded as having been shown to have a satisfactory maximum design load of 180.2/2.0, say 90kN each.

Under Section eight, clause 64 'Use of tested structures', BS 5268 warns that 'a structure, or part of a structure, which has been subjected to deflection and strength tests should not be used further. A structure or part of a structure which has been subjected to a deflection test only, and which satisfies the deflection acceptance criteria.... May be considered satisfactory for further use subject to agreement....'. This tends to support the contention of the writer that modules for use in a bridge (as opposed to experimental panels) should not have been subjected to loads so close to their potential ultimate, as there is a severe risk of causing them permanent damage.

Using the BS 5268: Part 2, Table 15 modification factor $K_3 = 1.5$ for short term duration of load, it is calculated that modules of this design using 'Roble' (Nothofagus obliqua) in Chile, should not be subjected to a test load of more than 1.5 x 90 = 135kN. This should be regarded as the 15 minutes deflection test load, in terms of BS 5268: Part 2: Section 8. It should not normally be necessary, for quality control purposes, to load modules for 24h, but where this is done, only the new recommended maximum design load of 90kN should be applied.

CONCLUSIONS

A successful prototype bridge has been built in Chile at los Quillayes, Municipalidad de Tome, 8th Region. The launching, construction and completion took eighteen days, and these aspects were achieved without any major difficulties. An inspection of the bridge was made on 12th March 1988, and it appeared to be in excellent condition, with no signs of wear or deterioration, other than a handrail barrier which had been broken in a traffic accident, and subsequently neatly repaired.

The test equipment ordered as part of the project has been fully installed. A new timber testing laboratory has been built by the University, using separate funding, and the opportunity was taken to include the bridge testing equipment in this. It was located along with a wider range of equipment suitable for the testing of structural timber materials and components. The DICITE of the University cooperated fully in this programme, carrying out its plans to install a test floor with load reaction points, and raised steel reaction beams. Thus the testing equipment supplied by UNIDO will fulfil a wide range of useful needs.

The test programme for bridge panels which was initiated during the first visit of the split mission was revised, and new recommendations were given, in line with the design developments which have been carried out in another UNIDO project, US/GLO/86/294, and with the development of the new test equipment.

Training was given on stress grading and on the recommended methods of test for structural sized, in-grade testing of timbers. Assistance was provided on the design and fabrication of test equipment for this purpose, such as,for example an improved method of deflection measurement, in line with international test standards.

A lecture and participation in a round table discussion took place on 15th March 1988. This was organized by the Direccion de Relaciones, Extension y Comunicaciones of the University and was open to the public, being held in the Instituto Chileno Norteamericano. It was attended by University staff, professionals and researchers. The theme was 'Vivienda de Madera en la VIII Region'. Two members of DICITE, together with two other professionals who are experienced in timber construction, took part as members of the discussion panel. Timber grading, drying, dimensional control, and timber frame housing methods were all included in the meeting. Earlier on the same day, a visit had been arranged to a low-cost social housing site. This was conducted by the president of the regional building federation, whose company was involved in the project. Some designs amongst the systems offered by this company are constructed entirely in timber frame, whilst others are in mixed construction. Extremely tight cost controls are being met.

Staff meetings and discussions were held on technical topics, and on policy means of promoting and improving timber engineering and construction in the region. These led to recommendations which appear in the following section of this report.

RECOMMENDATIONS

In this section, the writer sets down very clearly and briefly the direction in which he recommends that UBB/DICITE should continue. This assumes that the policy will remain of encouraging industrial and commercial contacts, and fostering an enterprising attitude amongst the staff. Also that clear budgetary targets continue to be drafted, agreed upon and followed. The further development of DICITE is seen to depend more upon building up further, and encouraging its human resources, rather than merely acquiring equipment and carrying out varied projects in a desultory fashion.

1. Modular wooden bridges

The modular wooden bridge design has now been established and proven in Chile. There has been considerable expenditure of effort in this, both on the part of UBB and other nationals on the one hand, and by UNIDO on the other. Information about it should now vigorously be disseminated to appropriate ministry departments, mayors and district councils, and to forestry companies. It should be put across as a well tried, proven and fully mature system, not as an innovation still involving doubts or alternatives.

