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# LOW-COST MODULAR PREFABRICATED WOODEN BRIDGES

SM/BHU/84/010

BHUTAN

Terminal Report *

Prepared for the Kingdom of Bhutan
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of C. R. Francis, consultant in timber construction

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## Table of Contents

## 1. PROJECT BACKGROUND

This project, the establishment of a bridge factory and the demonstration of modular bridge construction was the implementation phase of the project reconnoitered by Mr Harald Eriksen in 1985. His report UNIDO DP/ID/SER. A/587 of 16 May 1985 fully describes the background to and justification for this Project.

The immediate objectives, as stated in his report, included the establishment of a prefabricated timber bridge factory in the disused vehicle maintenance workshop at Gaylegphug.

1. Provision of advice on timber drying preservation and technology.

2. Fabrication and launching of about 10 bridges.

3. Preparation of a manual containing information necessary for continuing manufacture of bridges in Bhutan.

4. Investigation of sites in Bhutan.

It is considered that all these objectives except No. 2 were satisfactorily met. Only two bridges were actually constructed, but even so the launching techniques were satisfactorily demonstrated.

## 2. WORKSHOP ESTABLISHMENT

The workshop allocated to the project was the large (approx 45m x 20m) vehicle maintenance workshop previously established with UNDP assistance but lately disused due to financial problems. This still contained several machines in operating condition (lathe, 2 No. drill presses, welder) and was amply large, with spacious office and stores accommodation. In practice only about half of the available space was occupied by the timber fabricating operation.

In addition the PWD constructed an open sided timber drying shed 30m x 9m behind the workshop.

It had been initially proposed that the steel components should be fabricated in Phuntsholing by the Bhutan Government Transport Service workshop. However the prices quoted by BGTS for this work were considered excessive. Consequently PWD purchased a heavy duty power hacksaw and a large radial arm drill and the steel components were also fabricated at Gaylegphug.

In the later part of 1987 PWD advised that for the Road Mainenance Mechanisation Programme the workshop would revert to its orginal mechanical function and a new bridge workshop would be constructed at the rear of the PWD compound. A new 30m x 12m workshop was therefore designed by the expert to contain only the original woodworking machines and the welding facility. Fabrication of steel components would revert to the mechanical workshop.

When the expert left Bhutan in mid March 1988 the new workshop was substantially complete and the major machines were positioned. Still to be provided were electricity and water supplies, and the shifting of the timber drying shed and construction of the drying stack foundation. Work on these two last was in hand.

Overall the working facilities provided by the PWD were excellent. In spite of the disruption caused by having to relocate workshop equipment, there were no delays due to lack of accommodation.

## 3. MACHINES

The four main woodworking machines provided by the project were:

1. Startrite - Harwi model 500 circular saw bench 10 HP.

2. SCM model S 52 thicknessing machine with blade jointing attachment.

3. Radial arm saw with roller table, 350mm.

4. Overhand planer, 305 mm.

All these machines were damaged in transit, probably by being manhandled between Calcutta and Gaylegphug, but were repared satisfactorily.

The expert considers that for undeveloped countries, 500mm diameter saws should not be run faster than about 2000 rpm (rim speed 3100m/min). Running at 2800 rpm requires perfectly balanced saws. Of a batch of five saws supplied by an English manufacturer, only two were well enough balanced to run without excessive vibration at 2800 rpm.

The expert has recommended that this safety measure should be undertaken. This can be done by fitting a $4\frac{1}{2}$" dia. pulley on the saw arbour and a 3" pulley on the motor. The convenience of the rise and fall and also the tilt feature would be lost, but these were not originally specified in any case.

The "sharpening attachment" on the thickness planer proved to be merely a jointing attachment. Alternative although not very satisfactory sharpening arrangements for the knives of this machine were made.

All other machines including the Vollmer CHHT 20 H carbide saw grinder were satisfactory.

## 4. MATERIALS - STEEL

Steel for all components except round bars had been purchased when the Expert arrived in Bhutan. Much of it had been sheared from plate and in consequence was twisted. Considerable effort was necessary to flatten this. 12m bar, when purchased proved to be hard anti-burglar bar, totally unsuited for cutting into thousands of short lengths. This was apart from the extremely poor quality of the rolling.

Detailed recommendations for specification purchase and fabrication of steel have been made in the accompanying Technical Report "Steelwork for the UNIDO Bridge".

## TIMBER

Sufficient Chir pine (*P. roxburghii*) for one bridge was on hand when the Expert arrived and later Katus (Castanopsis spp) was delivered for a second bridge.

