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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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THE DEVELOPMENT OF THE PRE-FABRICATED MODULAR WOODEN BRIDGE SYSTEM AND PRIORITIES FOR ITS FURTHER IMPLEMENTATION

Prepared by

C. J. Mettem

(Timber Research and Development Association,
Buckinghamshire, U.K.)

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PREFACE

The Timber Research And Development Association (TRADA) has undertaken a number of contracts and Special Service Agreement projects for UNIDO relating to development and training needs in the field of timber construction in developing countries. In particular, it has been privileged to have been heavily involved in the pre-fabricated modular wooden bridge system. It must not be forgotten however that the system was devised by an individual expert, Mr. J. E. Collins, under a UNIDO programme in Kenya in 1973. Furthermore, TRADA has in many instances done no more than collate and write up knowledge gained by others. In this respect, the experience of the SECOPT Pre-fabricated Wood Bridge Department in Honduras is noteworthy. Also gratefully acknowledged are the ideas and advice received from several other experts who have worked on the bridges, some of whom were able to attend the Expert Group Meeting (EGM).

It is hoped that this paper will be of use in consolidating the current state-of-the-art of the wood bridge system. Further, that it will provide guidance on future developments that will enable these types of bridge, uniquely appropriate for the urgent needs of many developing countries, to be deployed on a realistic scale. That is to say, by the thousand rather than by the dozen.

The views and comments contained in this paper do not reflect those of any government or agency which has been assisted, nor those of the United Nations Industrial Development Organization.

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THE DEVELOPMENT OF THE
PRE-FABRICATED MODULAR WOODEN BRIDGE SYSTEM
AND PRIORITIES FOR ITS FURTHER IMPLEMENTATION

1 - INTRODUCTION

Objective of the report

This report sets out to give a summary of the state-of-the-art of the UNIDO bridge system and to make recommendations for further development. It arises in connexion with a Special Informal Bridge Meeting (SIBM) which was held at the end of an Expert Group Meeting (EGM), in UNIDO,s headquarters at Vienna. The EGM on Timber Construction took place on 2 - 6 Decmebr 1985, and the SIBM on 9 and 10 December 1985.

It was agreed to review the state-of-the-art of the bridges and the standard system; their use in developing countries and current activities of UNIDO with respect to bridges. It was also intended to review the manual, discussing details and possible corrections. Design calculations for the bridges were also considered. Extensions to the system and other designs were also on the agenda, together with consideration of quality assurance and bridge maintenance.

An informal technical report of the proceedings of the SIBM itself are appended as Annex 1 of this paper. The chapter headings of this report are taken from the terms of reference drawn up for TRADA by the UNIDO subcommittee staff.

Road bridge requirements for developing countries

Industrial, agricultural and economic growth are normally interlinked, and dependent to varying degrees on a good transport network. For most developing countries, road transport is fundamental to progress and to the achievement of social and political stability.

Bridges represent a significant part of road construction costs, and in countries where bridge construction is dependent on imported steel and cement, lack of foreign exchange seriously inhibits road evelopment programmes. The United Nations Industrial Development Organization (UNIDO) has been instrumental therefore in introducing the use of timber bridges in such countries, especially for rural feeder roads. A special feature of these UNIDO bridge projects is to place emphasis on the use of locally grown, tropical timbers, thus saving the costly imports mentioned above.

A UNIDO programme in Kenya was responsible for the early development of a pre-fabricated wooden bridge system at less than half the cost of reinforced concrete bridges. Whilst tremendous investment has gone into improving rural roads in a number of developing countries, until recently relatively little effort has been made towards the problem of providing low cost bridges. Hence this project was seen as something of a breakthrough.

In the rural areas of developing countries, bridges are key factors, enabling road networks to continue across rivers, streams and creeks. Fords and causeways are common alternatives, but these have severe disadvantages when flooding occurs, and they may cause expensive diversions from the ideal route. Apart from fords, normal alternatives for rural access roads are bridges made from round logs with a rough decking, or a crude structure of square section baulks. Such bridges deteriorate rapidly, and in order to avoid the complete breakdown of communications and the isolation of market towns and villages, large scale investment programmes are needed, but often unavailable.

These alternative wood bridges are based on sound technology and modern techniques, adapted to ensure appropriateness to developing country conditions. They consist of pre-fabricated triangular wooden panels, joined during assembly on site to make up trusses. These trusses are in turn further assembled into stable, three-dimensional girders, which are launched into position. The nailed laminated deck runs over the girders, and is also built on site.

The use of a high level deck on a timber bridge in tropical developing countries brings several advantages. These include the fact that the main timber structure is protected by the deck from severe alternating exposure to both wetting by tropical rains and radiation from strong sunshine; it is equally relatively safe from total destruction by impact from crashing vehicles, and finally the slightly higher approach embankments which such a design entails are less liable to wash away under flood. The design is intended principally for spans of between 9 metres and 24 metres, and loadings up to about 20 tonnes. Further details of this are given in this report. It has been estimated that a typical 15 metre design uses about the same amount of timber in volume as two large tree trunks. However a rudimentary log bridge constructed with these would have only a quarter of the load carrying capacity, and a fifth or less of the life of one of these new types of bridge, which are always to be constructed with naturally durable timber or with wood that has been pressure preservative treated.

2 THE STATE OF ART OF THE SYSTEM

The first stages of dissemination

Towards the end of the Kenya project, there was considerable input to the wood bridge system by the Transport and Road Research Laboratory (TRRL) of the UK. The organization assessed the bridge design, carried out prototype testing and published a report illustrated with diagrams and photographs.

Following Mr. Collin's departure from Kenya, Mr. C. R. Francis was involved in a more general programme on the use of structural timber in the same country, and the previous bridge project was continued within the framework of the wider one. Meanwhile, Mr. Collins visited Laos, South East Asia, where despite great operational difficulties due to political conditions, a prototype was built.

In 1981, similar to that established in Kenya TRADA was awarded a contract from UNIDO to introduce a system for use in Latin American regions, initially for the Republic of Honduras. TRADA's main responsibility at that stage was to evaluate the suitability of indigenous timbers for bridge construction, to initiate and supervise the production of bridge components and to train local staff in the methods used.

The programme was subsequently extended to include further development of the system by developing the use of timber for abutments and approach structures and by introducing the use of timber tension chords in place of steel. A testing machine for the evaluation of each of the modules used in the construction of the bridges was also designed, since it was felt that the original field method was relatively crude and only suited to very low volume production.

TRADA was further commissioned by UNIDO to prepare a set of manuals detailing the design and construction of the bridges. The objective of this was to 'internationalize' the existing information, which was written first in terms of Kenya, and subsequently for Honduras. This was intended to facilitate introduction of the system in other countries. During production of the drafts for the manuals, TRADA has acted as an information centre for various UNIDO experts. UNIDO have now implemented bridge projects in the following countries:

Kenya
Laos
Honduras
Madagascar
Central African Republic
Dominica

Bridge projects are underway in:

Chile
Bolivia
Peru
Nicaragua
Bhutan

Definite requests for projects are being processed by UNIDO for:

Costa Rica
Guatemala
Papua New Guinea
Colombia

In addition, exploratory missions have led to serious interest, and probable requests for assistance from:

Belize
Equatorial Guinea
Brazil
Cameroon
El Salvador
Gabon

The definitive bridge system

The bridge system uses standard triangular panels which are 3m long and 1.6m deep, and which can be handled by four to six men. The triangular modular panel, when assembled, forms the top chord and the diagonals of a Warren truss. Each module also has a king post which reduces the span of the top chord panels. The panel is the basic pre-fabricated module, and these panels are joined in lines to make trusses; however trusses are never launched singly or used in bridges in this manner, because they would be laterally unstable. During assembly at the site, the trusses are made up into pairs. Each panel has lateral top and bottom bracing lugs, to which are attached cross bracing members whilst the pairs of trusses are being made into girders. As previously mentioned, the system was assessed by the TRRL, and following their report, small but important changes were made to the detail of the module's members. Further changes were introduced at a later date by TRADA, including alteration of the top chord to form a completely nail-packed spaced column, and introduction of stitch bolts in the top corner plates.

In Honduras, the components are manufactured from pressure treated local pine by semi-skilled labour. One of the manuals gives strength grouping details allowing a wide range of species to be employed elsewhere. The vertically nailed-laminated deck is built in-situ.

The bridges were stated to have been designed for a clear span of up to 30m and will carry up to 40 tonne loads. More usually, spans between 9m and 24m are optimal, with loadings up to the American Association of State Highway and Transportation Officials (AASHTO) H20 specification for 18 tonne, two-axle trucks. In the new design manuals, span tables have been pegged to 27m since it is believed that there is no experience of spans in excess of this. Bridges are erected without the need for cranes by the use of derricks or towers, in a fashion similar to the 'bosuns chair' used for sea rescue. Thus the bridge is 'launched' across the gap, so that the system is suitable for use over deep rivers as well as dry stream beds.

Other methods of launching have been used. A dry launch technique used for a bridge at Yuscaran, Departamiento El Paraiso, Honduras, is described in the official manual. Francis (ref) also describes alternative techniques. Further he has recommended elsewhere the advisability of welding nuts and other connectors after construction, to prevent theft of steel parts.

Construction of the bases for the bridges in Honduras is by a traditional method used for walls and abutments, similar in principle to a dry stone wall but locked together with concrete and steel reinforcement. The United Nations World Food Programme provides rations for site workers carrying out these operations, and local employment on this basis has been guaranteed until the end of 1986.

Fourteen bridges have so far been constructed in Honduras using this system, and about ninety sites are scheduled for development. All the Honduran bridges are in rural areas, where community and agricultural communications have been improved; an estimated 300 000 people have been integrated into the economy and society by the resulting improved roads.

Manufacture

A simple workshop to commence a prototype project can be very small and inexpensive. The original one was the subject of a film made in Kenya, and the manual prepared there gives some idea of this. The essential equipment consists of a radial arm saw, heavy duty power drills and a welding transformer. A low-volume manufacturing jig can be based on a wooden bench.

Manufacturing operations consist of pre-cutting the components; drilling holes in the timber parts through pre-drilled holes in the steel joint plates; driving mild steel pins having a slight interference fit; welding pin ends and cross plates, vertical nail laminating of the lift members and other carpentry operations, grinding and painting the steel work. In such a low-volume operation, about one panel per man per day is produced. The official manual details the assets procedure in a step-by step manner, giving great detail and based on sketches made from a series of models.

Costs have not yet been firmly established, since even with ten bridges constructed in one country, projects are essentially at the development stage. The need for bridges on rural and access roads in a country such as Honduras is substantial, and the government ministry concerned have expressed a desire to raise the production target of the Bridge Workshop to four bridges per month in the near future. Such a level could certainly be sustained, and the resulting production easily absorbed. Clearly the achievement of such a target depends upon many constraints when applied to developing countries which are dependent upon aid and have balance of trade problems.

Conditions in developing countries differ widely with regard to steel and imported hardware prices for example. Labour productivity and the bridge site conditions also vary greatly, but in general, abutments are lighter than those for reinforced concrete bridges. Design costs, except for abutments, are practically eliminated by following the standard truss tables given in the manuals. Material and transport costs are lower than for pre-fabricated steel or concrete. The aim generally is to use local timbers, so reducing substantially the imported inputs into the construction.

Annex 6 gives a simplified indication of costs for a 15 metre span, four-truss bridge, suitable for a single lane, carrying two-axle vehicles up to AASHTO H20 loading.

Recent activities

Following the success of this UNIDO project, TRADA became involved in discussions with the UNIDO Senior Industrial Development Field Advisor (SIDFA), the Honduran Government's Ministry of Public Works and Transport, and the ODA Regional Advisor, to seek British Overseas Development Administration support. The aim of this was to continue to oversee the project, implement the design modifications, and put into operation the testing machine which was already partially constructed. The ODA commission also included advising on the specification and purchase of steel parts and equipment, and on the refurbishment and replacement of civil engineering equipment.

Other new activities included in the ODA contract were the development of a launching system for multiple-span bridges, and the provision of advice on the purchase and commissioning of a pressure treatment plant for bridge timbers. The latter was intended to be located at the bridge workshop, which by that stage had already been established.

Abutments and a central pier for a double span bridge are currently still under construction in the Choluteca District of Honduras. Multiple span bridges are discussed further in Chapter 3. The object of drawing up a specification for an appropriate, small scale pressure treatment plant which could be located at the bridge workshop was to reduce dependence upon outside commercial interests and pressures; to reduce the costs of multiple transportation of timber and prepared wood members, and to increase the ability to control the quality of treatment from within the project. Further self-sufficiency has been recommended in a recent TRADA visit report.

At the Honduran forestry school in Siguatepeque, there is successful practical experience in the use of a low-cost solar kiln of the type developed by the Commonwealth Forestry Institute, Oxford. Trials have shown that by the use of such equipment, 50 mm thick Honduran pine can be dried in a short time, without serious degrade. The installation and commissioning of such a solar kiln at the bridge workshop has been recommended therefore, since the holding time for necessary drying, both before and after treatment, can thereby be considerably reduced.

Another item carried out recently under an ODA contract has been the preparation of video films of the bridge system. Two videos have been completed, and final texts and sound commentaries are currently being added. The first video is an introduction to the concept behind the bridge system, suitable for presentation to government agencies, technical ministers and heads of departments. This should give an overview of the bridging, and generate interest in its application. The introduction may also of course be used for others, who will follow it up by viewing a second more detailed video, and reading manuals and other guidance. The second video includes a description of the design selection process, and a step-by-step guide to manufacture and launching techniques.

A Latin American regional course in timber construction was organized by UNIDO, with technical direction from TRADA, in April 1984. The three-week event, covering both building construction and timber bridges, was located in Costa Rica for two weeks, and near the pre-fabricated wood bridge workshop in Honduras, for one week. The time spent in Honduras included visits to existing bridges and bridge sites, and lectures and practical demonstrations on wood bridges, which were given by the national project staff.

Noting the successful technology transfer achieved by such a course, a shorter, lower cost training event was included in the terms of reference of the ODA project for Honduras, which followed. It was intended that this would be a national course only, with attendance by about a dozen junior professional staff, including project personnel and some craftsmen.

As the project developed, it became apparent that thrugh the cooperation of several parties it might fortunately be possible to increase the scope of the planned course. UNIDO had a resident expert, Mr. J. C. Cano, located in the project at the time, and the organization was also able to assist with pre-course publicity and selection of candidates. The National Forestry School (ESNACIFOR) at Siguatepeque were able to offer a conference hall, classrooms, laboratories, demonstration facilities and dormitories at a price which only defrayed their actual costs. They also arranged transport to several bridge sites, a sawmill and a timber yard.

A considerable training input by national lecturers, both from ESNACIFOR and from SECOPT, was therefore achieved. An actual bridge launch was witnessed by attendees, with transport to site arranged by TRADA, through SECOPT. Practical calculation and drawing projects involving footbridge designs, housing and timber classrooms were performed and presented at the end of the project. Draft versions of the video training films mentioned above were used during the course, and a version suitable for Latin American television systems was donated to the UNIDO expert for use elsewhere.

Further proposals have recently been made for supplies of additional woodworking machines to Honduras, as well as the solar kiln mentioned above. It is considered that this should be backed up by more training at the artisan level. The sections and addenda included in this report dealing with manufacture, quality control and maintenance are especially commended for future development into additional training material. It is firmly believed that it is at this level that activities should now be concentrated, especially in mature projects such as that which is ongoing in Honduras.

3 - MAINTENANCE AND INSPECTION

In the introduction, comments were made on the importance of effective road networks and bridges to rural development. Equally, these would appear to justify the need for considerable effort to be made on the upkeep of existing routes and crossings. Yet this effort is seldom made. Inspection and maintenance of civil engineering work connected with roads is increasingly neglected, even in a number of industrialized countries. In developing countries, deterioration of road pavements, roadside areas and drainage structures, as well as the bridges themselves, is so serious that some development agencies are beginning to believe that there is greater pay-off in concentrating effort entirely on remedial work and maintenance schemes.

As with all types of maintenance, relatively minor attention given at regular intervals can pay dividends. It can be expected that such effort will ensure that these pre-fabricated modular wooden bridges achieve the long life of permanent structures, as intended in their original design. A number of the recommendations that have been given are especially intended to give the structures a long life. These include pressure preservative treatment, or the use of sap-free durable hardwood timbers; carefully designed and fabricated steel parts; instructions on placing abutments and following measures such as soil poisoning against termites. Neglect of maintenance work however, is likely to result in the need for expensive repairs, or even the dismantling of the bridges, before they reach an age at which they can be said to have provided good service. Lessons can be learnt from the past.

A number of papers are available on historical wooden bridge structures which indicate where weaknesses can be expected to lie. Frequently, decay of decks and rot at interfaces in the structure, where pockets of moisture can be trapped, are the causes of eventual failure. Wooden railway viaducts have been known to survive more than a hundred years in temperate conditions, but in other cases, structures have deteriorated far more rapidly. A number of railway bridges with timbered decks are to this day, still being repaired in Britain. Contact surfaces between the longitudinal running planks and the top flanges of the steel transom beams, where water accumulates after seeping through the ballast and planking, are common problem locations.

As a result of inability or unwillingness to carry out road and bridge inspections and maintenance, there is dire disruption of vital communications for rural communities in many developing countries. The original funds and effort invested in construction work are wasted through neglect of simple measures. Costly premature rehabilitation, if undertaken, diverts scarce resources from other maintenance and new constructions. Hence a vicious spiral of underdevelopment sets in; a picture unfortunately all too common in this and other comparable contexts.

Items which have been recommended for particular attention to counteract these tendencies, include the following:-

1. Governments of developing countries should be encouraged to restrict axle loads on rural roads, distinguishing between these types of route and main highways. They should also take effective measures to enforce the relevant legislation.

2. A greater proportion of development funding should be devoted to preventive maintenance programmes. These may adopt inspection and maintenance management systems that are now quite well documented, in a developing country context.

3. Training is recognized as a vital activity for all aspects of development, but a greater emphasis on inspection and maintenance should be included in training material and in courses, than at present. The aim should be to create more skilled and trained manpower, with emphasis upon foremen, craftsmen and artisans.

4. All new designs and processes that are developed for emerging countries should not only put local materials and resources to efficient use, but should also take account right from the start of the probable arduous conditions of service and the elementary maintenance facilities that are likely to exist.

Existing publications

Guidelines and handbooks written for use in industrialized countries are seldom appropriate without adaptation for developing regions. Assumptions are made that hardly ever apply. These include regular inspection by qualified engineers, and the availability of sophisticated machines.

Several publications exist which have been written especially for developing countries however, and these need special mention. In considering bridge maintenance, it is impossible to avoid concern over associated roads, embankments and drainage structures. Not only will these often be maintained by the same district teams (dependent upon national and local works ministry arrangements), but the loss, or serious deterioration of related civil engineered constructions, can result in the loss of bridges themselves. This is particularly true with embankments and approach carriageways. On the other hand, it is impossible to extend the scope of bridge maintenance discussions, or draft sections for manuals, to embrace all these other aspects. Reference to other suitable guidance is therefore recommended. Arrangements for training in bridge maintenance and for its subsequent performance, whenever possible, should be made in conjunction with steps taken to improve related measures for road networks in general.