A particularly important contact in the Ministry of Public Works was established during a visit shortly before departure from the project. This was with Mr Patricio Ruckoldt R., the Chief of the unit responsible for the Carretera Austral, in the 'Direccion de Vialidad'. This introduction was provided by Mr Eduardo Castro Z., the ministry engineer who had participated in the UNIDO fellowship at TRADA. Mr Castro had subsequently presented a favourable paper on the costs and opportunities of the prefabricated timber bridges to a Chilean Society of Civil Engineers.

Mr Ruckoldt had also been impressed by the possibilities for timber bridges. This had been reinforced by his experiences whilst a post-graduate student in the USA. He told us that 200km of Carretera Austral had already been constructed, and that a further large programme is planned. This will entail the necessity for low-cost single carriageway bridges to the extent of about 2000 metres per annum, over a five-year plan. Future intentions are for the road to travel south to Villa O'Higgins. The wet conditions and difficult terrain would make a bridge capable of being assembled rapidly from light, portable elements very attractive. Hardwoods would probably be used for the modules in this region. UBB might consider cooperating with a southern regional counterpart, such as the 'Instituto Profesional de Valdivia', for example.

Mr Ruckoldt agreed to discuss the potential use of the system with Mr Gonzalo Carrasco, the Chief of the Department of Bridges, who had already approved the principles of the design. Follow-up measures should be undertaken by UBB to these, and other persons in the Ministry of Public Works.

Means of disseminating information about the bridge design and promoting the system that should be considered include the following: promotional seminars and more informal or smaller-scale presentations involving round table discussions; personal visits and contacts; use of material already prepared such as 'Documento Tecnico No. 27, UBB/CONAF' and the slide set of the prototype bridge. Consideration could also be given to use of the broadcasting facility of UBB radio, and incorporation where appropriate, into the 'Extension y Comunicaciones' activities of the University. Further dissemination and technical announcement publications will undoubtedly be required in order to do this effectively, and these will have to be budgeted for.

The existing bridge at Los Quillayes should be monitored more closely, for example the expert saw no evidence of moisture content monitoring or of such records being kept. The maintenance of the bridge should be watched, and if necessary those responsible reminded of the necessity for simple operations such as deck cleaning and embankment clearing. Drainage slots were not included in the deck construction, which is surprising since drawings showing these were given to the project. These should now be cut into the completed deck, as a matter of priority.

By way of a student project, the University might consider the possibility of monitoring over a short period the frequency, type and estimated axle load of the traffic which is using the bridge, and compare this with the design assumptions. Such an exercise could provide valuable additional information, as well as good training.

Since the counterpart engineer who was involved in the prototype bridge project has resigned from his post at the University, then DICITE must consider as a matter of importance either the recruitment of a replacement, or if funding or difficulty in making an appointment prevents this, then the engaging on a part-time or consultancy basis of a qualified structural/civil engineer. An experienced engineer should be sought, who is able to appreciate the implications of a low-cost design which is constructed in a material and manner with which traditionally Chilean civil engineers are not familiar. If the role of this consultant is principally to carry on negotiations and promotion activities concerning the use of the bridge, then a person who is based in Santiago may well be better placed to carry on this dissemination campaign.

Further technical developments of the modular wooden bridge and of other timber bridges are certainly possible in Chile, and these would be of great value, given the background as explained at the beginning of this report, which still holds true. For DICITE, however, it is important at this stage carefully to consider its priorities, and for this reason bridges are mentioned again in the policy recommendations given below.

Technically, the obvious further steps in bridge work are as follows:-

a) Complete the improvements in the testing equipment, with particular regard to bridges. For example, providing a more effient and reliable means of monitoring the module in the test rig, and setting up permanent arrangements for deflection measurement and load recording.

b) Start to implement other recommendations given below relating to the use of Chilean radiata pine as a structural material, thus strengthening the ability to make use of it in bridges.

c) Fabricate and test to destruction, bridge modules to the existing design, using carefully selected and graded radiata pine. Develop a new bridge module using radiata pine, redesigning the members, joints and carrying out further tests, if necessary.

d) Carry out other developments already mentioned in previous reports and suggested by Chilean engineers, including the idea of a prefabricated and demountable deck; the use of timber abutments and other variations in the bridge supports, and implementations using other Chilean hardwood species.

