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LOW-COST MODULAR PREFABRICATED WOODEN BRIDGES

SM/BHU/84/010

BHUTAN

Technical report: Prefabricated building components*

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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1. Background

Bhutan is about to embark on a programme of school and associated building construction. A school will contain not only the classrooms proper but also boarding accommodation for pupils, staff quarters and associated minor buildings.

The programme aims at constructing $8000m^2$ of buildings per year for the next five years. Much of this will be in isolated areas with a minimum of local building resources. Prefabrication is one method of overcoming the problems of isolation.

Bhutan has a distinctive architectural tradition and it is Government policy that this tradition should be maintained in all public buildings. However, this does not preclude the use of modern techniques provided they are compatible with the traditional appearance. Principal features of this style are supported wide eaved, low pitch (20^{o}) roofs, half timbered upper storey construction and heavy joinery with distinctive window heads.

Bhutan's rich forest resources have attracted several woodworking industries. There are a number of small sawmills, generally poorly equiped with small low quality machinery which saw soft and hard woods to low standards of dimensional accuracy. A modern plywood mill, sawmill and joinery complex has recently been established at Gedu about 50 km north of Phuntsholing. This is well equipped with kilns and pressure treatment plant and deals almost exclusively in hardwoods.

In 1987 a modular timber bridge factory was installed under this project in Gaylephug. This deals only with softwood (chir pine). This factory was installed in the existing PWD workshop and besides wood dimensioning machines contains some heavy metal working machines for the manufacture of the steel components of the bridges.

Under the Road Mechanization Programme, it is proposed to re-establish and expand the old workshop, and to build a new bridge workshop close by. It is proposed that most of the metal working machines (No. 5 MT radial arm drill, hacksaw, 2m lathe, welding equipment) will revert to the mechanical workshop, only the necessary assembly machines going to the Bridge Workshop. Steel Bridge components will be manufactured in the mechanical workshop.

The woodworking side of the present Bridge workshop contains

- drying shed
- solar kiln 4m x 1.2m stack (proposed)
- ASCU pressure treatment plant 4.5m x 600 mm dia

- 500 mm x 250 mm thickness planer
- 300 mm overhand planer
- 500 mm dia. tilting table saw (ripsaw)
- 400 mm dia universal radial arm saw with roller tables
- Vollmer CHHT TCT saw sharpening machine
- Bench drill press No. 3 MT
- 2 No. large, 1 small portable electric drills with bench stands
- Basic hand tools

It has been found that the machining of the timber for one bridge takes about 2 weeks. A total of 20 bridges per year is planned, so the machining time would occupy 40 weeks. However, this two weeks included the learning process, and most of the time only one machine was working. Thus each machine would operate for only about 20 weeks per year, leaving a large excess capacity, provided always that the work for each machine is carefully planned.

All timber for the bridges is to be ordered in 4.0 m lengths when extraction conditions permit.

2. Educational Building Programme

2.1 Roof Trusses

The programme calls for 8000 m^2 per year of construction mostly of 7 m width. With trusses spaced at 1200 mm the programme will require about 1000 trusses per year.

It has been decided to use punched steel connector plates and stubby nails as described in UNIDO report DP/ID/SER. A/353. "A Trussed Rafter System" with trusses specially designed for Bhutan conditions.

Very approximate quantities of materials and operations are:

Annual timber volume (100 x 50): 133m^3 (4700 cuf)

1.2mm galvanized sheets 2400 x 1200 : 120 sheets

30mm x3.2 mm dia galvanized nails : 590,000 No (1400kg)

Number of cuts to fabricate components : 30,000

Overall the trusses will be about 9.5m long. This will require transporting in halves. The expert suggests that a nailing table should be made to take a complete truss, but that not all connections should be made at the apex and bottom chord and the three parts should be serialised to ensure proper fit on site.

The nailing rate averages about 6.5 nails per minute during an effective year of 280 days x 360 minutes, four nailing hands will be required to maintain this production rate.

2.2 Window Frames

Data supplied to the expert for windows are:

One 200m^2 building contains:

Window Length (m)	No	Total Length (m)	No. of muntins @ 500 mm crs
4.6	2	9.2	10
4.0	2	8	9
2.0	6	12	5
		29.2m	24

Details of the window units were not shown to the expert, but assuming three rails and muntins at 500 mm centres, the following figures arise:

Total length of rail 3500 m
No of mortises and tenons 3840

2.3 Door Frames

Again the expert has not seen detailed designs, but it is assumed that each unit consists of 2 stiles and one lintel, morticed together. The estimated number required per year is about 200 and the proportion of work compared with windows is comparatively small.

2.4 Other Timbers

Floor and ceiling joists are also required. These will be 150 x 50 and 130 x 50 respectively. The volume, and the amount of working required has not been discussed or estimated.