The Road Maintenance Handbook produced by the United Nations Economic Commission for Africa (UNECA) in three volumes, aims to give guidance mainly to the maintenance foreman. It is also intended to provide useful reading to the engineer, in order to make him more conscious of his duties towards the programme the foreman has to carry out. It is based on the premise that trained engineers are seldom available in sufficient numbers in developing countries, or as is often the case, are unwilling to leave their city offices for prolonged tours of the countryside. These guide books for the road foreman give instructions, in very basic language and diagrams, on how inspection and maintenance of structures, including bridges, should be carried out. The inspection guides are available in the form of small, strongly bound handbooks, which can be carried in the field for easy reference. Specimen formats for forms are included, to encourage simple but efficient record keeping.

A District Engineer's Guide for road maintenance is also available. This is a TRRL publication, written for the qualified engineer in developing countries. It gives advice on the preparation of a bridge inventory. This was a topic included in the discussions at the EGM. Guidelines on bridge inventory preparation are also available from the USA, where a major new programme concerning rural road and forestry bridges in timber is underway. Reference has been made to an ITDG publication entitled 'Earth Roads' in a section of the UNIDO bridge manuals already published. As well as dealing with earth road maintenance, this short, simply written book, also contains a considerable amount of practical, well illustrated advice that can be of help in the upkeep of bridges and associated structures. Drifts, causeways and culverts are also covered, whereas the UNIDO programme has so far been unable to embrace these alternatives

Draft Maintenance clauses

Draft maintenance clauses for the pre-fabricated modular wooden bridges are included in Annex 2. It is proposed that after circulation amongst experts and further written discussion, these should be amplified and illustrated to form another section or volume of the manuals.

Selective constructional measures can often be undertaken to eliminate the causes of defects in bridges, or to alleviate them in some way. In drawing up draft maintenance recommendations, this has to some extent been borne in mind, although clearly the tendency to write another comprehensive construction and maintenance handbook must be avoided. Strengthening parts as they are replaced, providing extra drainage structures, and reinforcing river banks, piers and abutments are all possibilities that may be considered if experienced foreman and maintenance crews are available and such measures will undoubtedly prolong the life of the UNIDO bridges, just as they have been advocated for other designs.

As was discussed at the EGM, it might be considered that instructions for maintenance of the UNIDO bridges, should separate the responsibilities of the recipient authority, in relation to the prefabricated modular wooden bridge itself, from their general maintenance responsibilities. This would avoid giving too many details on items such as waterway repairs; upkeep of embankments, repair of abutments etc. On the other hand, as has already been pointed out, in many instances the maintenance clauses proposed may be the only written instructions available. Since survival of the bridge itself is so dependent upon these other factors also being attended to, some diversification from purely timberwork maintenance has been deemed advisable.

Another useful point which arose at the EGM is that it would be desirable to have the date of construction permanently marked upon each bridge, as it is built. This could be chiselled into the wood or otherwise permanently attached to the superstructure itself. It is a common practice to embed dates on all forms of abutment, but since these can have different life spans to girders and decking, then the two parts need separate dating. When proper handover procedures and inventories for the UNIDO bridges are established this dating and serial numbering should be incorporated. Reference can then be made to these details in the appropriate paperwork.

Service life experience

Few of the bridges, built following the prefabricated modular wooden design, have been observed over a long enough period to state with certainty what, will be the likely causes of their deterioration. Contact was lost with the structures erected in Kenya, when the projects terminated there. Occasional failures have been reported of individual bridges in scattered locations. However in the case of some of these, such as the Madagascar bridge, for example, it was known beforehand that non-durable untreated timbers had been used. In this particular case the bridge was only considered to be a 'demonstration' prototype. Gross overloading was ascribed as the principal cause of failure of this, and another broken bridge in Kenya.

In Honduras observations to date point to the following weakspots, some of which are common to all types of bridge whilst others are peculiar to this design.

1. Silt and debris becomes trapped in the corners of the wood members of each module, at the lower apex point. This has been observed in several Honduran bridges, and is not being attended to in routine maintenance. It might almost be deemed a design fault. Serious consideration should be given to its elimination, for example by redesigning the member versus plate positioning as shown in the elevational drawings of the module. Filling with pitch or similar methods were discussed at the EGM, but in TRADA's opinion these measures would not be effective.

2. Wear of running boards, and protrusion of nail heads. If neglected until there is loss of planking then this will obviously lead to damage to the structural deck itself. At earlier stages than this, protruding nail heads damage vehicle tyres. Neglect of split running boards and planks with chipped edges also leads rapidly to far worse problems. This is a problem common to all types of bridge using wooden running boards. They are often used on Bailey bridges for example, as well as on the UNIDO type. Solutions are well known, and are described in the draft maintenance clauses annexed.

3. Accumulation of silt on the wood deck. Again this is a common defect, mentioned for example in the UNECA Handbooks. Scuppers and deck drainage gaps are now recommended in the standard design. Also their clearance is recommended in the draft maintenance clauses. Measures are also mentioned, which can

substantially reduce or eliminate silt being carried onto the deck. Side drains should be kept clear and functioning, or cut, if not provided in the first place. This is an example of how maintenance of the bridge itself cannot be separated from care and upkeep of the surrounds. Substantial slope and approach carriageway erosion has been observed on some on the Honduran bridges. It is TRADA's opinion that complete collapse of a bridge in future, initiated by floodwater washing behind the abutments, is a very real possibility. As mentioned above however, there is a limit to how far bridge maintenance texts can detail the complete protection of such roadway areas.

4. Inevitably, the riverine areas in developing countries where bridges are built, are often hot and humid. Hence they are ideal sites for prolific plant and weed growth. Recommendations on clearance of vegetation are included in the draft maintenance clauses. Generally, growth on the bridge structure itself should always be cleared away. Weeds, long grass and shrubs are also to be kept off the banks and riverside verges beneath the bridge. Weeds should be kept out of cracks and joints in the timberwork and masonry. However larger shrubs and trees which do not interfere with the structure or impede traffic or sightlines, should be left in place. These perform an important role in stabilizing the soil and the riverbanks.

4 - HAND-OVER PROTOCOL AND BRIDGE DEFLECTION TESTS

Having initiated a substantial number of projects introducing and implementing the modular wooden bridge design, UNIDO became concerned to ensure that proper responsibility should be accepted by recipient authorities when bridges are completed. UNIDO took advice from its legal department. Correspondence was also initiated with TRADA on this topic, prior to the EGM. A deflection test was one of the suggestions made by UNIDO substantive staff. It was proposed that this might be undertaken at the handover stage, jointly by UNIDO or UNDP staff and experts on the one hand, and by the Counterpart Agency staff on the other.

In order that the recipient authority should be in a position to accept full responsibility certain items need to be clarified. These include the basis of the design, the items for which it needs to make provision, and the state of the construction at the time of handover. Annex 3 reproduces a draft protocol form which was proposed by UNIDO for this purpose, and the following summarizes the EGM discussions of the form and its intentions.

Hand-over form

The form contains a series of ten footnotes indicating where items pertaining to a specific project, counterpart agency and bridge are to be entered on an actual form of agreement between UNIDO and the recipient authority. Item 1 is the name of the counterpart agency. Item 2 designates the bridge. In the case of a project where both light and heavy chord designs are used, or steel and wood lower chords may be used as alternatives, these facts also need recording. The word 'timber' is preferred by TRADA to species, with reference to the standard or pilot timber name designated in the Part 4 of the Manual.

Item 3 names the location and the river crossing. A map reference might at least be recommended, although not all developing countries are sufficiently conscientious in cartography to appreciate the value of this point. Items 4 and 5 are routine matters.

Item 6 indicates the loading code used for the design. If this follows Part 2 of the manual, then only AASHTO or BS loading will be possible. Other loadings may be followed in individual projects however, and provision could be made here for 'other'.

Item 7 and 8 deal with the maximum loading and the speed. The former follows from the loading code. The latter has not yet been stipulated in the manuals produced by TRADA for UNIDO, nor have standard traffic signs been drawn and recommended. Consideration might be given to these items for inclusion in the future. Suitable advice can undoubtedly be obtained from TRRL for example.

Item 9 refers to a deflection test which is considered below. The EGM drew attention to the fact that UNIDO's documentation should also formally be passed to the recipient authority, and that this should be duly recorded on the form. At present, this documentation consists only of the manuals, which comprise five parts, including the 'typical design' drawings. Special drawings related to a particular project may also be passed to the counterparts at the handover stage. In future, as mentioned elsewhere, it is hoped to include design calculations, at least for typical bridges.

Chapter 3 dealt with inspection and maintenance procedures, and Annex 2 gives draft clauses, which it is proposed should be included in future manual editions. The necessity of relating inspection and maintenance to existing procedures and practices in the country concerned has been mentioned. This should be acknowledged in the design of the handover protocol form. The district maintenance section responsible for routine upkeep of the bridge may not be the same office as that responsible for the original design and construction.

UNIDO have proposed that prior to transferring responsibility for a newly installed bridge to the recipients, a simple proof load test should be carried out to assess the overall structural stiffness. This, they anticipate, would be undertaken by measuring the vertical deflection of a bridge component at mid-span. The deflection would be caused by loading using a vehicle of predetermined weight, parked statically on the centre of the bridge. Two methods of arranging and carrying out such a test were drawn up by TRADA prior to the EGM, and these are presented in Annex 3. The following commentary is based upon the discussions of the test, which took place at the EGM.

In general, it was felt that the load-deflection test was too complicated for it to be expected that it might be carried out with a worthwhile degree of accuracy, in all situations, and in all developing countries. TRADA itself is inclined to share this opinion, although the test was discussed with counterparts in Honduras, who felt that the procedure was quite straight forward. On the other hand familarity with civil engineering surveying instrumentation and methods is essential. This may not be available with all the types of personnel who may in other respects be expected to have the ability to construct these types of bridge.

Several simplifications were suggested. The most basic way of measuring deflections quite approximately would be to use simple rules or tapes. These could be connected to the bridge and to a firm datum base of some sort by means of materials such as fishing lines and small pulleys. The theodolite measurements shown in Annex 3 could also be simplified, if the site is such that a horizontal alignment between the instrument and the target can be arranged.

Some experts suggested that the deflection measurements would be of more value if they could be collected over a long period of time. Theoretically, this might be true, but TRADA has experience of long-term building movement measurements for example, and would advise caution as these types of tests are expensive and time-consuming both to set up and to monitor effectively. The first difficulty is that of leaving measuring targets and datum bases reliably in place over a long period of time, at a bridge site in rural surroundings, in developing countries. In addition, it is felt that cumulative deflections under transient live loads, such as passing traffic, should not be significant in a healthy bridge structure. Creep will take place under dead load and self weight, but this should settle down to a negligible rate of increase in a correctly designed structure. Only the gross deterioration of some parts of the structure therefore, could be expected to show up in the form of fresh additional deflection under normal loads (ignoring the accidental overload situation). Therefore, a long term deflection test is viewed as of inconsequential importance, compared with other means of ensuring correct inspection and maintenance of the bridges.

Reverting to the deflection test as a short term measure, if this is viewed as an occasional procedure to be undertaken on a few bridges of each timber type in a given country, then a worthwhile data base could be built up over a period of time. This would depend upon the abilities of an organization such as UNIDO to establish the procedure, and maintain the records. A recent proposal to construct a demonstration bridge in Austria, near the UNIDO headquarters itself, may afford the opportunity to initiate such a test. As suggested by Mr. Robin Francis, a series of standardized loads would be preferable to a single vehicle loading. These might be applied with preloaded, weighed vehicles, or with hydraulic equipment. This would make possible the plotting of load-deformation graphs for several measuring points on the girders of a complete bridge. If possible, measurements of girder deflections under load, prior to the addition of the deck could be of analytical value. At present, no such data are available. Structural analysis, carried out using computer models, could, with benefit, be compared with such results. Once plots have been obtained, similar data could be collected in tropical regions using a series of perhaps, three vehicles, such as a small jeep, a vehicle of the Toyota or Range Rover type, and a larger contractors' truck or, Bedford 6 ton type of lorry.

The conclusions of this chapter therefore are that the draft protocol handover form should be modified in various ways, as discussed above. A revised form is proposed in Annex 3. The load-deflection measurement test on a complete bridge, should not be considered as part of the routine handover procedure. It should be retained however and used in the future to expand the data base of information on the design. This will be of value in comparisons with the design analysis work which, it is proposed should be carried out later. For comparative evaluation of different bridges in various regions of the world, and to make best use of a range of timbers, the deflection data which could be obtained from such tests would also be an asset A deflection test may also be required on individual bridges when there is some doubt as to their continued serviceability, or when suspected damage has occurred through overloading. In these circumstances, the techniques given in Annex 3 may be of value.

5 - QUALITY CONTROL CONSIDERATIONS

General

Although the pre-fabricated modular wooden bridge is simple both in concept and in execution, it should be borne in mind that it is an engineered system. Other types of wood bridge, of which there may be experience in some areas, particularly logging bridges of the large, solid tree trunk type, tend to be designed by rule of thumb and are not intended to last. The UNIDO bridge on the other hand, is designed as a permanent structure, intended to carry heavy vehicular traffic loadings, under all weather conditions. It is necessary to try, at an early stage, to impress these basic facts upon counterparts and bridge workshop staff when introducing the project to a new country or region. Unfortunately, timber construction experience in many developing countries is limited to ad hoc 'stick built' construction of a low quality nature. Indeed it is part of UNIDO's long term strategy, encouraged by technical support from its' contact with organizations such as TRADA, to use the bridge design as a spearhead for good timber construction, to counteract the tendency towards such low quality thinking. Rather, the aim is to promote timber as a serious and valuable natural local material, which can better be put to use in good quality buildings and other structures, in place of expensive imported materials such as steel and concrete. Quality control is at the very essence of all that is to be achieved in this respect.

Simple but strict quality control must be encouraged throughout the entire process. This runs right from choosing the appropriate timber at the sawmills which are visited when a project is first set up, through to checking off the items to be looked after during routine maintenance, when the recommended bridge handover protocol is followed.

When the jigs to produce the panels are being set up in the new workshop in the first place, care over dimensional accuracy and symmetry is important. This is then to be followed by equal care during panel assembly. Without precision in the pre-fabricated parts, subsequent problems are inevitable during the assembly of girders at the launching site. Dimensional irregularities, and lack of symmetry, throw uneven strains onto the installed structure. They are dangerous for this reason, as well as for the manufacturing defects which they inherently imply.

A complete bridge project entails the successful completion of a wide range of operations which call upon a variety of skills and trades. Some knowledge of timber sawmilling; a good appreciation of timber technology; workshop practice and jig layout; metalworking and welding; surveying, and various aspects of civil and structural engineering plus an ability to lead others in the handling of heavy loads are amongst the abilities required of an 'expert'. No single individual, however excellent, is likely to be equally strong on all these points. Hence advisers should be encouraged to view each operation critically; to assess the factors likely to lead to success or otherwise, and to distill these observations to simple instructions and advice. They should not be ashamed of seeking help from other organizations, text books or individuals, as required.

The concept of modular panel testing is discussed below. It should be admitted however, that this is an aspect of the Honduran project to date that has not been entirely successful. Effort on this item has diverted valuable resources that might otherwise have been spent on less spectacular, but more thorough and basic documentation and training on known quality control measures. These should be related to the various trades involved, and should be applied to the object in hand of producing well made, repeatable bridge parts and complete structures. During an earlier project undertaken by TRADA on behalf of UNIDO whose aims were to design and implement a modular wooden building system, an experienced woodworking shop chargehand was involved in the actual overseas work. This included advice on setting up the workshop jigs, and constructing the prototype. Such cooperation between professional advisors, (civil and forestry engineers etc.,) and skilled experienced expatriate tradesmen, should perhaps be borne in mind by UNIDO. It is a means of ensuring a better balance between complicated and somewhat over theoretical means of achieving quality on the one hand, and practical trades and artisanal technology transfer on the other. Unfortunately, over-emphasis on 'paper' qualifications, and linguistic ability in job descriptions, tend to militate against the recruitment of such individuals.

The following sections of this chapter discuss individual aspects of quality control that have come to TRADA's attention throughout the bridge projects to date. Points that arose during the EGM discussions are also incorporated. Subsequently, the modular panel test is considered. Finally recommendations are given for a complete review of quality control requirements for the bridges, and the need for a separate manual or additional annexes to existing manuals, dealing with various aspects of the subject.

Timber and Wood Parts

The timber used in a pre-fabricated modular wooden bridge panel undergoes many processes in its transition from a piece of raw wood to a structural member in the finished bridge. Quality control is required at each stage to ensure that the bridge eventually handed over at the site is sound and durable. It also avoids unnecessary and expensive rejections of part-processed pieces, to which value has already been abortively added.

The parts of the manuals dealing with the Design Selection process (Part 2) and Timber Technology (Part 4) go into considerable detail on the selection of appropriate timbers and the choice between naturally durable species and pressure treatment of the wood with preservatives. It is important in a new project that the advisors should explain these concepts clearly to the counterpart staff. The discussions should involve the workshop foreman or carpenter, as well as the professional personnel. Visits to forestry departments and sawmills should be undertaken by the local staff, and not just the expert, in order to ensure full involvement and committment to the correct choice and assurance of quality from the start.

Some initial work will be necessary by the expert and his team in assessing suitable sawmills. In some small developing countries or regions, only one source of supply may be practicable, and one will be left with no choice. It may well be that the local wood conversion industry is unfamiliar with the needs of a bridge project, or with similar types of timber construction, which calls for regular dimensions and quite long lengths. Mills may be geared more to furniture production, and to small scale local carpentry needs, providing random widths and lengths to meet these. The chances of the sawmill owners or operators ever having heard of the term 'stress grading' are remote, but this need not matter, as explained presently.

The eventual requirements must be clearly understood by both the expert himself and by the project team. These are to achieve a designated stress grade (in European terminology, as explained in the manuals) of timber in the finished pieces in the bridge, with an acceptably low rate of rejection 'en route', once the timber has been delivered to the project from the mill.

Equally important will be the dimensional accuracy in the finished pieces which are waiting on the jigs to be assembled into bridge panels. The drawings given in the manuals do not at present make it clear whether sawn, regularized or planed-all-round timber is to be preferred. Since full dimensions such as 50 mm x 250 mm (for the diagonals) are shown, it might be assumed that sawn material is to be used. Indeed this may have been the case in the original design. However, it was soon found in the Honduran project that sectional processing of the timber in the workshop was essential. Nominal 50 mm thick pine was found to vary on receipt from the mill in a range from about 46 mm to 60 mm in actual thickness. Such irregularities were quite unacceptable in attempting to produce an accurately jigged component. Similar experiences had occurred in the past in Laos, where tropical hardwoods were used for UNIDO's pre-fabricated modular building system. In future therefore, it should be assumed as normal practice, that in producing workshop-made structural components in the developing country, planing will be one of the necessary steps in the processes involved. This will affect both the working drawings produced, and also the equipment which UNIDO will be required to supply or to ensure is present.

There are various preliminary factors which are to be taken into account when selecting a suitable sawmill from which to obtain the project's raw material. General quality of the woods which will eventually lead to the desired stress grade, is obviously one of the foremost of these. The way in which 'grade' in a general quality sense, is assessed at this stage, will depend to some extent upon the type of timber concerned. Important factors for example in Radiata pine, which is likely to contain knot clusters, and quite clear, perhaps fast-grown material in between, will be different to those in a Caribbean pine, with much more sparse, cylindrical knots, but with wood of a wide range in density and perhaps a tendency to sloping grain. Again, straight grained tropical hardwoods of the Dipterocarpus species from South East Asia, cannot be assessed in the same way as rainforest species from West or Central Africa or the Amazon, where heavily interlocked grain may have to be taken into account.