2. General recommendations for DICITE, including future policies

As a matter of priority, a suitable Chilean structural/civil engineer should be recruited to 'champion' the bridge system, as explained above. Until definite steps are being taken to build without UNIDO help a further standard bridge, using the existing information, then further technical assistance in the field is unlikely. Unless this happens, there seems little point in DICITE undertaking further development work on timber bridges.

The DICITE projects in general should be run in a careful way, with attention to detail and timeliness. There should be strict prioritization of projects. For example, it could be considered that in the future it should be agreed only to allow each staff member to carry out one non-externally funded project at a time, and not to start a second until the successful completion of the first. There should be a clear understanding of the balance which is decided upon between research, fee-earning activities and teaching.

Table 1 shows the DICITE projects involving timber structures and joinery which are current or planned, including an indication of the type of financial support they are receiving or are likely to attract. This was used to discuss the possible selection of priorities, when the above-mentioned points were considered in meetings with the DICITE Director and staff.

Consideration should be given to broadening the scope of fewer, more selected research and development topics, with a deliberate decision not, at present, to enter other fields, so that efforts are not excessively diluted. Concentrated areas of expertise should be chosen, and project proposals within these selected fields should be broken down into smaller constituents, so that the scope and aims at the start of these projects are not unrealistically ambitious in terms of what can be achieved within a given timescale and funding. A greater variety of applications should then be made to international agencies and bilateral aid contacts for support in these selected areas.

At the request of the DICITE staff, Table 2 was drawn up, showing, in TRADA's experience, relevant British Standards covering five of the most important types of structural timber tests and timber component tests. Table 3 extends the information given in Table 2 by describing the equipment which is essential for each type of test; the present status or availability of such equipment, and desirable future additions to the equipment. It can be seen that a considerable amount of work remains to be done, both in terms of setting up these tests, and in acquiring the new facilities mentioned. It may well be that DICITE would be unable, at this stage, to entertain such a broad scope of structural timber activities, and that it would be preferable to specialize in a narrower scope, at the same time allocating each chosen subject a more realistic resource.

By way of examples only (recognizing that DICITE must choose its own technical priorities, through internal consultation and by means of its industrial contacts) the following shows how several projects could be proposed in two related fields, namely the structural use of Chilean radiata pine, and window joinery. It should be noted that either of these two examples would be regarded in terms of comparable UK-based research and development programmes, as at least five or six year programmes of work, involving several man-years per annum:

a) Structural use of Chilean radiata pine, sub-projects:-

i. Develop structural sized in-grade test procedures and facilities, in line with modern internationally-adopted methods.

ii. Develop simplified low-cost non-destructive grading methods, based both on cheap grading machines and also upon vibration testing and other applied physics procedures.

iii. Commence investigations upon the influence of growth patterns, log quality, conversion methods, and drying techniques upon the strength and stiffness of the radiata pine currently available in the region, making use of the excellent sawmilling and drying facilities available at UBB.

iv. Develop design rules, fabrication techniques and confirmatory test procedures for small section, standard-sized, straight laminated beams in Chilean radiata pine.

b) Development of window joinery using Chilean radiata pine, sub-projects:-

i. Concentrate efforts first upon the central geographic region, e.g. Santiago to Concepcion/Temuco, in terms of climatic conditions, exposure and biohazards.

ii. Complete the installation and commissioning of the machine shop and joinery facilities in the PTM, including means of laminated production. Develop and install test rigs and facilities for assessing wooden windows.

iii. Develop standard designs; opening types; profiles; frame details etc.

iv. Investigate hardware, fittings, security aspects etc.

v. Carry out commercial trials and monitor the installation of the new designs, modifying them as indicated by the feed-back thus obtained. Analyse costing information obtained during the trials. Plan further in-situ monitoring and record reactions of inhabitants/users.