2.5 Summary

It must be emphasised that the figures above are very tentative and must be revised on receipt of detailed schedules and designs from the Chief Architect P.W.D. Even so it appears that the machining capacity (apart from mortising) exists at Gaylegphug, and that with relatively minor extension, this manufacture of prefabricated components in the quantities required is feasible.

3. Additional Machinery and Tools Required

3.1 Machines

4 ft guillotine - to cut steel sheet into strips

Punch - to cut nail holes in strips

Shears - to cut punched strip to length for nail plates. Also to crop 12mm bar for bridge pins.

Chain and chisel mortiser - mortising of joinery components.

Universal tool grinder - sharpening of mortising tools, drill bits, if provided with enough stroke, also planer knives.

Knife grinder - with the additional planing load, the existing knife sharpening arrangements will not be satisfactory. Required 630mm stroke, if facility not available on universal grinder. Detailed specifications are attached as Annex A.

3.2 Tools

Three full sets of hand tools will be required for joiners, and other tools, particularly measuring rules and tapes for the other workmen. A full schedule of hand tools is given in Annex B.

4. Materials

With a large and fairly complex workshop manufacturing specialised precision products it is essential that the material supply should be kept up, otherwise work stops.

It must be remembered that the lead time for timber including air seasoning is about 5-6 months from placing order for logs to receiving the material into the workshop and for pressure treated timber it is about 10 months.

Similarly, delivery times for special nails including galvanizing which does not appear to be common in India are also likely to be several months.

Every effort must be made, if the project is to function at all, to ensure that administrative delays are minimized.

5. Standardisation

A cutting schedule has been devised for the Modular Bridge where all components are cut from 4.0 m long lengths. It would greatly ease the factory operation and add flexibility to both bridge and building component operations if all building components are detailed to be cut from 4.0 m lengths. It should be noted that this is a very common trade length in Europe and Japan where vast volumes of wooden joinery are manufactured.

6. Organisation

With two separate output responsibilities and shared functions, a reorganisation of work will be required, with workmen performing only their specialised functions.

A suggested organisation chart is shown in Fig 1. This totals to 4 leading hands, 13 tradesmen (of varying degrees of skill) and 19 labourers. The leading hands and tradesmen can hardly be reduced, but the number of labourers might be cut by extensive use of trolleys etc. At the same time a tradesman should not have to carry his raw materials nor remove his product.

Conclusion

It appears quite possible to approximately double the planned timber throughput of the modular Bridge factory by adding a prefabricated Building Component section. This is achieved by reorganisation into functional sections in the timber preparation stage.

In numbers, the Building section would have about 14 men while the bridge section would have 6. Common to both in timber preparation and servicing are 16 men. These numbers are tentative and subject to revision.

The Building section requires an additional two woodworking machines and two sharpening machines, which would also service the Bridge section. Also required are two small metalworking machines, later to be located in the Mechanical workshop.

The estimated capital cost of tools and machinery is US$24,650.

A N N E X A

MACHINERY

			US$
1.	Universal radial arm saw 400 mm dia e/w 2 x 3m roller tables. (Recommended "Stromab" model RS 65 to match existing saw)		4707
2.	4 TCT cross cut blades for above		
3.	Chisel/chain morticer 25 mm capacity 2 Nos. sets chains 12,16, 25 mm 2 Nos. sets drills and chisels 12, 16, 20, 25mm		8000
4.	Planer knife grinder 630 mm hand feed		
5.	Universal tool grinder with attachments and stones for sharpening mortice chains Mortice drills, spur drills (5 bandsaw blades)		5000
6.	4 sets stones for above		
7.	1 No. stone arbour for each different profile stone (4)		
8.	Diamond wheel Vollmer type CNHB 31-30/30	1 No 1 No	165 415
9.	200 Fx bandsaw blade x (60m)		84
10.	Guillotine, foot or air operated to cut 1250 x 1.5mm m.s. sheet		2461
11.	Bench shears, 200mm blade length with facility for cutting 20 mm dia bars c/w		500
	2 No. sets spare blades for shears		130
	Punch to do multiple 3.5mm dia. holes through 1.5mm thick m.s. sheet		1500
		Total Machinery US$	22,762
		Say US$	23,000