Those who have had opportunities to get to know particular types of timber in given regions, soon learn the importance of provenance and quality of logs. In this respect the 'expert' is likely to have to bow to superior local knowledge, unless he is fortunate enough to have worked in the country concerned for a considerable period of time. Hence it is important that he should involve his counterparts. A local workshop foreman or carpenter may well have a better knowledge of which sawmills supply the best logs for the timber chosen for the bridges project. He is unlikely to volunteer the information to an outside 'expert' however unless his confidence has been gained.

It is perhaps worth mentioning that there is a tendency amongst timber engineers who in their normal work are mainly involved in design, to overestimate the actual stress grade likely to be obtained from a given visual quality of timber. This was first observed by the writer when involved in U.K. design. The tendency was particularly prevalent with the older 'grade ratio' type of stress grading, as exemplified in CP 112. If the calculations did not show that a proposed member size was quite justified, there was an inclination for the engineer to try to assume that the next higher stress grade in the scale could be used, irrespective of the actual quality of the wood likely to be used in the factory or on the site. The proper procedure would have been to increase the member size in the design.

Newer softwood stress grades were introduced in 1979 and these were named 'General Structural' (GS) and 'Special Structural' (SS). These two grades were intended to simplify matters, and also to counteract this lack of realism and to ensure that quite 'run of the mill timber' would be specified for normal construction. In older terminology, GS has an approximate grade ratio of only about 35%, whilst the SS, even in the higher grade, is only approximately a 55% grade in the older terms. In translating the experience to the bridge projects in developing countries, similar realism should be applied. An important decision, is the careful choice of which of the simplified grades designated in the bridge manuals, and discussed in Parts 2 and 4, should be sought from the material seen in the sawmills visited in the preliminary stages of a project. Care must be taken not to overestimate the quality of material which is economically possible. It may be for example, that the engineer or project leaders hope that four trusses, rather than six, can be used for an important, useful bridge span. This may be achieved using a given timber, if it can be assumed to be No.2 quality, thus giving a higher stress grade (F number), rather than No.3 Quality. However the advisor and his counterparts must check by actual careful measurements of the timber on offer whether or not this assumption would be justified.

At this preliminary decision taking stage on quality, they should not hesitate to use a grain scribe and a rule for knot measurements. Instructions in the use of these simple quality control tools should be given at a very early stage in the project. Whilst measuring the knots at this stage, sample measurements can also be taken of any production that may be in stock at the mill, of a similar size to that needed for the bridge project, to compare actual dimensions being produced with nominal sizes. By this means, in combination with discussions and polite questioning, local practice as regard to 'sawing full' or 'sawing bare' for the home market can also be established. Earlier comments should be borne in mind about the need to use planed members. Also it should be realized that the actual dimensions specified are required to hold good after the second, post-pressure drying treatment, when preservative treated timber is being used.

Modular Panel Testing

A pre-fabricated bridge whose structure consists of a series of trussed frameworks is heavily dependent upon adequate workmanship during the fabrication of each of the parts which go to make up the frames. An established engineering procedure in such cases is to institute some form of testing routine, to be carried out on the vital parts before they are passed into service.

It is interesting to note that the development work on the Bailey bridge, which provided inspiration for many aspects of the pre-fabricated modular wooden bridge design, also incorporated a procedure for the bulk testing of panels. Sir Donald Bailey and others gave a clear account of this. The proof testing was one of the many rapid and labour intensive developments which were necessary to ensure the outstanding success of their ingenious and adaptable design.

There was concern over the reliability of welded parts for the Bailey bridge, which were produced by inexperienced labour in a large number of different small factories throughout Britain. For this reason, a central testing depot was set up, later to be increased by two others. The system of testing was to make up the panels into a girder, and to apply loads by means of other Bailey bridge equipment. It would be possible to use the same principle for pre-fabricated wood bridge testing, especially in a situation where considerable production is to be achieved, so that ample spare parts are available.

The Bailey bridge test loads were so arranged that there was a pre-determined overload in bending and shear. These were 55 per cent above working load in shear, and 17 per cent in bending. Each test plant was capable of dealing with about 500 panels per week in summer time. Production at one period reached 26,000 panels a month, and 100 per cent testing became impossible, so a 10 per cent sampling system was set up for manufacturers who had achieved at least 200 satisfactory panels.

Later, a testing machine was developed for the more important Bailey bridge panel works, and 100 per cent testing was resumed. The total British production during the war period alone is recorded as nearly 700,000 panels, of which about 70 per cent were proof tested.

As indicated earlier, load testing was also deemed advisable for the pre-fabricated modular wood bridge panels. This was evidently decided early in history of the design, as a rudimentary form of back-to-back panel testing as illustrated in the UNIDO colour brochure, based on photographs taken in Kenya. The Kenya project manual also describes panel testing, but proof testing and prototype testing to failure seem confused in the accompanying narrative. The way in which it was intended that the load should be applied and reacted against is also unclear in this particular section of the manual concerned.

As a consequence of the above, and adopting suggestions by the UNIDO substantive staff, TRADA designed a test rig which was developed and assembled in Honduras. Accompanying test rig manuals and quality control charts were also produced.

When properly followed, it is believed that the test rig manual and quality control charts will ensure that isolated low capacity panels and major changes in quality of production will be identified. The charts provide a method for deciding when to reject individual panels, and in the extreme will indicate if the stress grade (F number) of the timber needs to be reassessed.

The testing applies a simple point load, spread through a radiused loading block, immediately over the king post of the panel. The module is supported by means of the male and female spigot positions on the top chord. Strains are induced by this means in both the top chord and the diagonal members. The spigot positions are also subjected to shear forces similar to those experienced in service. The lower plate lateral pins are not tested by this means.

Alternative test configurations were considered. Amongst these, arrangements were sketched which would apply a compressive force normal to the end of the top chord, tending to shear the male spigot pin. At the same time, the female spigot position to the top chord would be permitted to hinge on a pivotted bearing, whilst the lower lateral pins would retain a tension strap. Although more thorough, the arrangements of this type were thought likely to be more difficult to implement and slower to set up and dismantle. Consequently these ideas were not pursued.

The test procedure and use of the quality control chart is fully described in the appropriate manuals and need only be summarized briefly here.

A preload is applied twice to each panel, prior to taking deflection measurements. Durations of loading, load levels for each stress grade, and deflection measuring methods and accuracies are prescribed. Prior to use of the test rig in Honduras, there was little indication of likely deflections to be expected under test. As predicted, deflections were considerably less than would be suggested from structural analysis of the panel assuming pinned joints. Sets of deflection readings are only available for panels made from Honduran pine and tests using other species are needed to amplify the information given in the manuals.

Completion of the panel testing quality control charts is a means in itself of ensuring that an amount of routine but valuable information is properly recorded for the panels which are produced. The information required includes a unique panel identification number; the test date; the tester's identity; the moisture content of the timbr, taken with deep probes, at the time of test; the consignment number and source of the timber; additional notes, for example on visible defects or other special points.

The quality control charts were designed using normal industrial statistical control sampling techniques. Inner and outer control deflection limits are marked upon the charts, once sufficient panels in a particular project have been tested to establish these.

Considerable judgement must be exercised to determine what action should be taken when deflections outside the limits start to occur regularly. Single, occasional values outside the inner limit are to be expected, as this is set at the deflection that 1 panel in 20 should exceed. Panels outside this inner limit should be reinspected more carefully, looking for reasons for the excess.

However, the extra deflection may well be caused simply by less stiff than average timber. The panels may if desired be segregated for use near the centre of a span, where stresses in the regional members and shears are less heavy.

Values outside the outer limit are a serious matter, and their cause must be investigated and determined. Under no circumstances may such panels be used.

Values frequently outside the inner deflection limits may indicate that some consistent fault has crept into the production process, and this must also be investigated urgently. An alternative explanation could be that a change has occurred in the timber. This may be a drying fault, a grading problem, or possibly an alteration in the fundamental strength grouping (S number) that should be assigned. Stress grade (F number) reassessment may then be required.

It has to be recorded that installation and implementation of the panel testing in Honduras was not without problems. Nor have all of these yet been resolved. Some were due to local operational difficulties. Although these are always to be expected in projects in poor developing countries, in other circumstances, the rig design is not felt by TRADA to be excessively complicated or difficult to set up, under most reasonable conditions. Part of the problem was an inadequate provision of equipment funding and expert time in the first instance, so that the test rig became a 'problem child' whose correction during successive attempts by both experts and counterpart staff was constantly thwarted. Eventually, a simple, stupid problem of inadequate electrical wiring to the mains supply was allowed to be an excuse for neglecting to use the machine at full capacity.

Testing procedures such as that instigated in Honduras were discussed at the EGM. Some felt that a rig large enough to take a complete panel is too heavy, expensive to construct and difficult to operate in all projects. TRADA maintains the view that 100 per cent testing, coupled with the use of the quality control charts, is an excellent measure that should be adopted whenever possible. It should certainly be included in any mature project, where it is intended that a substantial volume of bridging is to be produced. The view expressed by some at the EGM that panel test facilities could be operated only on a regional centre basis, seem unrealistic on account of the probable cost or impracticability of shipping or transporting panels over long distances.

Alternatively for pilot projects, or others where fewer than about six bridges are likely, include testing using the self weight of assembled girders, as described above, or some form of localized shear tester, applied to the steel plate spigot positions, and the lateral panel pins themselves. Undetected cracks or poor welding in the steel parts are considered far greater dangers than weaknesses in the timber parts, all of which are at least doubled up, and thus to some extent load sharing. A relatively simple device, constructed with steel linkages and hand operated hydraulic jack, might therefore be adequate if designed to locate against the wood parts, and merely apply shear stress to the critical metal connecting details of each panel. Further design, development and testing work is recommended to try if possible to construct such a device.

Quality control of steel parts and welding

AT the EGM, there was considerable discussion on the control of the quality of the steel parts and of the welding. The system depends strongly on these aspects for safety, even though it is a wood bridge design. There are real dangers if these items are neglected or inadequately provided for. Several experts feel that dangers of failure of a bridge lie more heavily in this area of the technology rather than in the risks of, for example, inadequately graded timber. There are certain key parts in the structure, such as the end plates of the top chords with spigots or female connections, whose fracture could lead to sudden collapse. Some parts, including the spigots mentioned, have to be welded in the bridge workshop after panel manufacture is nearly complete. The solution of supplying ready made parts welded together in an industrialized country is not available therefore, even if it were to be socially and economically desirable. The only answer is to improve quality control documentaion, instructions and training in bridge workshops. Some guidelines, which follow, arose at the EGM. Othere are suggested on the basis of information available to TRADA. The basis is insufficiently complete for an annex giving draft clauses at this stage, and it is recommended that further work should be commissioned by UNIDO to this end.

Mild steel strengths are presribed for the steels to be used as follows:

BS 449 'The use of structural steel in building' Grade 43A, minimum yield point, 236 N/mm 2, ultimate tensile strength, 435 - 494 N/mm2.

ASTM Grade A36, minimum yield point, 248 N/mm2, ultimate tensile strength, 400 - 552 N/mm2.

Some sources of supply of mild steel, particularly that produced in developing countries and sometimes containing remelted scrap of unknown quality, may fall well short of the minimum strength presumed in the design. Testing facilities for steel samples are likely to be available, at university departments for example, in a reasonable number of cases in various developing countries. Simple instructions should therefore be produced for the tensile testing, in cases where the material is not to be supplied to the project from a well established source.

Arc welding is the usual technique intended for joining the steel parts during final assembly in the bridge workshop, and the following notes may be expanded and modified to form the basis of a future section on quality control of welding. Annex 5 gives notes on British Standard relevant to steel specifications and welding which may also be of help in drawing up future recommendatins.

Correct choice of welding rods is an important consideration. Care was taken over this in choosing the original supplies sent to Honduras, and specifications relating to British and US purchases are still available. Items to be detailed include diameter of rod related to material thickness to be welded; recommended current range; degree of penetration related to welding technique and steel type. Damaged rods, or flux cracked or dampened by bad storage can give rise to poor welds and instructions to avoid this must be provided.

Arc welding involves a powerful emission of heat and light and precautions are necessary to avoid damage, personal injury and fire risk. The area immediately around the workpiece must be clear of imflammable materials. In the contexct of the wood bridge workshop, this clearly means that shavings and sawdust must not be allowed to accumulate in the welding area. Normal workshop waste such as paper, cartons, cleaning rags, should also be kept clear. The welding area should preferably have a concrete or stone floor. Metal bins should be provided and used for spent electrode stubs, which themselves constitute a safety hazard. People working in the vicinity of a welding arc can be exposed to stray radiation from the arc which can cause discomfort or even permanent eye damage. Screening should be arranged around the welding area to avoid this.

For all arc welding operations, it is essential to protect the welder's head and body from radiation, spatter and hot slap. Ample recommendations are available on protective clothing and equipment for the legs, head and body, and this should be rigorously followed. Those in charge of projects should ensure that this equipment is available at all times and that the importance of its use is understood.

Safety hazards, and risks of inadequate welding exist, if the electrical arrangements of arc welding equipment are incorrectly set up and operated. Both mains-operated equipment, and mobile generators may be used. In either case, there is a primary, high voltage circuit, which should be installed and maintained by a skilled electrician, and a secondary, low voltage, very heavy current circuit, arranged by the welding operator. Damaged insulation, oversized fuses, and lack of adequate earthing, are sources of fire and electric shock hazard in the first instance. Poor earthing arrangements, damaged equipment and inadequate connections are safety and work quality risks in the second instance.

Reasonable ventilation is required to avoid operator discomfort from electrode fumes and avoidance of local temperature build up.

Welding principles which can affect quality

As already stated, it is beyond the scope of this paper to deal with the subject in depth. Compilation of proper guidelines should be considered by UNIDO. Helpful standards have already been mentioned as being annotated in Annex 5. In addition, textbooks for craft courses such as 'Basic Fabrication and Welding Engineering', F J M Smith, Longman, London, 1975, may be consulted.

Metal arc welding can be performed with direct current or alternating current equipment. The choice affects the method of connecting up the equipment, the selection of electrodes, and the setting of current. A stable electrical supply is necessary.

Factors involved in the choice of electrodes are the type of fuse covering, wire type and diameter. Standard specifications should be consulted. Welding positions must be stated for the metal part of the UNIDO bridge, flats and horizontal welding, the easiest methods should always be possible if work is correctly planned and arranged.

Excessive or low welding currents give rise to poor work and instruction should be sought and directions followed. Manipulative techniques which the welder must master include striking the arc; maintaining the arc length; obtaining the correct rate of travel, and laying the beads correctly.

The skilled operator must be able to achieve:

(a) Adequate penetration

(b) correct weld profile

(c) correct width of weld bead

(d) minimum spatter

(e) minimum difficulty in controlling the slag.

Welding defects are desribed in the relevant craft textbooks and British Standards. Defects which can ocurr, and which have been observed in some instances in pre-fabricated wood bridge steel parts include the following:-

(a) undesirable fillet-weld profiles

(b) undercutting

(c) incorrect penetration

(d) lack of fusion and presence of porosity

(e) poor smoothness and discontinuities

(f) inadequate de-slagging and cleaning

Guidance is available on visual inspection of welded workpieces and test pieces. Simple naked-eye and lower-power magnification techniques can be employed. Workshop testing of welds can also be undertaken to advantage, if instruction is given on faults to check against. A simple hydraulic press can be used to bend test pieces.

6 - SYSTEM DEVELOPMENTS AND EXTENSIONS

Timber piled approach spans and other new abutment types

Bridges constructed up till now under the UNIDO system have mass rock-filled concrete or masonry abutments. However, a timber piles/ wooden approach span system may be of more value in some cases, by helping to reduce the primary span and by traversing shallow profiles. Its appropriateness will of course depend upon site conditions, and the availability of suitable pile driving equipment.

Under a contract related to the project DA and DC/HON/81/002, TRADA was commissioned by UNIDO to develop proposals for timber abutments or timber piled approach spans. A timber abutment design consisting of treated timber poles, resting on a similar treated pole timber foundation, and incorporating backing planks to retain the earth, plus timber ground anchors with steel tie rods, had been obtained from piles remaining after the Kenya project. The design seems sound in principle. It awaits trial in practice, and in TRADA's opinion it should be put to use as soon as appropriate need arises. Possibly it could serve in Chile for example, where its potentially good earthquake resistance would commend it. Because of the existence of this suitable design, it was decided that TRADA's effort should be directed towards another seemingly useful possibility for use of timber in the civil works of the bridge - namely timber piled approach spans.

A drawing is available showing the general arrangement for a typical timber approach span construction which has been developed. For any particular construction, it may be necessary to modify the detailing shown in this drawing, to take account of specific site conditions, loadings, approach pitfalls and other aspects. This particular design employs Class 1 pine poles which are available in Honduras, 75mm x 300mm main beams, 75mm x 250mm stringers and 50mm x 100mm bracing members. The end bearing plate has been modified to sit on the top of the pile elevation). The principles shown in this design are not limited to the use of round section piles as shown here. Sawn or hewn sections, (normally square) could equally be used if required, without difficulty. A most important requirement is that all pile timbers should be naturally very durable (e.g. greenheart or sapodilla) or that they should be pressure treated with an appropriate preservative. Guidance would need to be given in a project using this type of design for the first time on the handling of long timber piles. For example, care should be taken that they are supported at a sufficient number of properly located points to prevent their damage due to excessive bending. Also they must not be dropped, bruised or cut by sharp metal pieces on rocks which would break the fibres or penetrate the surface. Piles should be selected for uniformity of size and straightness to facilitate placing of the bracing timbers. Suitable grading rules are available, for example in the Guyanese rules for sawn and hewn greenheart piles. A table of recommended timbers for piling is given in a TRADA Wood Information Sheet entitled "Timbers for River and Sea Construction". This table is not exhaustive, and there are other timbers which are suitable in addition to those listed.

Pile Driving Equipment

Obviously, suitable pile driving equipment is required to construct the small timber trestles shown in this prototype design. Whilst these are simple in comparison with the large trestle bridge structures built in North America, New Zealand, India and other places in the past. Non-availability of serviceable equipment may be an inhibiting factor in developing countries lacking in timber tradition. Timber piles may be driven directly into the ground or they can be driven into pre-bored holes. Friction or displacement piles derive their supporting strength mainly from skin friction, hence driving the piles directly gives greater strength than driving into pre-bored holes. The most common pile driving machines are drop hammers, steam hammers, diesel hammers and hydraulic hammers.

In addition to the hammer itself a rig is required for driving the piles. A variety of different types may be used. They generally consist of leads, which form guides for the hammer, and a supporting framework or crane to raise and hold the leads in position. Power from the crane or a winch raises the hammer within the leads. Driving rigs are usually mobile, and may be mounted on trucks, cranes or on floating barges. Many driving rigs have swinging or tilting leads for driving inclined or batten piles.

The simplest type of pile driver to set up is the pile frame with a drop hammer. The drop hammer is simply a block of cast iron, fitted in a pile driving frame and allowed to drop from varying heights onto the head of the pile. The drop hammer travels up and down the face of the pile guides, which also form the main uprights of the frame. The drop hammer is raised using a winch by means of a cable running around a pulley on top of the frame. When the drop has reached the required height, it is released, and falls under gravity onto the head of the pile.