Christopher J. Mettem

April 1988

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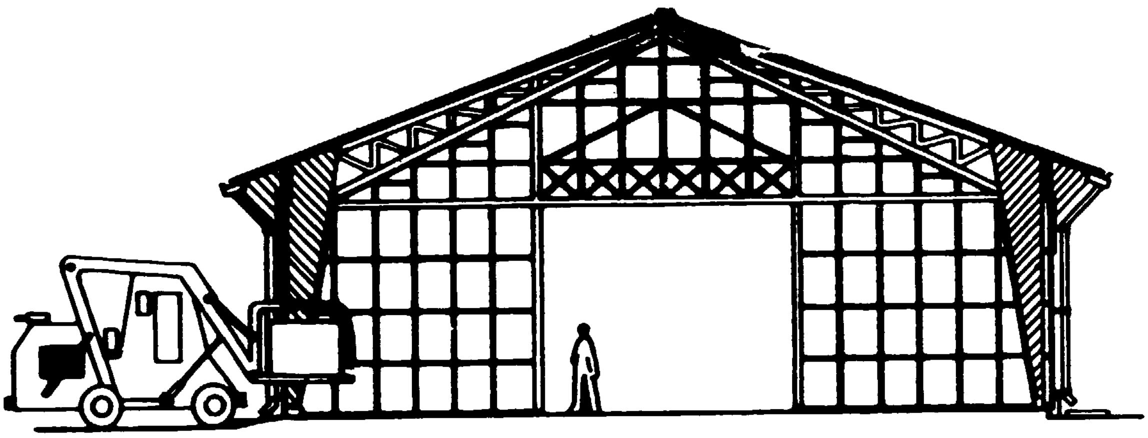