The Chir pine was moderately to severely decayed and infested with large worm holes. Very little of the 100 x 50 was up to the 4m lengths specified. Later it was discovered that the longest length normally extracted is 12'-6" (3.8m) and not much of the cut is that long.

The Chir pine treated well with waterborne CCA salts and dried reasonably rapidly.

The Katus timber dried very slowly and was prone to drying collapse and warping. Much of it had to be rejected for this reason. It is too impermeable to be pressure treated yet is reputed to be non durable. For these reasons it is not recommended as a bridge construction timber.

Detailed recommendations on specification, processing and fabrication of timber are given in the accompanying Technical Report "Timber for the UNIDO Bridge".

## 5. TRAINING

No formal training classes were arranged. All training was of a one to one "hands on" nature.

Subjects covered were:

Timber Engineering

UNIDO bridge system - counterpart engineer

Woodworking machine safety and operation - - Carpenters and designated labourers

Timber preservation - Counterpart engineer
Treatment plant Operator

Lathe Turning - Mechanic

Power tool safety and use - Carpenters and designated labourers

TCT saw sharpening - Leading carpenter.

Appropriate notes and instructions were issued as necessary. A major effort was made to change traditional work attitudes towards the adoption of a mass production approach and to the use of machines and power tools. This is of considerable importance in Bhutan.

Bhutan is the only country in the region which has a shortage of general labour. Current policy is to restrict immigration and the importation of contract labour. The increase of unit tradesman productivity is therefore important to the industrial development of Bhutan. Every endeavour was made to do this through the introduction of modern techniques in the use of machines and power tools and also in such basic improvements such as working at a bench with a vice, rather than squatting on the floor and using the toes to hold workpieces.

Towards the end of the project duration the joinery for the new workshop was being manufactured. The difference in productivity was significant between project carpenters and those casually employed, who worked in the traditional fashion.

## 6. REPORTS

Five technical reports have been prepared as a result of this project. These are:

1. Launching the UNIDO bridge. This is a revision of Technical Report UNIDO/IO/R.223. Like that report it is of general applicability to all countries using the UNIDO bridge.

2. UNIDO Bridge Bottom Chord Design Changes. This report contains details of recommended changes to the original design. It is also of general applicability.

3 and 4 Timber for the UNIDO Bridge
Steel for the UNIDO Bridge
These reports contain specific recommendations for the specification purchase and working of these two materials.

5. Prefabricated Building Components. This report examines the possibility of extending the functions of the present bridge workshop to manufacture principally trussed rafters to support the school construction programme in Bhutan.

These reports contain the bulk of detailed recommendations made to the P. W. D. as a result of this Project.

## 7. BRIDGE CONSTRUCTION

The Project document called for the construction of 10 bridges during this Project. Only two were built due to lack of materials.

There were several administrative reasons for this. Some of these now appear to be resolved and at the end of February 1988 good quality timber for further bridges was being delivered. The material shortages were exhaustively discussed at the Tripartite Review held in November 1987.

One major fact which was not previously appreciated is the lead time of 10 months between placing of orders and availability of dry treated timber ready for panel fabrication.

The bridges were built at Panching, Bumthang district (18m) and Dimoli, Deothang district (12m).

At Panching, both Timber Engineers gave detailed instructions, and actively assisted in the work. At Dimoli, the Timber Engineer, although present, deliberately gave no advice or assistance. (The Master Carpenter by this time had left Bhutan). This bridge was erected in the normal time, with no holdups or accidents completely by Bhutanese personnel. This reflects very favourably on the ability of the AE Modular Bridges and his key staff.

The Sixth Plan calls for the construction of 15 - 20 bridges per year for the next five years. The "standard" bridge is 15m x 4 panels = 20 panels. Experience in the workshop showed that the major operations took

Machining - one week per bridge lot

Panel construction - one man day per panel

In fact these production rates were slightly exceeded, however, considering the frequency and duration of electricity supply interruptions it is considered unwise to assume a faster rate. These figures show that even the higher construction level is easily attained in terms of workshop fabrication. On the other hand, site work occupies nearly three weeks per bridge, more if travelling time is included. Site work does not require the presence of all key tradesmen all the time.

It is recommended that a construction gang should be formed, consisting of a permanent nucleus of, say, three men. To this can be added in rotation another two or three workshop staff. In this way site work progress can be maintained, and contact between workshop and site will continue, a consideration which is important in the maintenance of workshop morale and enthusiasm.