The construction of this type of pile driving frame is within the capability of workshops in most developing countries. The frame is normally constructed of steel sections, but it is also possible to use timber. Winches are usually driven by petrol or diesel engines. However, there have been occasions when manually operated winches have been used. In most cases, therefore, it would be possible to fabricate a drop hammer frame locally. An alternative would be to have it imported in kit form and assemble it as the site.

If funding and local availability permits, a pile driver with an air hammer or diesel hammer would be more efficient and rapid. It would need either a mobile crane with pile guides, or a pile driving frame, in addition to an air compressor to operate the air hammer, or a diesel power unit to operate the diesel hammer.

Unfortunately there seems little likelihood that the timber piled approach span design, now incorporated in the bridge manuals, will be implemented in the near future in Honduras. The districts in which bridges have been constructed to date have boulder clay soils in which pile driving would be difficult or impossible even if serviceable equipment were to be available. Other regions may be developed in future with more suitable types of soil and terrain. For example, the District of Atlantida on the North coast, has alluvial soils, deeper slower running rivers and also better possibilities of obtaining equipment due to the presence of railways and large fruit companies. A number of bridges have been proposed to the Honduran public works ministry in this region. The drawings already produced, and the report on civil engineering equipment compiled under British Government (ODA) sponsorship, will provide a basis for development of timber approach spans in this, or any other part of the world, where the technology is adjudged appropriate. Consideration will have to be given to providing civil engineering expertise and advise, as well as timber engineering input, to ensure the success of such a project.

A much shorter civil engineering back-up to a future project, could in fact open up a number of possibilities that would be very beneficial to the counterpart of many developing countries undertaking or wishing to undertake bridge construction. In discussions with British Government engineering advisers and others who have been involved in bridge work for developing countries it has become evident to TRADA that time and again it is the lack of experience, funding and equipment for good abutment and support work construction that gives rise to unserviceable or absent bridging where it is most required. Other abutment and pier forms that have not been fully developed for the UNIDo modular bridge include concrete, masonry or reinforced earth types which can be built over timber piled foundations, various types of timber abutment such as that already mentioned which was drawn in Kenya, and various forms of gabion and piled crib supports.

Extra heavy duty modular panel

The concept of an extra heavy duty modular panel has been the subject of discussion between UNIDO and several of its experts for some time. At the time of writing, it has not been possible to give priority to this possible development however, and no specific details are yet available. The idea arose from a preliminary planning visit by Mr. H. Erichsen to Gabon. It appeared that in order for the prefabricated modular wooden bridge system to be of maximum value in that country, the design would have to cater for 65 tonne logging vehicles, which commonly use the roads in the district reviewed. Such loads are common in regions of tropical developing countries where hardwood logging occurs. Hence an enhancement of this nature to the system would have great appeal and would increase opportunities for its use.

An axle loading profile of the vehicles used in Gabon was made available in the preliminary visit report, and this could be taken as the basis for calculations, once the loading effects, member forces and timber engineering calculations are properly worked out and documented for the standard design. It could be assumed that high stress grade tropical hardwoods such as the F17 class would be available in a country such as Gabon, but at present, as design calculations are not available, it is impossible to tell how far short of the required loading some arrangement (number of trusses, span etc.,) the present design falls.

Two methods of increasing performance of the standard modular panel have been discussed in principle at TRADA, but at present, because of the lack of an initial firm base of design as mentioned above and also lack of funding, these are no more than concepts. Firstly, a fairly obvious way based on elementary principles of geometry would be to increase the breadth of the members making up the panel. If an approximate 50 per cent increase in load carrying capacity is required (assuming the present system maximum is 40 tonnes and 60 tonnes are to be carried), then it should be possible to gain this by using 75mm thick timber in all cases in place of 50mm. This may well take the self-weight of the module beyond reasonable bounds. It has always been stated that an intention of the design is that modular panels can be lifted simply by a few men, and that handling equipment is unnecessary. However, even the panels made in Honduras with a dense pine have been found to be quite cumbersome to manhandle on difficult terrain. Hence it is assumed that panels made under the present design with timbers such as azobe must be near the upper limit in weight.

A possible redeeming factor in the above performance versus weight argument, may be the reserve capacity that it has been suggested may exist in the present design. Thus an increase in thickness to 63mm could be acceptable, if together with other design modifications this could achieve the desired capacity. Additional measures to help increase performance without major alterations to the fundamental design and geometry might include the addition of nailed-on members to the side faces of some or all of the main module members. This could, if desired, be carried out at the site during the truss assembly process, to avoid adding to the weight of the panels during transport and thus assembly. Another possibility, which would have to be investigated on the drawing board, would be to increase the depth of either the top chord (probably having no important effect on the overall geometrical elevation of the truss) or both this and the diagonals (the effect on geometry would need investigating as the bottom plate spigot pin might need to be moved). Increasing member depths, both as an alternative to, or in conjunction with greater breadths, would of course have a greater pay off in terms of improved structural performance than just increasing breadth. However, in addition to the considerations of panel weight mentioned previously implications for lateral stability of the trusses would have to be considered, as well as availability of the required timber dimensions.

A second completely different concept in increasing the system capacity would be, in effect, the doubling up of the entire modular panel in each truss forming the girder. At present, the system goes some way towards this when extra trusses are used for example, in a six truss bridge. The extra line of modules used in each auxilliary truss of this type however, are not fully linked in a structural sense, to the main trusses of the girder. What is now suggested may in fact, even make it possible to make each individual module lighter, rather than heavier.

Under the proposal, a standard truss for the extra heavy duty version of the design would consist of two lines of modular panels each firmly connected laterally to the neighbouring panel. The individual modules might be made of 38mm thick pieces, thus keeping modules made from timbers such as azobe to a manhandleable weight. In place of the present lateral spigot on the lower panel plate, which is provided to attach the lower steel chords, a hole would be drilled during panel manufacture. The panels would require to be built on steel jigs, to obtain adequate dimensional accuracy, and a sufficiently powerful drill, with a deep enough throat to the radial arm would be needed to drill through the steel plate and the timber in one operation.

This is not an unreasonable technological requirement however, such operations are commonplace in manufacturing heavy tropical hardwood bridges in Europe. The object of drilling through the entire module in this way would be to obtain an accurately positioned, plumb hole through which a pin could be passed during site assembly. This pin would have sufficient length to pass through the bottom plates of two modules, with a length in between upon which could be attached two lower chord end holes. Two similar lower chord links would be placed, one on the outside face of one module in the pair and the other on the opposite outer face. The arrangement envisaged for the top chords of the composite truss would include packing blocks, nailed to the sides of the individual top members, that would face inwards. The top chords would also have through-bored holes at these packer positions, so that bolts could be fastened during site assembly, to transform the entire top chord into a semi-rigid mechanically fastened spaced column.

As already suggested, the concepts discussed above would require considerable development, involving design calculations, drawing and prototype testing. Each individual module contains eight main pieces of timber, even in the standard design, and there is a fair degree of load sharing achieved by the vertical nail laminating and the blocking of the top chord. Because of this, the number of replications required in prototype testing can be kept reasonable. It is suggested that allowing for some design modifications to incorporate improvements that become evident during the testing work, material for five modules would need to be purchased, with plans initially to test three replications.

It is important also to bear in mind the implications of increased weight due to the improvements discussed above, on the launching operation. Experiences of launching discussed between the experts at the recent meeting and in earlier correspondence, have indicated that within the range of the present system, launches can vary from easily achievable, even with lightweight or less than perfectly maintained equipment, to near disasters. Careful planning, heavy duty poles, winches and cables, and the use of additional pulley and shackle systems would all be needed to launch a heavy duty bridge safely and successfully. It would be preferable if the prototype were to be initiated in a country already having experience of launching conventional bridges.

Deck design would also have to be considered, but would be unlikely to pose a problem, since existing bridges, taking quite heavy loadings, require only 100 or 125mm wide deck pieces in the vertically nailed laminated design now adopted as standard. The larger member sizes or thicker composite trusses discussed above would have adequate fixing surfaces for 150mm or even 200mm deep decking, should they be required. TRADA agrees with the TRRL recommendation that the deck adds an important, albeit inquantifiable margin, to the strength of the bridge. To cater for the large vehicles discussed, attention would also be paid to substantial and well-fixed bracing in all planes of the design.

Abutment design would also be required to cope with the extra heavy loads involved. For this reason also, the project should be initiated in a country, and with a counterpart agency, having adequate civil engineering skills or potential for their development, to cope with the entire system. Finally, in discussing modifications to the thickness of members used in the system, the possibility of developing at a later date, a special lightweight panel should also be borne in mind. This could be used in bridges such as the 5.5 ton pick-up truck type being developed in Malawi in a project under Mr. R. F. Campbell. It may be that standard modules for such bridges only require members of 38mm thickness, and this would be better established once standard design calculations are documented for the normal bridge.

Multiple span bridges

An important objective of the project DA and DC/HON/81/002 in Honduras was to rehabilitate the Choluteca District, in the South of the country, where a tropical storm had caused severe damage to the infrastructure of the countryside, before the project began. Part of this plan was to complete a circular road linking a number of villages and market towns, some near the national border with Nicaragua. Four single span conventional prefabricated modular wooden bridges were built during the project in this region, but to complete the road link, several crossings were required that were too long to be spanned by any of the standard designs in the system.

It was considered that sufficient experience had been gained in use of the system to attempt to implement multiple spans, a concept that has been discussed on a number of occasions but that as far as is known has never yet been put into practice. Accordingly, a requirement to design a system for launching multi-span bridges was included in the terms of reference of a contract to TRADA.

A report and drawings have been completed, detailing the proposed method of launching multiple-span bridges. The essence of this is to provide portalized support frames and anchorages which enable the launch procedure for each individual span to remain the same as the conventional wet crossing method for simple bridges. The support frames require tall, strong poles. They also make use of bolted - on cross pieces and stiffeners. The frames rest on the stream bed close to the piers. An earlier proposition had been to found them in built-in pockets in the piers themselves, but this idea was abandoned due to the concern over the possible overturning effects on the masonry. The frames require stay attachments to the piers, and fairly extensive guying. Apart from the extra materials required for the launching frames themselves however, and the extra precautions obviously advisable in their erection, the launching uses existing equipment and techniques. It is unlikely however, that a project which has been equipped with the minimum of winches, cables and shackles for a prototype bridge will have sufficient of these for the multiple span launch envisaged, and extra quantities will have to be provided.

Unfortunately, the method has still not been implemented at the time of writing, although further details of the multi-launch proposals were worked out under the auspices of the ODA project in Honduras. Furthermore a double span site is under construction in the district mentioned above. Side abutments have been built, and the central pier is underway. A report has been prepared ,in Spanish giving details of the stay tensioning methods, the dimensions and fixings of the launching frames, and lists of equipment. In addition, some of the standard bridge design details have been especially modified for multiple spans. These modifications include a method of providing a continuous deck over the length of span passing across the central pier, and accompanying bearing details for the main girders.

Although each main span remains simply supported in the multiple span proposals, thus avoiding structural design complications that might arise from continuous girders, it is felt important to maintain a sub-deck structure of comparable rigidity over the piers. In this way it is felt that difficulties which might otherwise arise due to vehicle impact forces when passing over the piers can be obviated.

The report comtaining the multiple span proposals has been made available to projects in Malawi and Ecuador and it is hoped that experience will be forthcoming in this potentially valuable extension to the prefabricated modular wooden bridge concept.

Wooden lower chords

The original prefabricated modular wooden bridge design developed by Mr. J. E. Collins in Kenya used steel lower chords. Very low quality grades of plantation grown softwood were sometimes required to be used in the bridges there. The lower chords are a vital link in the structural integrity of the design, since rupture of a single chord could quite possibly lead to progressively complete collapse of a bridge through a 'domino'effect. For this reason, Mr. Collin's choice was undoubtedly wise, particularly as about the time of his development design stresses for softwoods in tension were being reduced in codes of practice worldwide, following failures which had occurred in North America. It had been realized that although small defect-free specimens of timber are stronger in tension then in bending (conventional 'wisdom' upon which earlier codes had been based), the effect of defects such as sloping grain on tension strength is more marked than previous grade factor allowances had provided for.

Notwithstanding the above considerations, it was felt that with suitable care over selection and training in stress grading for the bridge workshop staff, pine of excellent quality and straightness of grain could be selected in Honduras. The proposal to develop a design using wood lower chords was therefore agreed with UNIDO and included in terms of reference to TRADA.

Because of the lack of fundamental design documentation mentioned elsewhere in this paper, it was necessary to design a wood chord that would have a strength better than the strength calculated (and later proven by test) of the steel chords established as standard for the design. It would be preferable to have designed the timber chords directly to have the required strength for given stress grades of timber (F numbers) expected of other parts of the design, and given in the design trables in the manual. This point will be followed up later in this section.

Another constraint that was accepted as a practical compromise in producing the wood chord design, was that no modification would be proposed to the geometry or assembly process of other parts of the bridge. Thus, end attachments that would fit onto the existing lateral spigots on the lower panel plates of the triangular module were included in the wood chord designs. As with other proposals, such as the use of plywood gussets in a bridge truss (abandoned after initial recommendations, at TRADA's recommendation) there are many alternatives to the standard design that can be suggested if major changes to the concept are admitted. However it is felt that the standard design has established itself as so robust and well proven, that it is ill advised to meddle with its principles in such ways.

The wooden lower chord designs were developed by a combination of calculation methods and prototype testing. A total of four full-sized chords were tested to destruction on a large tension testing machine. Advantage was taken of this testing also to check on the modulus of elasticity of the Honduran pine in tension, and the figure so obtained will be useful in future design analysis work.

Drawings of the finalized TRADA designs for light chord and heavy chord lower wooden chords were made available to the project in Honduras, and a 15m four truss bridge has been built using the light version. The drawings have also been incorporated in the official manual. The method of fixing steel end strips, with holes for the lower panel plate spigots onto the wood chords, depended upon a main steel swivel pin, and steel plates attached to the wood parts by means of dowel pins with welded heads, on in other parts of the bridge manufacture. Several fairly complicated steel pieces are thus needed to effect these end connexions. Thus the actual saving in raw material costs through the use of wood chords in place of the all-steel design is not great. It has been found however that there are other quite substantial cost benefits and other advantages in this design. Under the ODA contract for continued advice to Honduras, TRADA arranged the shipment of steel parts fabricated in the UK. The wood chord design permitted all these parts to be kept to sizes that could be boxed in small wooden crates and handled on small lorries, whereas in the past considerable difficulty had been experienced in fetching large mild steel flats from the docks. It is hoped and expected that in bridge projects which may in future be undertaken elsewhere, the flexibility of transport arrangements, and choice of steel part cutting methods from smaller stock sizes may similarly be found advantageous.

It is felt that with a certain level of training in timber selection, grading and processing, which should in any case be given in projects such as these, bridge workshop personnel can be taught to select material of an adequate quality to provide wood lower chords in most circumstances. Exceptional situations such as that found by Mr. Collins in the first instance must of course always be taken into account. However the use of correctly graded timber for tension chords may in fact lead to a safer bridge than splice-welded, steel tension chords, that a project may be tempted to try to use if long steel flats are not available.

The work which TRADA was requested to carry out on wooden lower chords is complete, and as mentioned above, these have been incorporated in an actual bridge. Unfortunately however, it is not possible to give a range of wood chord designs for the various stress grades (F members) used elsewhere in the design manuals. This is because direct design criteria are not available for the structural members in the bridge. It is not possible to state the tension force to be carried for a given span,number of trusses and loading type, until the design has been recalculated and the details documented, therefore adding another reason for the urgency of the need to carry out this recommended item of future work.

632/1(8)

Drafter:R.M.Hallett
13 December 1986
Revised: 19 February 1986*

Attended by:
[redacted]
C.R. Francis
F. Sorensen
A. Campbell
H. Erichsen
J.C. Cano
A. de Freitas
R.M. Hallett

cc: A.A. Vassiliev
L.F. Biritz.
K. Sepic
H. May
A.V. Bassili

NOTE FOR THE FILE - REV. 1
Special Informal Bridge Meeting

Vienna, 9 and 10 December 1986

It was agreed to:

-review the state of the art and the standard system, its use in developing countries and current activities of UNIDO with respect to bridges.
-review the manual with details, additions, corrections, plus review the design calculations and responsibility in this area.

-extensions, which would comprise only a list for later detailed discussion
-protocol for handover including deflection test and any other material such as maintenance and inspection which would be the next sub-agenda item.

Regarding extensions, this would cover designs of the UNIDO bridge, then the through-truss design of Robin Francis and other designs going from logs to larger span bridges and discussion of the role UNIDO should play in bridge technology in developing countries.

Discussion first covered whether or not UNIDO should have a more liberal attitute towards release of the manual.

It seemed that there was confusion especially amongst SIDFA,s who possibly should have a special letter explaining our thinking as to who should receive copies. The postal packing by UNIDO was not always a good quality and this manual and other documents often arrive in tatters. The main point was that it was impossible to stop people from building things in general but UNIDO should try to restrict receipt of these manuals to engineers who would in the end have to put their name to the structure.

The point was made that if UNIDO is too mysterious with its circulation, people will loose interest since people like ministers or chief engineers of

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* Incorporating extensive comments and additions by C.J. Mettem, TRADA, UK.

departments want something in their hands soon after they have shown serious interest. Chris Mettem pointed out that the whole intention of Part I of the manual was to provide a brief review of the bridge design, its usefulness, methods of manufacture, constructions and implementation for serious engineers of transport ministries, chief engineers, etc. Therefore UNIDO should make a special point of this in the proposed letter to SIDFAs, and other future circulation literature. Thought could also be given to the possibility of printing (perhaps even binding and illustrating) additional copies of Part I only, especially for this purpose. Part I does not contain sufficient detail to implement the system fully, so dangers of inadequately supervised 'private' projects are not increased by this proposal.

The point was made that the name "UNIDO BRIDGE" should be spread just as a brand name like "Bailey Bridge" but it was not always possible to include this in a sign because country feelings varied on this, others felt it should be called the "Collins Bridge". In general, it seemed that the experience UNIDO has had with the bridge is sufficient to withstand the odd abuse or failure since we can point to such good success in several countries. Harald Erichsen suggested that it sould have been a good idea to have printed in large letters "UNIDO" across each page of the manual which would help identify the design as UNIDO's. In future amendments or additions this should be seriously considered. In fact, it would be a good idea to put UNIDO across each of the drawings as well. Chris Mettem pointed out that in fact all separate drawing sheets produced by TRADA do already have drawing titles including UNIDO's name. (However, these do not appear on the figures in Part 5.)

There was considerable discussion on the quality of the steel parts and the question of whether, for prototype bridges, whose objective was principally to introduce timber technology, the steel parts should be accurately machined and provided from an industrialized country such as Germany or Britain

Peter Campbell pointed out that there were redundancies in some of the dimensions given for the steel parts in the manuals and that tolerances are not shown which is impractical since in all cases there must be some variations in actual sizes delivered versus those specified. Robin Francis suggested one way of solving the problem, which occurs with certain types of standard length stock, of getting out two lengths from each for the bottom chords. This is to take the standard 20 foot/6m mild steel flat for two tension chords and weld a reinforcing piece on the one end to make the hole and on the other end weld an extension of thicker material to obtain the required length. This also enables a greater degree of control on their manufacture since a welder at the bridge workshop is easier to control by the expert. Chris Mettem pointed out that in countries with good quality timber, timber tension chords are a better solution since their use allows more convenient sizes of steel, especially if this has to be imported, and also gets away from the problem of the incompatibility of 6m length when in fact you need two 3.01m pieces. If the timber packing pieces are considered in the cost comparison, then the timber/steel tension chord is cheaper than the all steel chord with these packing pieces. Peter Campbell noted too that some sources of supply (e.g. China) can give rise to mild steel of a strength considerably below that presumably assumed in the design.