Figure 1. Architects end elevation of new timber technology laboratory, UBB

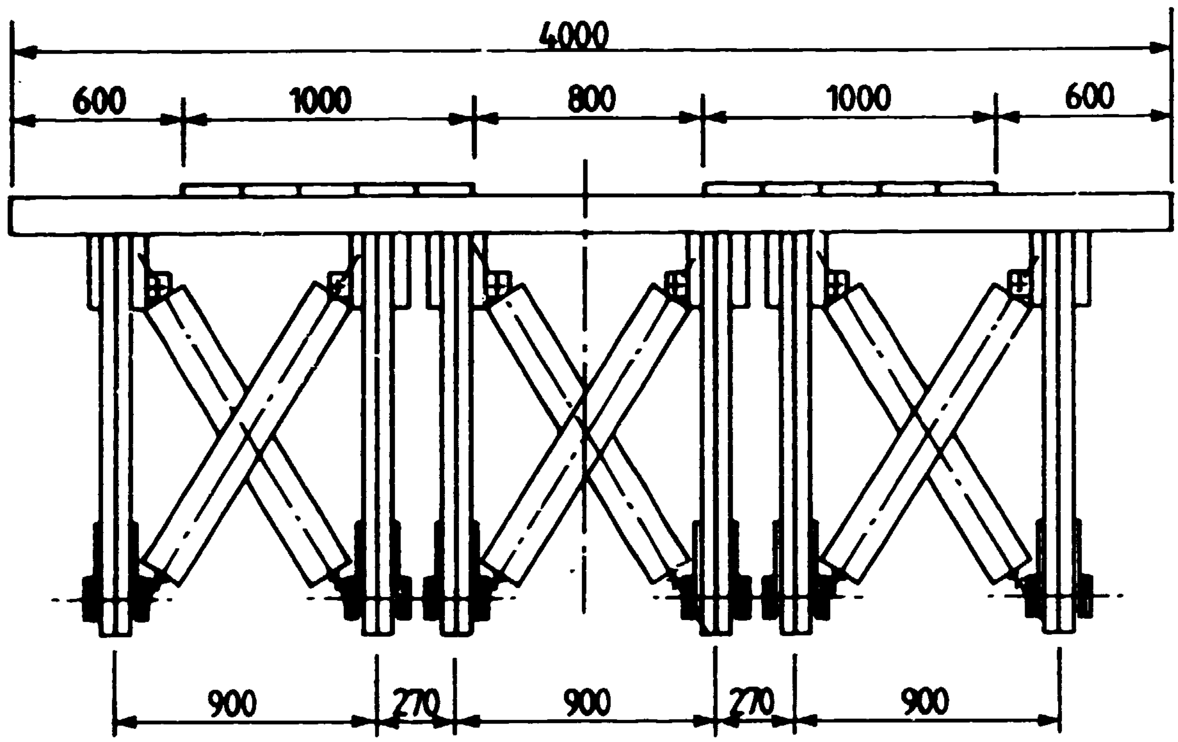

Figure 2. Cross section of revised six truss bridge

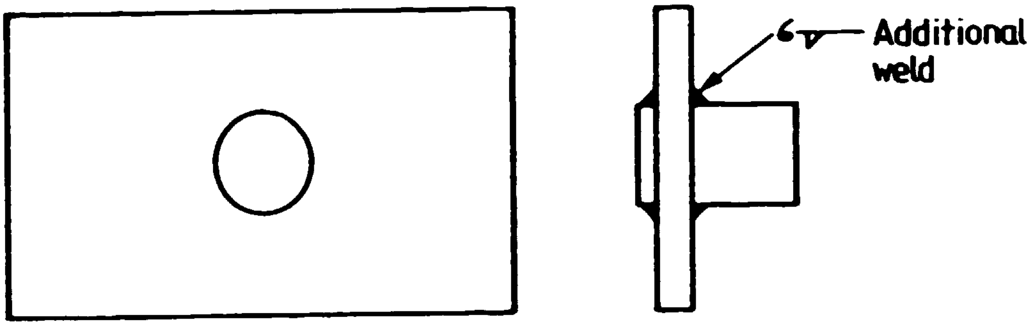

Plate No. 10

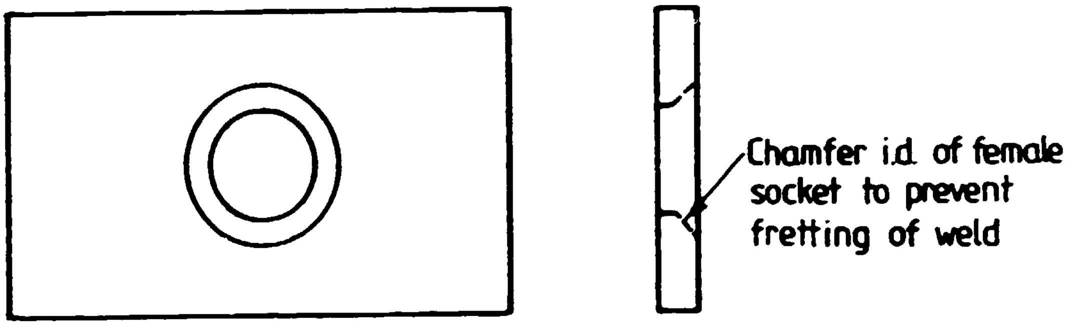

Plate No. 10A

Figure 3. Modification to welding details for top chord spigot joint.

TABLE 1 - DICITE projects involving timber structures and joinery, showing those in progress and planned, and financial status

Project title/description	Form of financial support	Current status
Structural-sized tests on solid joists of Pino insigne.	Industrial support. Joint undertaking with INFOR, CORMA and IDIEM.	Planned to start 1 April 1988.
Window joinery project.	Support from UNIDO, with input in kind from UBB.	Approved in Principle. Appointments awaited.
Modular wooden bridges.	UNIDO/UBB.	Completed.
Timber framed wall panels for housing.	Internal - Dept. of Architecture.	In progress.
Trusses and trussed rafters.	Internal - Dept. of Architecture.	Planned. No physical start yet.
Composite beams.	None.	Internal proposal - Dept. of Architecture.
Modular housing design based on post and beam construction.	Applied for in 1988.	Internal proposal - Dept. of Architecture.
Structural joints in timber.	None.	Proposal.