A N N E X B

TOOLS

1. Bench Workers

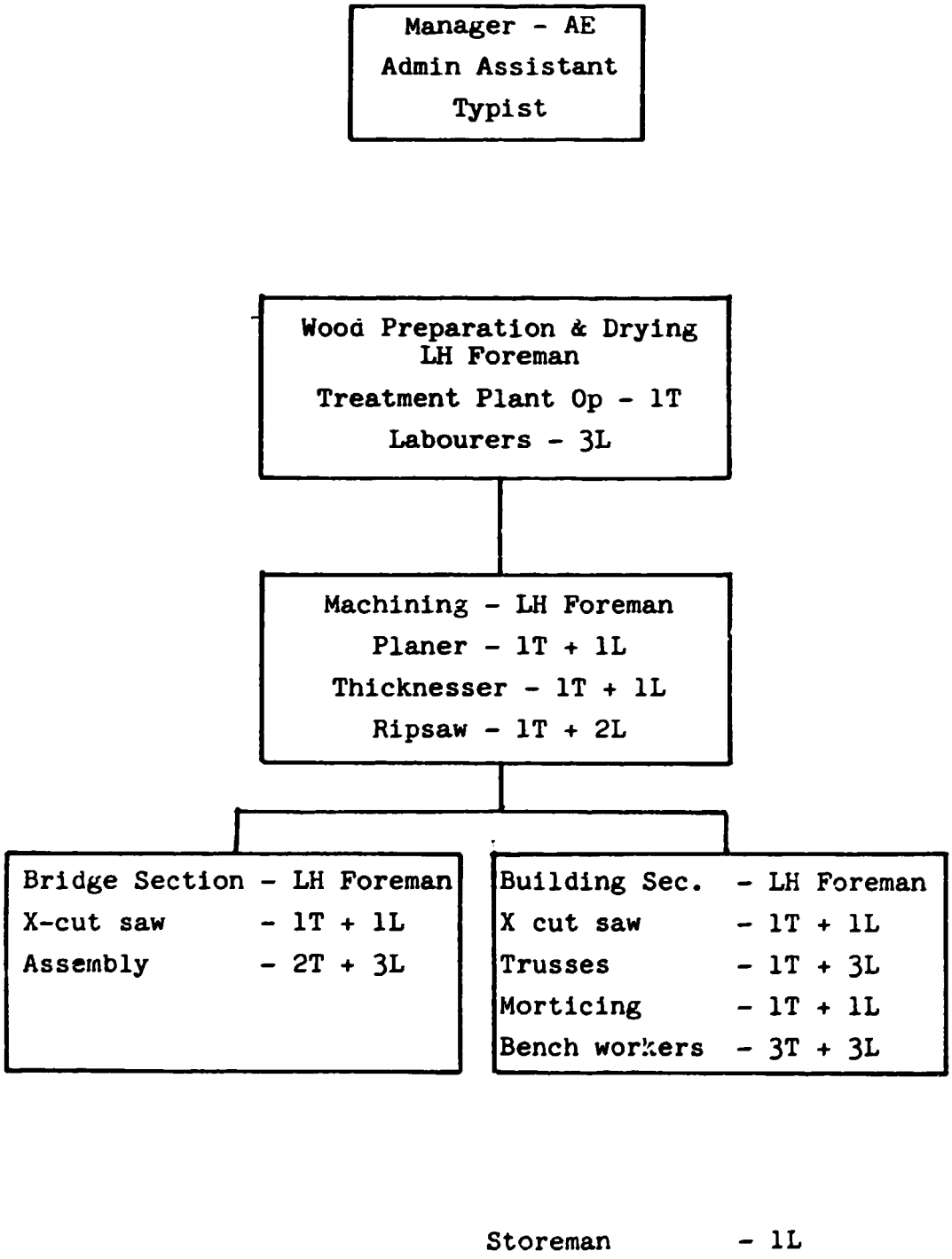
Item	Description	No.	Price $	Amt
1	20 oz Claw hammer	3	16	48
2	1m folding rule	3	16	48
3	3m steel tape	3	8	24
4	8 pt handsaw	3	25	75
5	10" carpenters vice	3	102	306
6	8" G clamp	6	18	108
7	set 4 chisels	3	25	75
8	Mallet	3	10	30
9	Comb. square	3	14	42
10	Mortice gauge	3	15	45
11	Nail set 3/16"	3	2	6
12	Carpenters pencil packet	1	6	6
13	Tenon saw	3	17	51
14	Bench plane 10" x 2.5"	3	37	111
15	Rebate plane	1	40	40
16	Rafter square	1	21	21
17	Replacement tapes 3m for Item 3	4	5	20
18	Spokeshave, round face	1	20	20
19	Saw setting pliers	1	34	34
20	Set 6 No wood turning chisels	1	60	60
		Total		$1170

2. Truss Manufacture

1	20 oz claw hammer	3	16	48
2	Combination square 12"/30 cm	2	14	28
3	Sliding bevel 10m 10"/25cm	2	9	18
4	1 m folding rule	4	16	64
5	5 m steel tape	3	14	42
6	5 m replacement tape for Item 5	6	7	42
7	Cam clamps	10	20	200
		Total		$442

Total tools $1612

Say $1650


Manager - AE
Admin Assistant
Typist
Wood Preparation & Drying
LH Foreman
Treatment Plant Op - 1T
Labourers - 3L
Machining - LH Foreman
Planer - 1T + 1L
Thicknesser - 1T + 1L
Ripsaw - 1T + 2L
Bridge Section - LH Foreman
X-cut saw - 1T + 1L
Assembly - 2T + 3L
Building Sec. - LH Foreman
X cut saw - 1T + 1L
Trusses - 1T + 3L
Morticing - 1T + 1L
Bench workers - 3T + 3L

Storeman - 1L