It had apparently been considered to order 6 mm thick steel in rolls for a project in Ecuador but it was pointed out that right from the start ? of design responsibility by TRADA, 9 mm had been fixed as the minimum thickness for lower chords. This had followed a correct observation by Robin Francis that most bridge design codes recommend this thickness as a minimum to safeguard against corrosion.

There was the point made that the range of spans of up to 30m claimed in the earlier promotional literature was too optimistic and that even 27m is rather long. It was generally felt that 21m is the most useful limit for very heavy timbers (due to the launching forces generated) and 24m for medium weight species such as pine. 24m is the longest span hitherto launched and the problem is both one of launching and of simply experienced observation of what a normal span to depth ratio should be.

Chris Mettem commented that on first reading of the dry launch technique in the Kenya manual, TRADA had difficulties in interpreting it. Insufficient details seemed to have been given for a safe and effective method. Robin Francis explained that it had been used occasionally in Kenya but that the twin tower 'wet launch' method was generally quicker, safer and more convenient. This was generally agreed. The 'dry launch' method given in the launching manual is based on a launch actually carried out successfully at a difficult, steep site in Honduras and sufficient details are included for it to te repeated if necessary. However, the manual already contains wording to suggest that it is not the preferred technique.

Due to less than perfect conditions often found during launching and despite best efforts to advise over maintenance of launching equipment, experience has shown that the capacity of the Tirfor winches should be overdesigned.

Another precaution, incorporated in the manual and now put into practice in Honduras is to increase the hauling power by using pulley blocks instead of a straight pull.

Another launching variation experimented with by Robin Francis in Dominica was the use of twin legs instead of four to make it easier to erect them if very heavy species are being used. In the example he quoted an 8m height had to be achieved to ensure sufficient sag in the main cable.

Mr. Francis recommended that it is often worthwhile to encourage the counterpart engineers to produce simple force diagrams of launching arrangements so that they appreciate the directions of pulls involved and possible derrick overturning effects.

There was a lot of discussion on the responsibilities for the overall bridge system and also on the abutment design and execution. Chris Mettem recommended that UNIDO should be prepared to provide expertise in abutment design, not only for timber piled and similar forms. Inadequacy in this area was a common cause of failure or underachievement of bridge projects in developing countries. There is now an opportunity to check and make written records of the excellent designs carried out successfully in Honduras. It was generally agreed that UNIDO projects, while not explicitly having responsibility, e.g. in the project document, for the abutment design, should nevertheless bear this problem in mind when being conceived, and the expert sent should be briefed to evaluate the levels of skills and experience of the counterparts in each particular case and be ready to advise extra expertise in particular areas as required, and thus make an early change in the project document to meet the needs. UNIDO's role is certainly one of helping recipient governments to evaluate the usefuless for them in this system, and to then point out the kinds of skills needed to complement the needed principal timber technology which forms the core of the project.

Next there was discussion of costs which, although inevitably related to the scale of manufacturing, should be able to be assumed even without full time production rates. It was felt that the costs do not need to be estimated with undue accuracy, yet nevertheless a guideline must be provided to governments and private sector individuals considering whether or not to produce the bridges. It was felt best to include a range of standard reasonable assumptions in the cost structure so that this might be more readily done. Chris Mettem handed out (Appendix 1 of his report) a cost indication for 15m four- truss bridges which worked out to about US$500 per metre span for materials. On the other hand, Harald Erichsen's experience in Ecuador indicated total superstructure costs of about US$400 per metre span.

There was much discussion on the conditions and terms and procedures for handing over responsibility of a bridge to the recipient government or organization including discussion of the draft protocol, a deflection test procedure which had been proposed by UNIDO staff and maintenance and inspection recommendations that would be followed.

As well as handover of the bridge, it was agreed that the following documentation should as well be passed over to the recipients. Full drawings and design calculations, when completed, and inspection procedures, possibly relating to existing practice in the country and also incoporating notes on the inspection of particular items such as running boards, the inside bottom apex where the tension chords join, the erosion of aprons and approaches, so the abutments are not back-cut, rusting of steel, foliage growth: this list can be added to in due time.

With regard to the complete bridge deflection test procedure drafted by TRADA at UNIDO's request, it was felt that it probably would not show enough practical value to be proposed for use on a widespread basis. Furthermore, it could in fact lead to a negative image of timber as a construction material, since such tests were not commonly done on bridges built with other materials.

Alternatives were discussed to the test described in the TRADA paper which depend upon surveying equipment. These simpler methods would depend on apparatus made up with fishingline, weights and rulers.

It was suggested by some that the information obtained would be much more valuable if it were collected over time, for example after an initial settling period and under load versus not under load on a yearly basis during the lifetime of the bridge.

The difficulty with this however, would be that it would not be possible to leave measuring apparatus in place, and the instantaneous deflection under a transient live load is not expected to vary in a sound structure at any stage in its life history, irrespective of the amount of creep that has taken place. Only a gross change in deflection due to a major defect ascribable to 'ageing' (biodeterioration, corrosion, etc.) would show up therefore, and this should be detected more efficiently by other means covered in the inspection and maintenance procedures. Mr. Francis suggested that it would be useful to use three vehicles of ascending (known) weight to test a bridge, e.g. a land rover, large Toyota pickup; Ford 10-tonne truck (preferably with known loads such as bags of cement) so as to get three or more points on the load -deflection graph.

The discussion of deflection measurements concluded that whilst on occasions these would serve the purpose of alerting users to possible problems, the main point was that they would serve to create a data base for UNIDO's own internal evaluation of this system around the world and for analysis comparisons.

It should be noted under instructions for maintenance, that a clear differentiation be made between the responsibilities of the recipient authority for maintenance which should be carried on for any kind of a bridge such as for abutments versus those which are of particular relevance to the timber bridge itself.

It was also pointed out it would be useful to have the date of construction permanently marked on each bridge as it is built and this should be recommended to governments.

The date could be imbedded into the abutments, but since the bridge itself might be erected later this should be chisselled or otherwise permanently attached to the inside of one of the panels, say end panel driver's side.

Chris Mettem pointed out that the UN/ECA road maintenance booklet incorporated many useful hints on maintenance and inspection of bridges and roads. These would be incorporated where appropriate into TRADA's draft maintenance and inspection document, which was handed out for review and additional discussion on a workshop basis as per a drafting session for a code or standard. A revised draft was returned to Chris Mettem for revision and submission as part of the draft protocol for transfer of bridge to recipient authorities.

During discussions, Mr. Bassili brought up the idea of taking advantage of the presence of the group in Vienna to conduct interviews on their personal experiences with the bridge system. It was agreed that this would reinforce the TRADA/ODA introductory film with the target of bridge openings, visiting ministers and possibly, in a somewhat expanded format (in a technical sense), for universities or more technically minded people. The introduction would briefly describe development and the fact of its exitence, and the way that such a technology can also be used for a range of other structures in the country. Chris Mettem would introduce the basic design and structure of a bridge; Harald Erichsen would comment on the practical range and some costs:

Jose Carlos Cano would mention the simple fabrication and simple machinery required, launching would be covered by Robin Francis. (This was done on 10 December).

Discussions took place on the documentation of design calculations and modelling of the bridge which was felt to be essential before it is possible to make any modifications or extension of the basic system to take greater loads. It was suggested that a proposal might be put forward by Robin Francis who would give guidance to TRADA on what specific loadings, load combinations and structural assumptions to analyze using their computer facilities, which would be the best combination of their practical and technical skills. This might then be passed to the UK Transport and Road Research Laboratory (overseas department) for comments and approval. They would lend an additional factor of independence to the calculations.

Modular panel testing was discussed under quality control. This was first suggested by UNIDO as a means of improving on the very rudimentary back-to-back testing carried out in Kenya. The Honduras test rig was developed as a result. Comparisons between calculated and measured panel deflection had been substantial, but not unexpected, because of difficulty in analyzing the rigid dowel joints in the panel framework. Test deflections had been collected by SECOPT and TRADA for a range of panel, but these only apply to Honduras pine. As yet, the performance of panels made from other timbers in unknown. The group agreed that such a test rig, which was expensive to design and build, should be kept as a regional central test facility, where panels could be sent from neighboring countries rather than as a specific quality control tool.

The group agreed that regular process control was essential in ensuring good quality of panels and other components and some aspects of this were discussed.

1. Welding This could be critical to panel strength and hence bridge safety, and the best solution would be to have all welding done at a specialized shop. However, the design of the bridge only allows certain plates to be made outside the workshop, since some of the welds have to be made on the assembled panels themselves. This concern over welding was a real fear voiced by all the bridge experts, since supervision was often lacking.

Peter Campbell suggested that timber bridge experts should be instructed that their responsibility includes welding, and if necessary they should be given additional training and learn the appropriate inspection techniques. It was recommended that a welding section, including quality control, be produced and attached to the bridge manual as an annex to part II.

2. Preservation A major problem was getting information on what effective preservation had actually been done, since many commercial plants do not keep records or charge sheets. It was suggested that Peter Campbell do a five or six page note on how to control penetration and retention using simple methods which would be available in the less developed countries. This would similarly be an annex to part II of the bridge manual. Chris Hettem reminded the group that small-scale mobile pressure treatment plants, as drawn up in a detailed specification for Honduras, under the ODA project, give projects better control over their preservation than commercial treatment. They also have the advantage of cutting down considerably on transport costs.

A low-deck timber road bridge design was introduced by Robin Francis, who explained that people felt there was a need for lower abutments suitable for more shallow river crossings but that there were problems in achieving this, particularly with a timber design. Also savings in abutment height are often less than imagined. Thus the need was more preceived than actual in many cases. In order to achieve the necessary bracing, sway resistance and stability, only about 0.9m height. would be saved at a cost which was likely to be about double that of the present bridge.

It was suggested that this new draft design was very suitable for low-lying, level terrain. Often such country exists in aluvial areas where timber piling would also be more suitable. Consideration of developing a complete package for these areas may be taken up.

An existing bridge workshop such as Honduras or Ecuadorcould then try to make a through deck bridge and look into the manufacturing difficulties. The supply of suitable sized timbers (4" x 12") would pose a problem and two alternative means of building these up were discussed. The first was nail laminating two pieces of 2 inch by 12 inch together, and the second was building up vertical laminations with through pins as presented by Mr. Markerink at the Expert Group Meeting on Timber Construction. (ID.WG.447/10).

It was uncertain as to whether it would be worth-while to explore the design further, although if a better estimate of its cost and technical feasibility could be made, a decision on further work could be made.

It was unfortunate that lack of time prevented a thorough review of the manual and discussion of:

i. Multiple launching of spans (the actual technique, continuity over the piers, etc.);
ii Timber approach spans; piles; round timber ground anchored abutments; timber foundations; civil engineering equipment for all of the above;
iii Very light trafic and pedestrian bridges and other completely newbridge needs for developing countries.

ANNEX 2

DRAFT MAINTENANCE AND INSPECTION CLAUSES

Introduction

This section gives recommendations for practical maintenance and inspection procedures for existing bridges. The object of these procedures is to maintain bridges in a sound structural condition and to keep the roadway using them in a safe state, enabling free passage of traffic.

Bridges represent a large investment of capital, and simple maintenance measures taken at an early stage protect this investment and avoid the great inconveniences and extra costs brought about by interrupted communications when a bridge fails.

Bridge maintenance will often be undertaken by departments also responsible for maintenance of roadside areas and other drainage structures such as culverts. Volume 1 of the UNECA handbook series will be found to contain valuable practical advice in this respect as well as complementary information on bridge maintenance.

The procedures outlined here fall into two parts. Firstly, inspection and accompanying light minor ad-hoc maintenance. Secondly, major routine practical maintenance. In some countries and types of transport system, procedures have become established at such a level that two classes of inspection are recognized. Annual inspection and light maintenance can then be followed up at a period such as five years with a more rigorous and detailed inspection, possibly involving some dismantling or uncovering of inaccessible parts of the structure. It is assumed that this would be too sophisticated for most developing countries using the prefabricated modular wooden bridge system, but if required, the details outlined below could be expanded to such a form of two-level proceedings.

2. INSPECTION AND ANNUAL AD-HOC MAINTENANCE

2.1 General

It is assumed that these bridges will normally be used to span over water, and when this is the case, the water flow must be unimpeded at all seasons. The watercourse beneath and in the vicinity of the bridge must be kept clear of driftwood and debris that could damage the bridge at times of flood. Collapse of embankments to the roadways at the bridge approaches could equally have disasterous consequences for the entire bridge. Inspection therefore involves a thorough examination of all the civil works at, and in the immediate proximity to, the bridge site. It is important that inspectors have a clear understanding that the objective of their work is to protect the entire river crossing, and not merely to check upon the condition of the bridge structure itself.

A check list should be drafted to ensure that the inspection is carried out thoroughly and adequately and that important points including those not relating directly to the bridge structure itself are not overlooked.

A copy of the previous inspection report should always be made available to the person going to the site, to enable checks to be made on previous damage repairs, incipient weaknesses or unattended faults.

2.2 Inspection procedure

It is highly desirable that inspection, and accompanying ad-hoc maintenance, is carried out annually, and this section assumes this to be the case. A report should always be completed and returned for action arising from the inspection. This can conveniently be filled in using a form related to the check list. A standard report form helps the inspector to make his recommendations clearly and briefly. Clear sketches and comments, accompanied by measurements when relevant, are preferable to long discriptions, and the standard report form should include provision for these.

It is expected that in countries with a climate having marked wet and dry seasons, inspection will normally be carried out at times other than during the rains, travel will also be easier during such periods. Hence it will be possible to check damage caused by any recent past floods, and to look for defects in abutments, piers and foundations. Damage erosion and scour of banks and riverbeds can also be detected at this time.

2.3 Inspection report

Information given by the inspection report form should include the name and job title of the inspector; the date of the inspection; the location of the bridge, possibly including map reference (depending on local practice); the bridge's name and principal details such as span, design type and loading.

At least two copies of the report will be required. These will be returned to the district engineer's office and to the maintenance section responsible for the bridge.

It is recommended that inspection crews (normally at least an inspector and a driver) be equipped with light tools such as a pick and shovel, broom, crowbar, hammer and nails, nail extractor and a bush saw. In this way, ad-hoc maintenance can be undertaken at the time of the inspection visit, avoiding the necessity for a return journey for minor clearance and repairs. A maintenance work sheet can be prepared for this light-duty annual maintenance, and this should be completed and filed, along with the inspection report.

2.4 Specific inspection items

2.4.1 Abutments and wing walls; central piers

Some or all of the following items may require checking on or around the abutments, wing walls and central piers of the bridge site (referred to as support structures):

a. Foundation settlement cracks in concrete, or concrete-reinforced masonry support structures. Rust stains and other evidence of reinforcement cracks. Cracks in joints in the structures e.g. between abutments and pier caps. Plumbness should be checked where tilting or movement is suspected, using a spirit level or plumb-bob.

c. Scour or undercutting and exposure of foundations beneath the intended river bed level, possibly accompanied by settlement or cracking.

Spillage of soil, or water leaks at all joints in abutments and wing walls. Blockage of drainage outlets in these.

Signs of distress in timber piled approach spans, timber abutments or piers, including evidence of loosening of piles or members, due to damage by excessive loads. In general, timber support structures should be inspected for similar points covered below for timber superstructure, such as loose or corroding nuts, bolts, connections and nails; termite attack; signs of decay. In salt or brackish water, damage by marine borers may occur at the foot of piles near the river or shore bed line. Forms of decay not likely to occur in the superstructure may also require checking for at this position. Otherwise the principles of inspection will be similar to those carried out for concrete or masonry supports.

2.4.2 Modular panels, bottom chords and bracing making up the structural girders of the bridge

As described in Part 2, the pre-fabricated modular wooden bridge system consists of a superstructure made up from standard triangular panels which are 3m long and which are joined in lines, using steel or timber bottom chords to make up trusses. The trusses themselves are braced together in pairs to form three-dimensional girder structures. It is upon this girder arrangement, often placed in pairs for a four-truss bridge, but sometimes supplemented by aditional trusses, that the bridge depends for its strength and stiffness under the heavy vehicular loadings for which it is designed.

The girders are protected to some extent from the worst of the elements by being located beneath the bridge deck in this design. If manufacturing and constructional recommendations have been carried out properly and instructions on selection of naturally durable timbers or application of suitable pressure treatment followed, then a permanent structure of great longevity is to be expected. As emphasized elsewhere, importance is attached to maintenance of the entire bridge crossing site, entailing care of abutments, embankment and deck etc. If these points are followed distress is not to be expected in the bridge structure itself, unless deliberate vandalism, sabotage or theft of parts has occurred.

The following outlines the check-list items to be covered in an inspection of the superstructure. Suspected faults in the superstructure should be reported to the engineering office responsible, and simple ad-hoc maintenance will not normally be appropriate.

a. Soundness of timber

Superficial evidence of decay may appear as discolouration, and the presence of fruiting bodies of fungi. Sound timber should be hard, in keeping with the density of the wood species used for the original construction and this hardness can be checked with a penknife or small handspike when in doubt. Unless superficially saturated by recent rains or flooding, the superstructure timbers should be expected to feel dry to the touch. The superstructure is designed to be placed in a position in the bridge where air circulation occurs, and where the timber members should reach an equilibrium moisture content similar to wood in a well-stacked air drying timber yard. Any water or silt staining, and lurking pools or patches of dampness should be investigated therefore, their causes reported or eliminated by simple ad-hoc measures such as deck cleaning. The lower points of the triangular panels may accumulate silt and debris in pockets caused by the steel plates, and these and any dirt traps similarly found to occur elsewhere, must be kept clean.

b. Termite activity if occurring will be apparent from the shell-like tubes enclosing the runs constructed by these creatures. These tubes should be swept off, and the infestation reported, so that the extent of damage can be assessed, and fresh soil poisoning put in hand.

Serious splitting of the structural timbers is not normal or acceptable. That which should be reported for remedial action is the occurrence of deep fissures, which appear to penetrate right to the centre, or through the pieces of wood, and which run lengthwise more than about one and a half times the member's width. It should be noted however that numerous small and longitudinal fissures, not joining up to one another lengthwise, and known as surface checking, are a common feature. They are more prevalent in some species of timber than others, but are to be expected in structurally acceptable and sound timbers when these weather naturally in external conditions.

Positions at which checking for timber soundness and absence of serious splitting should be concentrated include the panel plate positions, bracing bolt holes, and the areas near the bridge bearing plates.

b. Straightness and alignment

The trusses should be checked for straightness, by eye, aided by a stringline in cases of doubt. This would reveal possible incipient lateral buckling, due to inadequate or failed bracing or severe overloading of the bridge. Displacement of individual modules, or misalignment caused by partial or complete failure of lower chords on one side only will also show up in this alignment check. It should be noted that in bridges made from trusses using modules having sawn timber, as opposed to material regularized in thickness by a planing machine, some moderate 'dog-legging' in the trusses is to be expected, and this will have been present in the structure even when new.

c. Nuts, bolts, washers and split pins

The design stipulates bolted joints locking together the nailed laminated halves of each module at the panel place positions. These occur at each corner of the triangle of the module. These bolts should be tight with their original nuts and steel washers firmly in place. Other bolt positions include the fixing lugs for the vertical cross bracing. These have larger, timber washers, which should also be intact and held tightly by the correct nuts. All bolted-on bracing should be checked for rigidity and tightness of joints by grasping and shaking by hand. The bottom transom bracing beams which should have been firmly nailed in during construction should also be intact.