TABLE 2 - Test types, descriptions and relevant standards for structural timber tests in the timber technology project (PTM)

TEST TYPE No.	DESCRIPTION	RELEVANT STANDARD	TITLE	COMMENTS
1.	Structural-sized tests on solid joists of Pino insigne and other Chilean spp.	BS 5820	Methods of test for determination of certain physical and mechanical properties of timber in structural sizes.	It will be necessary to follow these test procedures in order to set grading machines for production for European markets.
2.	Prototype and quality control tests on modular panels for timber bridges.	BS 5268: Part 2: 1984 Section eight	Part 2: Code of Practice for permissible stress design, materials and workmanship. Section eight: Testing.	'Load testing is an equally acceptable alternative to calculations, and in certain cases can be a more positive method of establishing the structural adequacy of a particular design'. Section eight can be used to obtain general guidance on test procedures and philosophy. Some details, e.g. pre-load and deflection test, may not be directly applicable to bridge modules.
3.	Racking tests on a range of timber framed wall panels for Chilean housing conditions.	BS 5268: Part 6: 1988	Part 6: Code of Practice for timber framed walls.	A Chilean test standard also exists. It would be worthwhile in addition to make comparisons with NZ standards, having earthquake conditions.
4.	Load testing of trussed rafters (lightweight trusses consisting of triangulated frameworks spaced at not generally more than 0.6m apart).	BS 5268: Part 3: 1985 Section eight	Part 3: Code of Practice for trussed rafter roofs Section eight: Load testing.	Provides good general guidance on test principles. Some details, e.g. concentrated load, would need modifying for Chilean conditions.
5.	Prototype tests on composite beams, floor panels and other timber engineering innovations.	BS 5268: Part 2: 1984 Section eight	See 2	See 2. Adapt Section eight as necessary for each component. For composite beams, procedure can closely follow the standard. For floor and roof panels, modify to suit local loadings etc.

TABLE 3 - Equipment required for range of structural tests described in Table 2 and present status in the timber technology project (PTM)

TEST No.	ESSENTIAL EQUIPMENT	PRESENT STATUS - AVAILABILITY	DESIRABLE FUTURE ADDITIONS
1.	Means of conditioning test specimens and determining moisture content and other physical conditions.	Commercial kilns, wood fired and steam humidified, available in UIM. Moisture meters etc. available	Separate facility for storage of specimens at controlled RH/temperature within PTM.
	Swivelled and axially-held loading heads.	Not yet fabricated. Can be made by PTM. Requires purchase of ball bearings.	Better design, automatically locating correctly on specimen for large nos. of tests. Accommodate twist in specimens.
	Roller and knife edge reaction supports, with plates to eliminate indentations.	As above. Simple supports can cheaply be made up, but better designs should include ball roller bearings.	Comment: keep centroid of swivel on neutral axis of specimen.
	Lateral restraints to prevent specimens buckling.	Not yet fabricated. See ASTM for photograph of what is required.	Only essential when h/t of specimen exceeds 4.
	Loading equipment measuring to accuracy of 1% or better.	Hydraulic power pack, controls, jacks and load cells supplied by UNIDO.	Additional Macklow-Smith load cells and/or electrical (strain gauge) load cells, controls and data logging.
	Deflection equipment - similar accuracy.	Dial gauges supplied by UNIDO. Deflectometer cradle to be made up by PTM.	Induction transducers, better deflectometer attachments and controls/loggers.

TABLE 3 (Cont'd) - Equipment required for range of structural tests described in Table 2 and present status in the timber technology project (PTM)

TEST No.	ESSENTIAL EQUIPMENT	PRESENT STATUS - AVAILABILITY	DESIRABLE FUTURE ADDITIONS
2.	Timber preparation and control. Steel plate fabrication, welding and module manufacture.	See 1. Available	None, unless experiments made, with laminated Pino insigne for example, Welding details need further attention
	Loading and support arrangements, load measurement and recording.	700mm deep, 12m long paired steel I beams and lateral support facilities - available. Hydraulic power pack, controls, jack and load cell supplied by UNIDO.	Modifications and additions to be able to support and load modules more readily and to be able to change points of application of load(s). Load data logging.
	Deflection measuring and strain measuring instruments.	Basic magnetic support and dial gauges supplied by UNIDO.	Additions as required, according to whether tests are for research or quality control.
3.	Timber preparation and control. Sheet material preparation and control, for clad panels.	See 1. Basically available. More attention to control of distortion of studs may be required, and an area to be set aside for conditioning of sheet materials.	Better drying and conditioning facilities, readily available to PTM.
	Racking rig.	Available.	Check free functioning at head of rig. Add facilities for vertical loading of panels. Check stiffness of rig itself.
	Loading, load measuring and deflection equipment.	Basis available in UNIDO equipment. Present methods should be replaced.	Similar comments to 1 and 2. X-Y plotting particularly useful.

TABLE 3 (Cont'd) - Equipment required for range of structural tests described in Table 2 and present status in the timber technology project (PTM)

TEST No.	ESSENTIAL EQUIPMENT	PRESENT STATUS - AVAILABILITY	DESIRABLE FUTURE ADDITIONS
4.	Timber preparation and control. Component fabrication facilities, metal plates, nailed joints, plywood gussets and glued joints all possible.	Timber preparation and control available. Surfaced material recommended.	Attention to moisture content and dimensional accuracy required for trussed rafter members and joints.
	Test rig capable of applying uniformly distributed and concentrated loads to the components under test.	Not available. I beams and tubes for lateral support installed, but no rig yet.	-
	Means of providing lateral support during test.	Not available.	-
	Load points on trussed rafter actuated by pulleys, levers or dead loads, with means of ensuring even distribution.	Not available.	-
	Accuracy of loading and measurement to within plus or minus 3%.	Not available. Power pack, controls, dynamometer, three jacks provided.	Further jacks, load-retention controls (for 24h loading) and load recording equipment will be essential to undertake these tests seriously.
	Rigid datum for deflection measurements and ability to record to nearest 0.1mm.	Not available.	Set of deflection transducers, calibration facilities and logging equipment.

TABLE 3 (Cont'd) - Equipment required for range of structural tests described in Table 2 and present status in the timber technology project (PTM)

TEST No.	ESSENTIAL EQUIPMENT	PRESENT STATUS - AVAILABILITY	DESIRABLE FUTURE ADDITIONS
5.	Timber and in some cases sheet material preparation and control, as in 1-4 above. Range of simulated service conditions may be larger in these more general tests.	As in 1-4 above.	As in 3 above.
	'The test loading should be both applied and resisted in a manner approximating reasonably to the actual service conditions'.	I beams and reaction floor beam with modular anchorage screw points (8 tonne cap. each) available to provide basis.	Adaptable loading frames, beams, bars and plates for range of tests.
	Means of applying load and measuring it to within plus or minus 3%.	Basis available in UNIDO equipment.	Automatic plotting facilities, on-line during tests. Data logging onto microcomputer(s) at later stage of development.
	Load-holding and deflection measuring facilities as in 4 above.	Not available.	-

Annex 1. **Free translation of an internal UBB/DICITE planning document**

TIMBER TECHNOLOGY PROJECT

(PROYECTO DE TECNOLOGIA DE LA MADERA, PTM)

The PTM is a unit assigned to the academic work of the University. Furthermore it is intended to offer services and consultancy to industry and to construction companies, with emphasis on timber. This does not eliminate completely other materials and activities involved in this field.

DESCRIPTION

The PTM consists of two sections: one for tertiary processing of timber and its derivatives, whose principal object is to be the preparation of models and prototypes for tests. It is intended that it should collaborate with the model sawmill of the University, and with other requirements of the University. The other section of the PTM is dedicated to rigs and test machinery for the testing of materials and components. Amongst this equipment, the following items are intended to be operational in 1988:

1. Reaction floor beam, with modular anchorage screw positions and other 'Meccano' equipment, flexibly adaptable for testing components and frames.

2. A pair of I section reaction beams, raised off the floor, 12m in length, suitable for load testing solid and composite timber beams and other linear elements and materials.

3. A vertical rig suitable for testing timber framed wall panels in racking.

4. Heat transmission chamber, suitable for determination of the thermal resistance/conductivity of materials and composites, in the range between -15°C and +60°C.