Split pins retain the lower chords in position on the transverse spigots of the bottom panel plates. It should be checked that these have not been stolen or removed by vandals and that they are intact.

d. Steel panel plates and steel parts in lower tiers

The steel panel plates should be checked for sizing of rust and corrosion. Weld lines in the steelwork, and welded pin heads on the panel plates should be checked for obvious signs of stress corrosion cracking. Both all-steel ties and the alternative wood version of the lower chords have steel parts which should be checked in a similar way. The timber in the wood version of the tension chord should be checked as in (a) above.

2.4.3 Deck and upper parts of structure

The vertically nailed laminated deck of the pre-fabricated modular wooden bridge design plays an important part in the performance of the structure itself. It must be inspected and maintained carefully therefore and should not be allowed to fall into disrepair. The longitudinal running boards are intended permanently to carry the actual wheel loads of passing vehicles and to absorb mechanical damage such as scoring or gouges caused by stones carried in or between tyres, cuts from mechanical breakdowns of vehicles etc., Thus the running boards, rather than the deck itself are intended to be replaceable and to be sacrificed in the case of damage.

Later versions of the bridge design, including the drawings given in the official manuals, incorporate drainage scuppers in the deck. These are made by inserting occasional deck timbers which do not consist of a single continuous length, but which have deliberate breaks about 150mm long. Older bridges which were not built with this feature should have drainage holes cut retroactively. Drainage should be kept open as detailed below, together with other points to note in deck and upper structure inspection.

a. deck

All nailed laminated deck boards should remain sound and firmly held in place by the adjoining pieces. (All boards are tightly nailed to one another in the original construction). Any major distortion, mechanical damage or apparent coming apart of the deck should be noted, giving a simple sketch showing position and dimensions of the fault.

The deck should be swept free from silt, mud, dung and stones. The reason for continual silting-up of a deck should be investigated as this can be eliminated. Appropriate measures include cutting suitable herringbone pattened drainage ditches running off the sides of the uphill approach area of the roadway from which the silt is being washed. The drainage scuppers in the decking and in the kerbs should be poked free from stones and debris which may be retaining silt and mud, and preventing free passage of rainwater.

A short length of the decking near each end of the span is attached to blocks wedged between the bridge bearing anchor plates, since in this region it cannot be nailed to the top chords of the modules (see Part 3) Special attention should be given to the tightness of the deck at this point therefore.

b. Running boards

The running boards should be checked for looseness and wear whenever an inspection is carried out. Heavily trafficked bridges may in fact require this simple item to be checked more than once a year. Particular attention should be paid to the boards near each end of the deck, where most of the impact of oncoming vehicles occurs. The vehicle being used by the inspection crew to visit the site should be driven over the bridge whilst one person watches the running boards, since looseness or excessive deflection or warping may only then be apparent.

Excessively worn running boards may become polished and slippery due to curved edges and ingrained rubbed off tyre rubber and mud. Wear may also leave the heads of the running board fixing nails upstanding, causing great inconvenience and risk of punctures to traffic. The boards should be inspected for splitting, especially running along from the ends, and for splitting off and splintering away of pieces of timber from the edges caused by pressure on the edges from misaligned vehicles.

Advice on replacement of running boards is given in a later section on maintenance, but it may be decided as a policy to incorporate this operation as ad-hoc maintenance which can be undertaken by the inspection team. In this case the recommendations given elsewhere can be incorporated in the inspection procedures.

When running boards are removed, the areas of deck not normally visible can be inspected for patches of permanent dampness and evidence of biodeterioration (decay and/or insect attack).

c. Other upper structures

These include kerbs; balusters, handrails and handrail struts; guard pillars and bridge signposting. All types of damage to the upper structure which has been caused by vehicle impacts since the last inspection should be noted sketched and reported for action. The wood parts should be checked for decay, large splits, loose wood members, loose connectors and patches of entrapped dampness, mud and silt, as for other wooden parts. Weed growth and creeping, climbing or trailing foilage should be cut and swept away and the bases, roots and suckers removed from the soil and embankments near the upper bridge structure.

The reinforced concrete guard pillars which it is recommended should be placed at each end of the span in front of the first handrail balusters play an important part in protecting the upper structure and discovering use of the bridge by excessively wide loads. They should be kept in good condition, free from cracks and undercutting at their bases, and should be maintained, painted white and/or fitted with reflectors.

Bridge sign posting should be inspected for signs of damage by vehicle impact, rusting of steelwork or bolts; flaking and illegibility of paintwork.

3. Major Routine Practical Maintenance

This section describes the major routine practical maintenance it is envisaged may be necessary when major faults and deterioration are reported after the annual inspection reported above. As previously described, cleaning and minor repairs can normally be undertaken at the same time and often by the same crew, as the inspection work.

3.1 Safety measures

Bridge maintenance work can be hazardous, both to the personnel carrying out the operations involved and to the general public using the road. Safety considerations include the following.

3.1.1 Equipment

Inaccessible structural parts may have to be reached from ladders based on the stream bed below the bridge and from climbing on embankments at the sides of the abutments. Scaffolding may be required, either in the form of simple planking supported on the lower chords of the trusses between the girders, or using temporary tower platforms or scaffolding built on columns. In all cases, normal safety regulations applying to such equipment must be followed.

A few simple rules for the use of ladders are as follows: Always inspect a ladder before use to ensure it is in good condition and if in doubt don't use it. Ensure that the foot rest is on a firm base and that the top is supported at both rails and not by a rung only, or in a twisted position. Never attempt to extend a ladder with makeshift tied or nailed-on pieces. Place the base of the ladder between one quarter and one third of its length away from the vertical line of the wall or girder against which it is resting. Always face the ladder when using it and never attempt to overreach sideways, beyond normal comfortable arms length.

Hard hats should be used when working beneath the bridge and on the bridge superstructure. All normal safety rules applying to handtools such as saws, picks, sledgehammers etc., should be observed. Goggles should be worn for operations such as wirebrushing steel parts. Protective clothing and gauntlets may be required for work such as brushing water repellent stains and surface preservatives. Special safety rules pertaining to soil poisoning against termites are given in Part 3.

3.1.2 Sign posting

Temporary sign posting should be set up on arrival at the site to warn oncoming traffic and to protect those working on the bridge. If major maintenance is required, it may be necessary to close the bridge and arrange detours. In which case standard signposting plans are available involving the use of warning trucks or barriers and road cones. Speed restriction signs will be posted, depending on local conditions, e.g. 50 km/h at 200m ahead of the bridge or 30 km/h at 100m ahead of the bridge.

3.2 Preliminary tasks

Some simple preparation and checking will ensure that the maintenance operations carried out efficiently and in the time planned.

3.2.1 Work sheet

A bridge maintenance work sheet should be prepared. One report sheet will be required for each bridge. The number of copies will be indicated by local experience or practice. The maintenance work sheet must be related to the standard inspection report described in Section 2 above. A copy of the inspection report will have been made available to the engineer or foreman in charge of the maintenance work.

3.2.3 Check list

A standard check list can be prepared covering the following items:

Personnel:-

> Names, job titles and numbers of personnel required for each of the operations planned, together with their transport, messing, and if necessary sleeping arrangements.

Vehicles, plant and equipment:-

> Transport and travel distance involved; serviceability of vehicles, spare wheels, tools, fuel arrangements. Other equipment and materials required such as winches and cables, generators, replacement wood and steel parts.

Handtools and safety equipment:-

> Check off the items required and ensure that they are sec rely stowed for travelling. Consider security arrangements at the site and the possible need for a site hut and/or nightwatching.

3.3 Maintenance activities

Maintenance activities most commonly required involve routine cleaning and clearing of the area around the actual bridge itself, and desilting and cleaning the bridge deck. Parts of the superstructure damaged by vehicle impact must of course be repaired, and erosion of approaches and embankments may require attention. With bridges which have been well constructed in the first place, other operations should not commonly be necessary. As with all maintenance, inspection and routine action will avoid major repairs later. On the other hand, if minor items are ignored indefinitely, then greater deterioration will almost invariably occur with time, leading to the eventual need for large-scale replacements or even loss of the bridge.

3.3.1 Warnings

Temporary signposting should be set up. Night warning lights must be placed if equipment or materials have to be left on the verge of the road or if part of the superstructure is dismantled or obstructed overnight. Unattended obstructions or warning lights should not be left on the carriageway itself.

3.3.2 Cleaning site and bridge superstructure

The bridge deck should be thoroughly cleaned of silt, loose soil, dung, mud and stones using brooms and shovels. This debris should be removed and dumped in a place where it cannot be washed back onto the bridge. If there is evidence that during rains silt is being persistently washed onto the deck, then drainage gulleys should be cut in a horringbone pattern on plan, to carry rainwater off the uphill approach carriageway, draining down the sides of the embankment.

All dirt and stones lodged in gaps between or under the running boards, under the kerbs and in other places in the timber superstructure should be prized out. Associated minor damage should be made good by renailing.

As described under 2.4.3(a), drainage scuppers in the decking and in the kerbs should be poked free from stones and mud. The decking should be checked for tightness and soundness, paying special attention to the sections near the ends of the bridge.

Weeds and creepers should be removed from the bridge structure, the piers, guard pillars and other areas near the bridge where growth is possible. If growing on the bridge itself, the soil or silt from which weeds are obtaining support should also be cleaned away. Scrub, weeds and bushes growing underneath the bridge and directly upstream, downstream and on the embankments should also be cut down and cleared away. It is advisable however not to disturb any larger bushes or trees which do not actually impede the bridge itself, as these have considerable soil stabilizing value.

The area around the bridge should be checked for termite activities. Nests should be treated, and removed by shovel. Soil poisoning should be repeated, following the instructions given in the manual, Part 3. Particular attention must be paid to the safety precautions given in the manual and in the pesticide maker's instructions. These are intended both to protect users of the chemicals during the maintenance work, and also to safeguard humans and livestock living by, or using the watercourse.

The girders, bracing and other below-deck parts of the structure should be checked and cleaned as described under 2.4.2 (a) above, paying particular attention to the lower points of the triangular panels.

Paint on guard pillars should be renewed, and all signs and reflectors should be cleaned and repaired as necesary.

3.3.3 Repair or replacement of loose fasteners

The deck, running boards and other parts of the upper structure should be checked as described under the inspection measures, 2.4.3 above. Nails and bolts which have worked loose must be replaced. Stolen or missing bolts, nuts and washers must be replaced and if possible tack welded on to prevent repetition of their removal. Nuts and washers should be of the same pattern as the original design. They should not be so overtightened as to crush the timber itself.

3.3.4 Running boards

The running boards should be checked as described under 2.4.3(b) above. A vehicle should be driven over the bridge as part of this checking, a mere visual inspection without load on the deck is not sufficient. Worn, split or splintered running boards must be lifted, ready for replacement taking care not to damage the nailed laminated deck boards at the same time. During this operation, the decking which is normally covered by the boards can be cleaned and inspected. Repair of major mechanical damage or decay in the deck is beyond the scope of routine maintenance. If such conditions are found, they must be reported to the bridge engineering group responsible for the structure, so that temporary closure of the bridge and reconstruction can be planned.

Loose nails protruding from otherwise sound running boards must be extracted. The boards should be renailed at different positions, not in the old nail holes, using the appropriate size nails. If it is necessary to pre-drill the boards to avoid splitting, or in order to drive the nails in a hard timber, holes (0.8 dia) should be made. Annular ring shanked nails should be used if obtainable, since these will give better withdrawal resistance. Another improved method of fixing the boards, is to use lag screws, if available. These should be about 7 mm shank diameters and hardwoods should be pre-bored to the same size as the shank and as the root of the threaded part, being careful of the depths of each part. They should also be countersunk,lag screws will also be easier to remove to replace the running boards.

Running boards which have become excessively worn, split or splintered at the edges must be replaced with new boards of the same original size. The deck area at the position where the planks are removed should be cleaned. Pressure preservative treated or naturally durable timber free from sapwood should be used. The grade of timber should conform, as a minimum, to structural No.4 as defined in the Manual, Part 4.

Three nails should be used for the ends of each plank, and two nails at a staggered intermediate spacing of 250mm. Nails should not be placed closer than 50mm from the edges of the boards. Heads should be driven flush with the surface of the plank.

3.3.5 Painting

Painting of the structural timber components (the modular panels, lower chords if wooden, bracing members and cross beams) is not recommended. If a finish of coloured appearance is desired water repellant stain finishes may be applied. These have some additional preservative benefit, as well as water shedding properties. Conventional oil-based paints which seal the surface of the timber are expensive to maintain and upkeep properly, and if neglected do more harm then good. Information sheets on the types of finish recommended, and brand names of products which have been the subject of outdoor exposure trials may be obtained from TRADA.

Repainting of steel parts should be included in the routine maintenance. Dirt, dust, rust, scale and old paint should first be wire brushed off. A read lead oxide priming coat should then be applied, ensuring that the paint covers the entire surface as a thin even film. Intermediate and final coats should be applied following the paint manufacturer's instructions.

3.3.6 Wood Preservations

In-situ preservation of timber, especially in fully exposed tropical conditions, is of very limited value. Wherever possible, repairs should be carried out using pressure preservative treated timber, or naturally durable, sap-free timbers (see the manual, Part 4). For application to small areas of on-site repair work, where the above is not possible, the following treatments may be considered as palliatives.

Working with protective gloves, the wood preservative should be applied to the timber with a paint brush. As with new construction, this treatment must be applied after all cutting and boring operations are completed. Preservatives recommended for brush treatment include what is known as "bodied mayonnaise" types. These are thickened fluids with low viscosity, providing a "sticky" effect. Since they may not always be easy to obtain commercially in developing countries, an alternative may be mixed on a 'do it yourself' basis. This consists of a solution of coal-tar creosote in used motor oil, mixed in equal parts. It can be equally effective, but must be applied carefully.

The end-grain parts of the timber should be given special attention, as it is here that the risk of attack is greatest and penetration that can be achieved is the highest. The preservative should be flooded on to the ends, filling all cracks in the timber and repeating with a second coat after the first was soaked in. Where the principal risk is from insect attack, particularly termites, preservatives containing specific contact insecticides such as dieldrin or lindane should be used, if permitted by local regulations. These may be available in cream or paste form, in which case they can be applied thickly so that penetration takes place by diffusion over a period of time. Pentachtorophenol can also be used for in-situ treatment. The manufacturer's instructions on dilution must be followed, and an organic solvent such as white spirit is required.

It cannot be too highly emphasized that all the solutions mentioned above are highly toxic to humans, animals and plants and can also prove a fire hazard. They should be handled with care, using PVC or similar gloves, other protective clothing, and generally in accordance with the supplier's safety recommendations. If fluids are inadvertently splashed or spilt onto the skin, all traces should be thoroughly and immediately washed off using soap and water.

3.3.7 Repairs to masonry

Masonry supporting structures such as abutments, piers and wing walls should be repaired during routine maintenance activities, provided that major cracks, spalling, exposed reinforcement or large settlement are not present. These latter must be reported to the engineering department responsible for the site, so that appropriate remedial work can be planned.

Soil, stones and silt should be cleared out of weepholes, so that drainage of the masonry structure is functioning properly. Defective joints should be cleaned of old mortar, soil and vegetation, and repointed using an appropriate mix. For many situations, a mix of four parts of cement, one of lime, and twelve parts of clean sand has been found to be useful. Where termite infestation of the mortar has occurred or is likely, the mix can be poisoned by disolving 0.5 per cent dieldrin in the water, following the safety precautions mentioned under wood preservatives and in the Manual, part 3. To prevent the mortar from drying out too quickly, it may be advisable to cover the completed work with wet jute sacks or similar material.

3.3.8 Waterway repairs

Erosion of banks, riverbeds, and scour around foundations can be just as frequent a cause of loss of a bridge as neglect of maintenance of the structure itself. Such items should therefore be given regular attention. Extra inspections are recommended after execptional local flooding, after road accidents, earthquakes, earth slides etc.

The waterway should be cleared of debris and junk obstructing the channel beneath and near to the bridge. Vegetation which obstructs the free flow of water should be cleared away, taking care at the same time not to disturb harmless shrubs and trees which may be helping to stabilize the banks.

It may be possible to accomplish some or all of the following actions aimed at repairing erosion and scour. Otherwise, the matter must be reported to the engineering department responsible, as neglect will lead to collapse of the supporting structures and eventually the bridge itself.

Random block filling can be employed to build up undercut embankments, where the water is up to about 1.5 metres deep. Stone blocks or boulders are simply dumped into the eroded section at the edge of the stream, until the bank regains its approximate original shape. Jute or plastic sacks filled with gravel or earth and firmly tied can be used where stone is not available.

Fresh masonry retaining walls may be constructed to protect critical lengths of embankment, where possible, using local techniques and materials. Foundations for these should be thoroughly excavated and well based. Backfill should be placed in layers and well tamped.

Loss of riverbed material by fast flowing water at piers, abutments and wing walls should be repaired by one of the above methods. If work can be performed during a dry season, when little or no water is present, excavation, fresh foundations and block masonry fixed by mortar can be employed. Otherwise, stone blocks or gravel bags must be dropped into the depression.

Gabions make excellent stream bank protection structures and these can also be employed in repairs of scour pools around bases. Commercial wire gabion frames are made of zinc-coated steel baskets which are supplied folded flat complete with tying wire. Excellent alternatives may be constructed locally using 12-gauge diamond mesh wire netting tied with 16-gauge galvanized wire. A trench should be excavated at the side of the stream or around the support structure so that the gabions will be set at an even height on a good foundation. Fill consists of stones, including quarry waste if available, or river rocks and boulders up to about 45cm diameter. The gabions should be completely filled, in all corners, but not allowed to bulge so that the wire frame is stretched or distorted.

3.3.9 Completion of maintenance tasks

When maintenance work is finished, the site should be completely cleared and checked by the foreman responsible. Tools should be cleaned and loaded onto transport. Cones, warning signs, flags and barriers should also be collected up. On looking over the site, the underside of the bridge should be included in the check, and especial care should be taken to see that the carriageway of the bridge and its approaches are in a neat and clean condition. No heaps of material or dirt must be left on the carriageway or nearby shoulders.

The work report should be completed as follows. Record the personnel, the resources used, the time taken to complete the work and add any general remarks. The report should be signed and dated by the foreman, and it should be returned in the appropriate number of copies to the depot and the district engineer's office.

DEFLECTION TEST PROCEDURE PRIOR TO TRANSFER OF BRIDGE TO RECIPIENT AUTHORITIES

1. Introduction

It has been suggested that prior to transferring responsibility for a newly installed bridge, a simple proof load test be carried out to assess the overall structural stiffness. This will be undertaken by measuring the vertical deflection of a bridge component at mid-span, created by applying a load in the central region using a large four wheeled vehicle. The vehicle will first be weighed to enable the stiffness to be calculated from the load and deflection. It may be advantageous, if possible, to arrange for the vehicle to carry a standard load.