5. Infiltration chamber to test weathertightness and deformations in windows and doors.

PERSONNEL

The operation of the equipment requires specialized personnel, who should be recruited on the basis of their experience in this field, or failing this, will require a period of training, both of a professional nature and in the role of teaching assistants.

In the first stages the personnel envisaged will be as follows:

1. <u>Head of PTM</u>

A qualified professional person, with experience in laboratory research, he will have the following duties:-

a) Administration of PTM

- Coordination of its use between the three functions of teaching, research and testing services.
- Responsibility for the inventory and for other personnel of the laboratory.
- Preparation of budgets for operation, equipment, specimen treatment; purchasing of equipment etc. and accounting for same.
- Coordination between PTM and other UBB and external laboratories.

b) Technical activities

- Monitor requirements and prepare programmes for industrial assistance and services, to generate income.

- Control and approve the test reports before issue.

- Present externally the results of research undertaken in cooperation with the other academic and industrial departments.

c) Technology transfer

- Prepare, coordinate and take part in courses, seminars and talks.

- Provide teaching related to the PTM test activities, for the departments of Architecture, Civil Engineering, Forest Industries and Mechanical Engineering.

- Train other teaching assistants and lecturers in the use of the equipment.

2. <u>Assistant in test laboratory</u>

A technician will be established at the teaching assistant (paradocente) level, who will be responsible for the following duties:

- Equipment maintenance
- Preparation of tests and test specimens

- Maintenance of control of the test data relating to the research and testing services
- Control of the use of the equipment for teaching purposes
- Forecasting the requirements for consumable materials.

3. Assistant in model and prototype workshop

A teaching assistant technician and a carpentry assistant will be assigned to this section, with the following duties:

- Completion of models and prototypes required for test
- Maintenance of the machinery and tools
- Cooperation in the timber production undertaken by the model sawmill
- Preparation of orders for materials and spares.

Any research or consultancy requiring specific skills or experience not provided by the group, should be contracted specifically on a short term basis, if not available from within the University. It is suggested that the decision to do this should be the responsibility of the Director of DICITE.

OPERATIONAL COSTS

Three specific items are foreseen in setting up, putting into operation and running the timber technology laboratory. Proposed budgets are divided into initial costs and normal running costs:

1. <u>Initial costs</u>

These consist principally in the costs of setting up and fitting out the areas of the building.

a) Test hall

Some of the area will require to be controlled in temperature and humidity. In order to reduce costs, it is proposed to enclose an area around the test equipment. A small office for the Head of PTM is also included.

TOTAL $C 700 000

b) Assembly and completion of equipment

The equipment provided by UNIDO is required to be mounted in test rigs provided by the University. This also requires additional accessories:-

Loading beams: The cost of these is about $C 620 000, but it is hoped that they may be donated by COMPAC (Chilean steel consortium).

Air filtration chamber: Cost $C 600 000

GRAND TOTAL $C 1 300 000

2. Running costs

Personnel: In order to keep to a minimum these costs, only the contracting of the Head of PTM and one carpenter is initially provided for:

TOTAL $C 2 880 000

GRAND TOTAL 1 & 2: $C 4 180 000

INCOME

In the medium term it is not expected that the PTM will produce significant income. The initial objective should be the training of personnel in the use of the equipment provided in the laboratory, hence gaining its official approval. The time required for this will depend upon the previous experience of the appointees and the teaching staff who support them, as well as the types of consultancy undertaken. At present it is estimated that this period may be three years, including six months to commission the equipment.

Consequently, the returns are estimated as follows for the first three years:

1988 :	Tests on radiata pine in structural sizes in collaboration with INFOR	$C 500 000
	Approximately 5 thermal transmission tests	$C 200 000
	Seminars and courses	$C 700 000
	TOTAL	$C 1 400 000

1989-90: With the PTM and its physical equipment and administration completed, an income of about $C 3 000 000 is estimated.

1991 and medium term future to 1994:

Once fully installed and officially approved, the income should cover costs and leave a surplus for the University. One could estimate an annual income of about $C 8 500 000.

In these estimates of income, the internal benefits of providing services to the academic departments and to research have not been included, nor has the contribution to teaching which will be made by the personnel of the PTM.