2. Method of determing vertical deflection using a level and staff

The simplest method of determining the vertical deflection of a point on the bridge due to application of a load, is to use either an automatic or a dumpy level and a staff (See figure 1).

A section of a levelling staff should be secured to the bridge at mid span, and at any other points where the deflection is to be measured. If required this staff could be left permanently attached to enable the test to be repeated at intervals throughout the life of the bridge, as a check on in-service performance. It would also then be possible to measure at intervals the level of the point on the bridge relative to a fixed survey datum, to record any long-term deformations.

A level should be set up on a tripod in a position such that, with its axis horizontal, the staff can be observed. (Slight deviations of the telescope axis from the horizontal are acceptable provided that the distance from the level to the bridge is sufficient to make any corrections due to tilt insignificant).

The staff should be observed and the level recorded to the nearest 1mm. The bridge should then be loaded and the staff reobserved to give a direct measurement of vertical deflection.

3. Method of determining vertical deflection using a theodolite and targets

The problem of determing the vertical deflection of a point on the bridge may be resolved into two components:-

1. Measurement of the vertical angular displacement relative to a fixed reference point.
2. Measurement of the distance from the target on the bridge to the reference point.

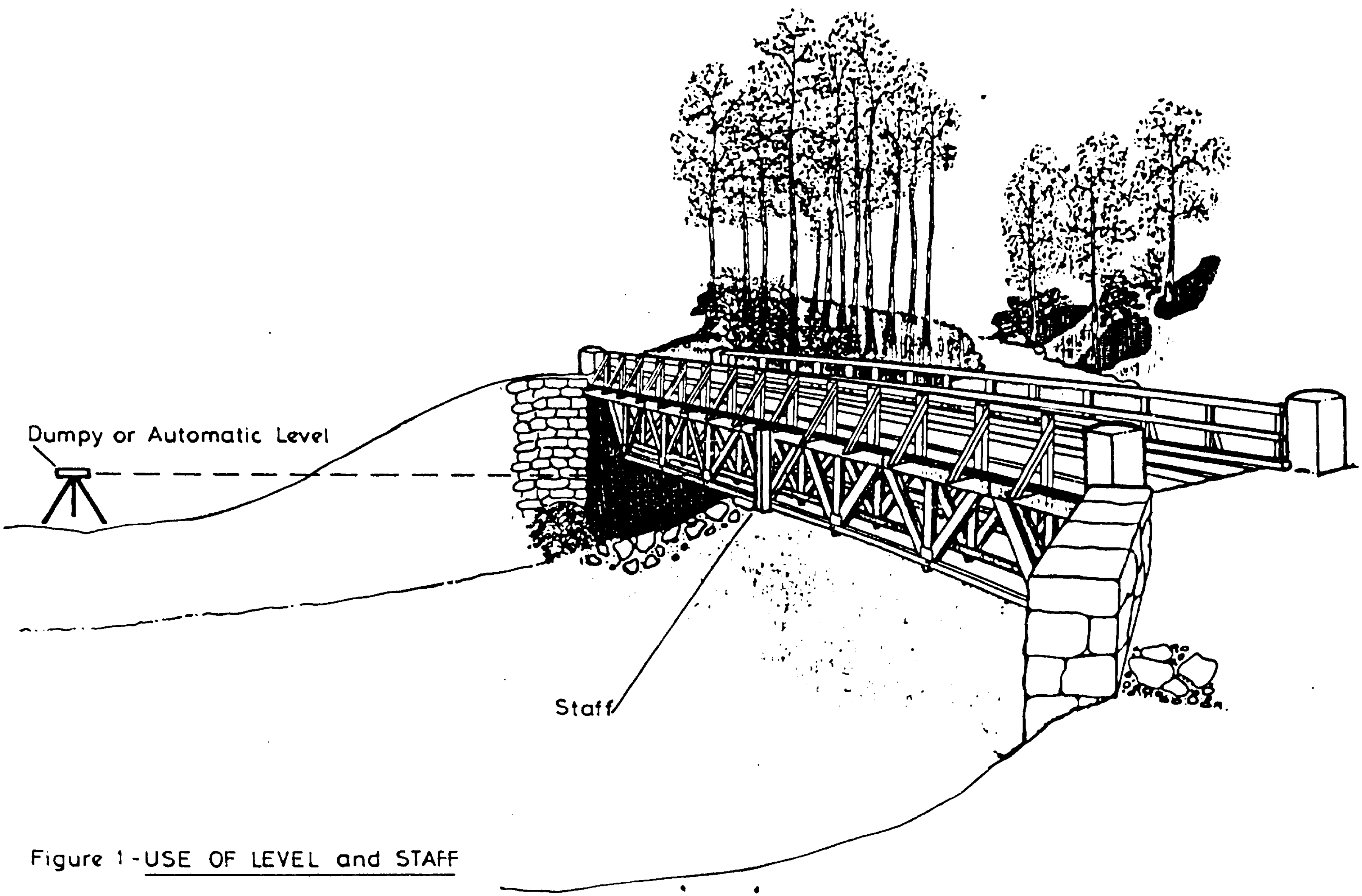


Figure 1 - USE OF LEVEL and STAFF

Both of these operations may be carried out using a 1" theodolite, conventional cross-hair survey targets and a subtense bar.

It is necessary to identify two theodolite stations for the survey and a minimum of one target on the bridge. Additional targets may be used in different locations to measure the deflection at points other than midspan, and the method of survey and computation for these other targets is identical to that for a single target. It is, however, important that the triangle comprising the two survey stations and the target is well defined to ensure that angular observation errors are minimised.

Figure 2 shows a typical set up with survey stations P_1 and P_2 on the banks of the valley, and target T attached to the outer horizontal timber beam of the bridge at midspan. The triangle P_1, P_2, T may be projected onto triangle P_1", P_2", T" in the horizontal plane.

4. <u>Accuracy of the two methods</u>

Using a level and staff, it is possible to observe the vertical deflection of the bridge member to the nearest 1mm i.e. to within 0.5mm.

With the theodolite method, it is suggested in the Technical Annex that an accuracy of length measurement of 0.5mm is achievable with the subtense bar, provided that the line between the bar and the observing theodolite is less than 52m. At this distance, with a 1" theodolite the vertical deflection can be calculated to an accuracy of 52 tan (1")m or approximately 0.25mm.

PROCEDURE FOR DETERMINING VERTICAL DEFLECTION USING A THEODOLITE AND AND TARGETS

Stage 1 - Measurement of vertical angular displacement of the target

Prior to the bridge being loaded it is necessary to measure the initial angular position of the target relative to the two survey stations, to serve as a reference. The bridge should then be loaded and the angular displacements measured again relative to the two stations. The method of observation both before and after loading is as follows:-

a) Set up a sturdy surveying tripod over each of the two ground station points P_1', and P_2' and attach a target to the bridge.

b) Install and level a theodolite on station P_1' and install a secondary target on station P_2'.

c) With the theodolite telescope in the face left (F.L) position, observe the vertical angles to the targets T and P_2'. Repeat with the telescope face right (F.R) and average the observations.

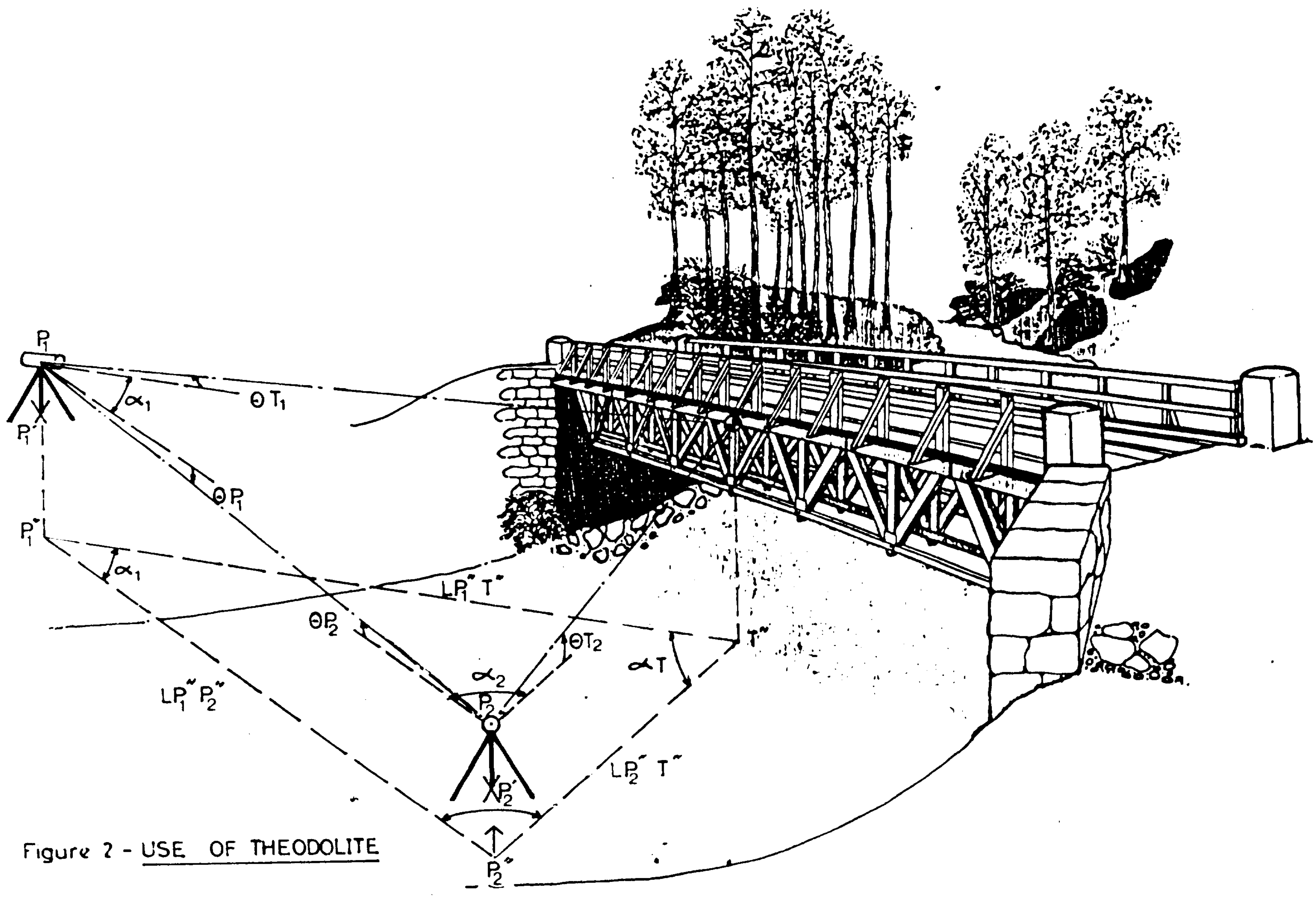


Figure 2 - USE OF THEODOLITE

d) Repeat (b) and (c) above with the theodolite on station P_1' and the secondary target on station P_2'. (As a check, angles θ_{P1} and θ_{P2} should be equal and opposite in sign).

Stage 2 - Measurement of distances

It is required to measure the distances LP_1 " and LP_2 "T" in order to calculate the vertical deflection of T from angles θ_{T1} and θ_{T2}. This cannot be achieved remotely and the solution therefore reduces to solving the triangle P_1 ", P_2 ", T" by measuring the horizonal angles α_1 and α_2 and the horizontal distance LP_1 ", P_2 ". Values for LP_1 "T", LP_2 "T"and may then be calculated.

The method of observation is as follows:-

(Note: this stage may be incorporated with Stage 1 to reduce observation time).

a) Set up surveying tripods on points P_1 ' and P_2 ' and attach a target to the bridge at point T.

b) Install and level a theodolite on station P_1 ' and install a secondary target on station P_2 '.

c) With the theodolite in the F.L position, observe the target on P_1 ' and record the horizontal angle. Swing the telescope clockwise to observe target T, record the horizontal angle and continue moving the telescope clockwise to re-observe the target on P_2 ' and close the circle. Any errors in closing the circle i.e. deviations from 360 degrees, should be distributed around the circle and correction made to the observation of T, in proportion to the angle measured.

d) Repeat (c) above, this time with the telescope in the F.R. position. After adjusting the results, the observations on F.L. and F.R. should be averaged to give the angles α_1 and (360 degrees $- \alpha_2$).

e) Replace the target on P_2 ' with a subtense bar, which should be aligned perpendicularly to the line P_1 ' P_2 '. Measure the angle θ_b between the two ends of the bar and calculate the length LP_1 "P_2" taking into account the inclination of the line of sight.

f) Repeat (c) and (d) above with the theodolite on P_2 ' and the target on P_1 ' to give angles α_2 and (360 degrees $- \alpha_2$).

g) Repeat (e) above with the theodolite on P_2 ' and the subtense bar on P_1 ', and again calculate the length LP_1 "P_2". The results from (e) and (g) should be averaged to produce a mean value for inclusion in later calculations.

h) The lengths LP_1 "T" and LP_2 "T" and angle α may now be calculated from the values of α_1, α_2 and LP_1 "P_2" measured above.

$$\alpha T = 180 \text{ degrees} - \alpha_1 - \alpha_2$$

$$LP_1 \text{"T"} = \frac{\alpha_2}{\alpha T} \, LP_1 \text{"}P_2\text{"}$$

$$LP_2 \text{"T"} = \frac{\alpha_1}{\alpha T} \, LP_1 \text{"}P_2\text{"}$$

Alternatively, a catenary tape could be used to measure directly the distances between P_1T and P_2T although this may not be practical over the river valley.

Stage 3 - Calculation of the vertical deflection of target T

Two independent values of the vertical deflection of T may be calculated:-

a) From station P_1 : $\Delta_{T1} = LP_1 \text{"T"} . \tan \theta_{T1}$

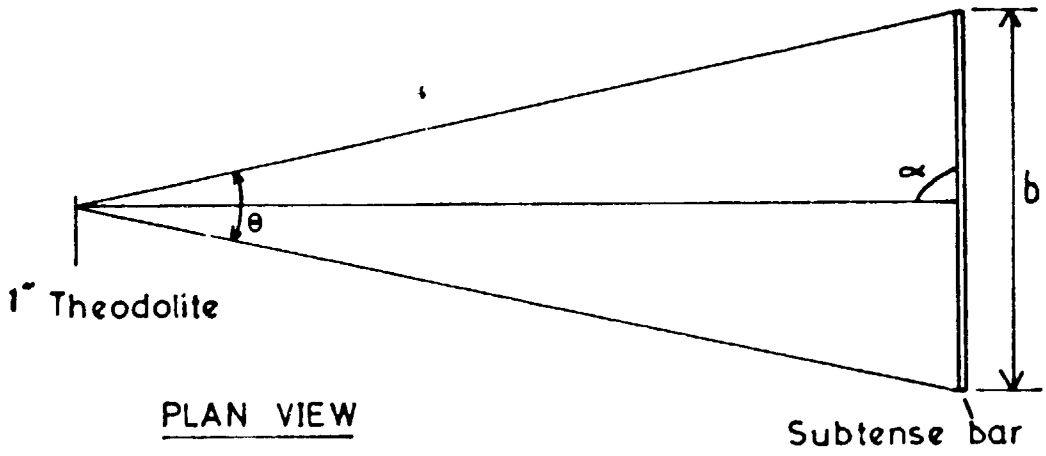
b) From station P_2 : $\Delta_{T2} = LP_2 \text{"T"} . \tan \theta_{T2}$

A final value for the deflection of T may be calculated as :-

$$\Delta_T = \frac{\Delta_{T1} + \Delta_{T2}}{2}$$

The Subtense Bar

The subtense bar is an invar bar placed horizontal and perpendicular to the line whose length is required. A sighting telescope is provided for alignment and an optical plumb for centring purposes.



PLAN VIEW

The angle subtended at the far end of the line is measured with a 1" theodolite.

Provided that α = 90 degrees, the length from the theodolite to the subtense bar, L, may be calculated as :-

$$L = (b/2) \cot (\theta/2).$$

Since b is usually 2m, it follows that $L = \cot (\theta/2)$.

The possible sources of error are:

(i) error in measuring
(ii) error in b
(iii) central hinge error
(iv) error in α deviating from 90 degrees or end-to-end slope of the bar

(i) Error in θ

$$dL = (-b/\theta^2)d\theta = (-L/\theta)d\theta \quad \text{or} \quad dL/L = -d\theta/\theta$$

If an accuracy of 1/4000 is required then dL/L = 1/4000

The limiting case is therefore d /θ = 1/4000.

d θ is the accuracy to which θ can be determined and for a single second instrument with two rounds on each face one may expect $d\theta = \pm 2"$

θ = 2 x 4000" = 2 degrees 13" (approx.) is the limit, giving a maximum line length of L = cot(1 degrees 6.5") $\approx$ 52m for a 2m bar.

(ii) Error in b:

$$L = b/\theta \qquad dL = db/\theta \qquad dL/L = db/b$$

for an accuracy of 1/4000 and 2m bar, 1/4000 = db/2

hence $db = \pm 1/2000 \text{ m} = \pm 1/2 \text{ mm}$.

Since an invar bar can be calibrated to .05mm and it would require extreme temperature change or obvious rough handling to exceed ± 1/2mm this souce of error can usually be neglected.

(iii) and (iv) These sources of errors are within the control of the operator. They can practically be eliminated by ensuring that the bar is set up correctly. An accuracy of 1/4000 will tolerate 2 degrees error in α and end slope which can easily be bettered.

SAMPLE ONLY

DRAFT PROTOCOL FORM

UNIDO ONUDI

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
ORGANISATION DES NATIONS UNIES POUR LE DEVELOPPEMENT INDUSTRIEL

VIENNA INTERNATIONAL CENTRE
P.O. BOX 300, A-1400 VIENNA, AUSTRIA
TELEPHONE: 26 310
TELEGRAPHIC ADDRESS: UNIDO VIENNA TELEX: 135612

CENTRE INTERNATIONAL DE VIENNE
B.P. 300, A-1400 VIENNE (AUTRICHE)
TELEPHONE : 26 310
ADRESSE TELEGRAPHIQUE : UNIDO VIENNE TELEX : 135612

REFERENCE: **DRAFT PROTOCOL FOR TRANSFER OF UNIDO-BUILT BRIDGES TO RECIPIENT AUTHORITIES**

This document serves to hand over to (1) responsibility for the (2) bridge at (3) built under UNIDO project (4) for the (5).

It has been designed , to specifications of (6) for a maximum load of (7) and speed of (8) as a secondary or access road with intermittent traffic. A sign (has been|must be) erected at each end clearly indicating these maxima.

Deflection tests have been carried out on.......(9)......... by the UNIDO expert assigned to the project together with a responsible representative of (1) and the duly signed results are attached as Annex 1.

Periodic maintenance is essential to realize the maximum possible service life and UNIDO's recommendations are attached as Annex 2. The (1) accepts the responsibility to follow these carefully and to keep records of maintenance and repairs carried out by its staff.

Having inspected the above mentioned bridge,.......(10)......, representing (1) hereby accepts it on behalf of (5) and any responsiblity of UNIDO and|or UNDP with respect to this bridge is hereby tranferred to (1), as a representative of (5) as from this date.

---

1. Counterpart Agency
2. Span, number of trusses, species.
3. Location, name of river.
4. Project number
5. Government of XXX
6. Loading code (AASHTO, UK-BS)
7. Maximum load (tons)
8. Maximum speed
9. Date of test
10. Name

On behalf of (1)	On behalf of UNIDO
Name Date	Name Date

WORKMANSHIP AND QUALITY CONTROL

General

The recommendations given in this Annex are intended to ensure that the fabrication, handling and erection of the modular panels and other bridge parts, is such that the assumptions regarding strength and stiffness in their design are achieved in practice. Workmanship in preparation, fabrication and assembly should conform in all respects to accepted good practice. It is recognized that 'good practice' may be difficult to define, particularly in countries or regions not having a strong woodworking tradition. Under such circumstances, there is a particularly strong need for craft training and education. Materials should be applied, used and fixed together in such a way as to perform adequately the functions for which they were intended in the design. There should be adequate supervision throughout the preparation of materials, fabrication and erection to ensure that all processes conform to these principles.

FABRICATION

General

The drawings and manuals should be made available showing the dimensions of the modular panels, and details of the individual wood members, steel plates, connections, cutting and drilling, and the specification of all relevant materials.

Fabrication should be in accordance with the design, specification and drawings, and no variations should be permitted with regard to panel dimensions, member sizes, and joint details outside the tolerances given.

Identification of panels

A system of unique identification of each prefabricated timber panel that is made should be agreed within the project, and this system should be used for all record keeping and quality control. A suitable method of permanent marking, such as with paint, carving or branding, should be adopted. The identification code and serial number of each panel should be clearly marked upon it at a suitable stage during manufacture. This is intended to help to ensure delivery of the correct panels to site and their subsequent assembly in the intended order. Also, if modular panel testing is undertaken as a routine quality control measure, then the identification system should be used in the programme of testing and record keeping.

Inspection

If manufacture of items such as steel panel plates is subcontracted, then it should be made clear to the fabricators at the start of their contract that project staff must be provided with the necessary reasonable facilities for inspection during fabrication. By arrangement, access should be permitted at all reasonable times to all places where relevant work is being carried out. Similar arrangements may be required for visiting sawmills from which timber is provided, and for plant where pressure preservative treatment is being carried out.

Stress grading

Reference to the stress grading rules given in the manual, Part 4, may be necessary at several stages in the timber purchasing, preservation and manufacturing process. It is essential therefore that project staff, and particularly those directly involved in supervision of the work, familiarize themselves with the stress grading rules and the accompanying explanations. Training in recognition of the defects described in the rules and relevant to the local conditions should be provided where possible.

The simple tools required for visual stress grading of timber include a carpenter's wooden rule, for measuring cross sectional dimensions, and a steel tape for lengthwise measurements; a grain scribe; thick indelible wax crayons or thick felt tip markers; a notepad, and pen or pencil. At the time of checking the grade, it is often convenient also to assess timber dimensions. During this operation, account must be taken of allowances for shrinkage due to drying, and reductions for machining. Moisture content may also be recorded, and for this purpose a moisture meter as described below, will be necessary.

Stress grading should only be performed under adequate light conditions, and it may be necessary to request the sawmill operator to provide an open but sheltered shed or lean-to, where preliminary inspections can be carried out under better conditions than in the sawmill itself. Wooden trestles or other similar supports, and a level clear floor will be required. There are subsequent stages at which checks should be made on timber grading. These are carried out when the timber parts are in the bridge workshop itself. Similar facilities will be required for this work, and the same general recommendations will apply.

Storage of materials

Precautions should be taken during storage of materials belonging to the project, both at sawmills or in fabricators' workshops or yards, and in the bridge workshop itself. Direct tropical sunlight is potentially harmful to timber, especially in combination with intermittent wetting by heavy rain. It should be noted that the bridge design itself is such that the permanent structure of the bridge is shaded from direct sunlight and heat by the bridge deck.

Materials and parts should be stored on dry bases, and if possible kept inside a building or temporary shelter. If a concreted area is not available, then the storage ground should at least be cleared of weeds, sawdust or shavings, and other material that would harbour dampness, termites and other pests. Timber should be evenly supported on adequate and regularly sized bearers. If it is intended that the timber should be stacked 'in stick' to ensure air drying, then spacer sticks should be correctly dimensioned, and positioned in the stacks at regular intervals over the bearers in accordance with instructions in the manual, Part 4.

Timber stacks should be temporarily roofed, or sheeted with tarpaulins or other impervious material. This covering should be arranged to give full protection, but at the same time it should permit free passage of air around and through the stack. Care should be taken not to deform stacked material, for example by placing further stacks of a different dimension on top.

Timber and other materials held in storage should be labelled. The labels should be marked using an indelible medium such as paint or permanent marker. Convenient labels can be made from thin boards of softwood, plywood or other sheet material, and they should be firmly tacked to the end of a timber piece in each stack. Information should include date of receipt; width, thickness and length; standard timber name or species; mill or source identification.

Timber delivered from the mill or pressure preservation treatment plant at a high moisture content should not be stored in a close packaged form, e.g. strapped or close piled. Where early use is not possible or intended, the packages should be opened and the timber should be re-piled in stick, and suitably protected as described above.

Steel parts, nuts, bolts, washers and other fasteners, should be stored in a separate area from the timber. It is highly desirable that they should be kept in a locked, closed building to prevent theft and misuse. For good order, stock control and record keeping, shelves and bins should be constructed. These should be labelled in accordance with the part numbers given on the drawings and correspondingly entered in the record keeping.

Moisture content

Control of moisture content is an essential aspect of quality control in all timber manufacturing operations. A properly calibrated moisture meter used in accordance with the manufacturer's instructions is an essential tool for each bridge manufacturing workshop. Deep probes of at least 30mm length, together with a hammer tool for their insertion, are required for the size of member used in the bridge panels. For meter calibration, and occasional checking of timber with greater accuracy, a small oven with ventilation and provision for maintaining temperature at 103+/-2 degrees C is desirable.

The moisture content of the timber members of the modular panels at the time of fabrication should not exceed a value which is 5% more than the average moisture content that the timber may be expected to attain in service conditions in the completed bridge. In many tropical countries, this average service moisture content may be expected to vary between 15% and 18%, depending upon the usual temperature and humidity. It follows therefore that the timber at the time of fabrication should not exceed 20% to 23% moisture content in these same ambient conditions.

Where preservative treatment is used as the means of protection rather than the use of naturally durable, sap-free timbers, this treatment must be applied after all machining, cross cutting and drilling has been carried out. Pressure preservation treatment with water borne chemicals will often be the method chosen, and in this case a second period of storage 'in stick' and re-drying must be provided for in the manufacturing arrangements. Recommendations given above concerning checking and timber for defects, measuring moisture content, and correct stacking and labelling apply especially at this stage.

Timber at the time of fabrication

Timber used in the fabrication of the modular panels should be of the stress grade required in the particular bridge design, the final checking of defects such as splits and characteristics being made when all pieces are machined and cross-cut ready for assembly. Wane, fissures, knots or other defects, even if within the allowances of the grading rules, should not be allowed at positions such as the location of the dowelled steel panel plates, if they might significantly affect the assemly, or subsequent performance of the joint. Timber members which have become damaged, crushed or split in accidents or malpractice during manufacture should be rejected and not used in the assembly of panels.

The cross-sectional dimensions of the timber used in the fabrication of the modular panels should be within a tolerance of +/-1.5mm on thickness and +/-3.0mm on width. It follows therefore that as sawing alone will often be inadequate to achieve this accuracy, regular sizing of the thickness by planing, or the use of planed all round timber, will be called for. Where either of these operations are carried out, it is reasonable to expect a tolerance of +/-0.5mm on the resulting sectioned dimension.

Assembly

Assembly of the prefabricated modular panels should be carried out on jigs having rigidly fixed steel locating plates and end stops, so as to ensure dimensional accuracy and flatness.

All members should be accurately cut to ensure firm contact along the abutting faces, and should be accurately cut to length within a tolerance of +/-1.5mm. No gaps over 1.5mm between abutting faces of timber should be permitted.

The modular panels should be fabricated so that horizobntal, vertical and diagonal dimensions are within +/-0.3mm of the specified size.

The method of assembly should follow that given in the manual, Part 2, since this was written to ensure that the geometry of the assembly as specified in the design, is achieved correctly within the specified tolerances.

All bolts, nuts, washers, steel dowels and nails should be of the type and size specified and should be located so that the specified positioning, spacing, and edge distances are maintained. Nailing templates, bolt hole position, jig attachments and drill depth stops should be used, as specified in the manual, Part 2. Nails and steel dowels should be fully driven home without causing undue damage to the surface of the materials being joined. Holes for the steel dowels should be drilled in the timber using the correct sized bit to give the light interference fit described. Under no circumstances should the fit of the dowels be slack, or so tight that on driving, splitting away of the back face of the timber member occurs.

Bolt holes should be drilled to a diameter approximately 10% larger than the nominal bolt diameter, so that the bolts can be driven through the components being fastened together with light taps from a mallet. Bolts should not be such a tight fit that they have to be driven by hard blows from a steel hammer or sledge, which can damage both bolt and the wood members being fixed. Bolts should be tightened so that members fit closely together. Correct sized ring spanners should be used on both nut and bolt head. Again excessive force should not be applied, and piping or extension bars should not be used to force the spanner. Washers should have a full bearing area under the tightened nut and bolt head. The fasteners should be retightened a few hours after assembly to take up slack from creep perpendicular to the grain under the washers. Washers should not be crushed into the timber to such an extent that splintery fibres start to lift at the washer edges, or the washer is deformed into a cupped shape.

HANDLING AND ERECTION

Storage prior to delivery to site

Similar recommendations to those given above for storage of timber apply to completed panels held in stock. The modular timber panels should at all times be stored on raised bearers to avoid contact with the ground, with vegetation and other sources of dampness. Roofed storage, either in a permanent, dry and well ventilated shed, or under temporary shelter, is highly desirable if the modules are to be stored for any length of time. As explained above, alternate wetting by tropical rain and direct hot sunlight is detrimental to timber which is to be used structurally. In the construction of the permanent bridge, this is avoided by the nature of the design. As a minimum, protection during storage by means of tarpaulins or similar impervious covers is essential.

During storage, the modular timber panels and other completed parts should be neatly stacked, using well placed bearers and spacing battens between the layers, so as to prevent distortion. Although the construction of the panels is sturdy, distortion can occur, for example, from the weight of a large number of further panels stacked unevenly on top of the stack. The best, and often most convenient way to store the panels is in fact to stand them vertically, point upright, in rows, with battens beneath the top chords and spacing timbers between each panel.

Handling and transport

Care should be taken in handling the modules and other timber members to avoid damage to the wood by cutting or crushing by metal parts, rocks or other sharp objects. The panels must not be dropped off lorries or fork lifts. Nor must they be damaged by steel wire rope slings or lifting bars. They must not be stacked over rocks or large stones during temporary storage whilst unloading, or left where they could be run over, or impacted by vehicles.

Lorries used for transport of the panels, lower chords and loose wood parts to site should be loaded and unloaded in an orderly fashion, with the items securely roped down and if necessary secured with temporarily nailed timbers.

The same general recommendations apply to storage during transport and on site as given above with regard to protection from direct sun and rain, and correct stacking.

Erection

No modifications to the modular wooden panels or repairs to damaged panels should be carried out without the approval of the engineer responsible for design decisions in the project. Also, damaged or defectively made panels shall not be used without this engineer's approval. He should assess then the extent of their defectiveness in relation to the requirements of the design, and give instructions for their positioning in the bridge, if a decision is made not to reject them entirely.

Panels must not be notched, cut or bored on site. Small holes may however be drilled in them if necessary, for example to assist in the driving of nails when a dense timber is in use for the design.

Panels should be assembled vertically, accurately aligned and positioned and fastened to adjacent panels in accordance with the manual, Part 3. A flat, level platform must be set up on the near bank, as detailed in the launching manual, to ensure correct assembly and avoid producing hoisted, distorted girders. Girders should be launched using temporary transom beams to attach the sling, as detailed in the manual, Part 3, thus avoiding cuts and chafing in the structural mensers from pressure of the ropes. Temporary bracing and fixings are detailed in the launching manual, to ensure stability of the girders during launching. Under no circumstances shall any of this be omitted. Nor shall any attempt be made to lift, and 'launch' individual trusses, which are too slender to be safely handled in such a way.

Handover protocol, and bridge maintenance

Once construction is complete, it is desirable that there should be a formal, official handover of responsibility for the bridge from the design, manufacture and launching project team to the road and bridge authority. A form, and accompanying instruction for this are under preparation.

Bridge maintenance recommendations are also under preparation, and these should be followed when available. Responsibility for maintenance should be agreed and arranged between the agency responsible for implementing the bridge projecrt and the national or regional roads and bridges authority.

ANNEX 5

NOTES ON BRITISH STANDARDS RELEVANT TO THE SPECIFICATION OF STEEL AND TO ARC WELDING

BS 4360: 1979

"Specification for weldable structural steels".

This standard specifies requirements for weldable steels for general structural and engineering purposes. It includes requirements for hot-roller plates, flat bars, wide flats, etc. Section 1 covers the general requirements; Section 2, tolerances; Section 3, testing requirements. Sections 4 and 5 provide for rough ranges, having specified minimum tensile strengths; a series of grades with chemical composition limits, yield strength and impact requirements.

Information supplied by purchaser:

(a) Details of the product form (plate, flat bar, wide flat, etc), dimensions and quantity.

(b) The grade of steel.

(c) Whether specified lengths or exact lengths are reuired (affects tolerances).

It should be noted that grade 43A, covered in this standard, is recommended for the UNIDO bridges.

There is a tensile strength and elongation test specification for this grade. A minimum yield strength is specified.

All grades of steel specified in BS 4360 are of weldable quality. For welding techniques which should be applied to these steels, reference shall be made to BS 5135.

BS 5135: 1984

"Process of arc welding of carbon and carbon manganese steels"

This standard specified requirements for the process of manual (and other) arc welding of relevant steels. Items to be documented are given in clause 3 of the standard. These may have a significant effect upon the performance of the fabrication. Some items which are documented and/or indicated by drawings for the UNIDO bridges, and which are mentioned in the standard, are as follows:-

1. Specification of the parent metal.

2. The form of the joints and the overall dimensions of the welds.

3. The welds which are to be made in the shop where, or when the steel parts are first made. These can be distinguished from those which must be completed after

panel assembly. No site welding is required for the UNIDO bridge, nor should it be permitted. (The minor exception is the recommendation to tack weld nuts onto the bolts if it is considered desirable to prevent their removal by theft or vandalism).

4. Written welding procedures as defined in the standards are not available, but some of the details recommended to be included therein are relevant, and some information is available, e.g.:-

   i Cleaning and degreasing recommendations.

   ii Classification, type and size of electrodes.

   iii The welding current and length of run per electrode would be specified in a particular project, knowing local equipment which is in use.

   iv Edge preparation and tacking arrangements could be recommended, with experience.

Full welding approval and quality control arrangements are not available for UNIDO bridge steel parts, nor are they likely, owing to the constraints operating in developing countries. However, BS 4870 is entitled 'Approval testing of welding procedures' and contains information that might be valuable, if extracted selectively and simplified.

The purpose of BS 4870 is to provide means whereby a constructor's welders can carry out tests so that the purchaser can assure himself that the welders can make satisfactory welds with the procedures specified. Hence a written welding procedure is required.

Another relevant welding standard is BS 4872. This is entitled 'Approval testing of welders when welding procedures approval is not required'. It contains recommendations aimed at being able to verify the ability of persons who may be certificated as approved welders. Clearly, certificated welders are seldom likely to be available to carry out the work on UNIDO bridge steel parts. However, this standard could also be used to glean recommendatins on welder testing and test piece assessment in a developing country situation. Information is given for fillet and butt weld test conditions, joint types and welding positions. Recommendations are made on visual examination of test welds, covering aspects such as weld contour; undercutting (absence of); smoothness and penetration. Destructive tests are also described. These may be of value when steel parts are supplied partly prepared from an industrialized country, or when facilities are available in the developing country, at a university for example, for occasional testing. A 'welder approval test certificate' proforma is given in the standard which could be adapted.

Reverting to the main welding standard, BS 5135, useful recommendations on welding consumables are given. For manual metal-arc welding, electrodes are the chief item of concern. Their correct selection and compliance to standard are mentioned.

Guidance is given on their storage and handling. Good practice here can avoid cracking and flaking of coatings and corrosion of wires.

Standards such as BS 638 are available for welding plant, instruments, cables and accessories. Health and Safety at Work booklet No. 38 'Electric arc welding', Health and Safety Executive, HMSO, is recommended guidance on safety precautions for operators. Earthing and adequate means of measuring current are important aspects of both safety and satisfactory work quality.

Fillet weld and butt weld details are covered in BS 5135. Preparation of joint faces, although a simple matter for the UNIDO bridge parts, is an important aspect of quality. Fusion faces and adjacent surfaces should be free from cracks, notching and other irregularities. They should also be free from heavy scale, moisture, oil and paint.

Parts to be welded should be assembled so that the joints to be welded are accurately located and easily accessible to the operator. This is a seemingly obvious point that has sometimes been observed to have been overlooked in the Honduran bridge workshop. Consideration should be given to providing a few more sketches and suggestions of simple fixtures to achieve better location, particularly of the top chord end plates.

Tack welds are part of the technique of a skilled welder, and there are detailed considerations to their use.

Protection from the weather is essential to ensure quality welding, and condensation or rain wetting should not be allowed on the metal surfaces to be joined. Precautions should also be taken, and good practice followed, to avoid stray arcing on the work.

Inter-run clearing of slap is another aspect of good practice to be followed. Multiple pass runs will be necessary on some of the joints concerned.

Permisslble stress in welds are not given in BS 5135, but the standard does contain several appendices giving guidance on topics such as design, and the configuration of butt and fillet welds.

Cost indications for a prototype 15 metre span bridge and simple workshop, with launching equipment

Timber	U.S. Dollars 2000

15 cubic metres (about 1 cubic metre per metre of span)

Cut to following main sizes:

50 * 150 mm
50 * 200 mm
50 * 250 mm

Plus decking, handrails, bracing etc.

Strength groups (Australian system) S3 - S6

A pressure preservative treatment, using such commercially available salts as copper-chrome -arsenic or creosote is desirable.

Steel	Total:	U.S. Dollars 2300

Structural mild steel, minimum u.t.s. 435 N/mm

Plates:	6 to 15 mm thick
Flats:	6 * 50 mm to 12 * 75 mm
Rods:	12 and 50 mm diameter

Galvanized nuts and bolts	U.S. Dollars 1000

12 * 150 mm to 12 * 300 mm

Nails	U.S. Dollars 100

100 and 150 * 5 mm

Welding rod	U.S. Dollars 1000

To BS 439 (E4333 R 21)
or AWS (E6012)

Concrete	U.S. Dollars 800

Structural quality 1360 kg/m
Maximum aggregate size 20 mm

Reinforcing rods 12 and 16 mm diameter	U.S. Dollars 200
Total Materials Cost	U.S. Dollars 7400

Workshop	U.S. Dollars 15000 - 20000 (European port)

Planer/thicknesser
Radial arm saw
Assembly jig and benches
Power drills
Hand tools
Power hacksaw) if steel
Steel drills) parts made
Welding equipment) locally

Launching Equipment	U.S. Dollars 4000

100 m wire rope, 6 tonnes s.w.l.
Hand operated winches (Tirfor type)
Pulley blocks
Sheaves and slings
Manilla rope
Poles or steel tubes for derricks
Shovels and other hand tools

Total Project Cost	U.S. Dollars 28900