UNIT 4 ESTIMATION OF QUANTITIES IN RCC FORMWORK AND IN TRUSSES

Structure

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4.1 INTRODUCTION

Estimation of materials (say, timber, mild steel, etc.) in RCC formworks is as much difficult as it is easy. It is difficult; if the juxtaposition of its components, their various dimensions, and purpose are not completely understood: and, it is very easy once the assembly is conceived full and clearly.

In the determination of quantities, either in timber or steel truss, it is comparatively easier to comprehend the make-up of the work. Length dimensions of various truss members (finished product) can always be read from drawings or measured off the drawing sheet if that is drawn to scale. It is accurate to retrieve the information from the design data that has been worked out.

Objectives

After studying this unit, you should be able to

- know about the general specifications of the items involved in RCC formworks, and trusses (of timber as well as steel),
- develop the intuition to conceive the important details of the relevant drawing, and
- estimate the various quantities required to be determined in these works.

4.2 GENERAL SPECIFICATIONS : TRUSSES AND FORMWORK

General specifications, as said earlier also, help all the concerned – the designer, estimator, as well as the executing engineer – to perform appropriately in the respective area of the job. General specifications, in fact, are relevant every time, and at every place, affording a tool to bring the work to the desired perfection.

Timber Trusses

Work shall be done as per drawings, using only specified timber. All scantlings shall be very accurately planed smooth to the full dimensions and rebates, roundings, as per design. No patching or plugging, whatsoever, shall be tolerated.

Joints shall be simple, strong and neat. All joints – mortise and ***tennon***, mitred, scarfs, etc. – must fit in fully and accurately without wedging or fillings. Holes of correct sizes shall be drilled before inserting screws or bolts. No screws shall be driven with hammer. All screws, bolts and nails shall be dipped in oil before using. Heads of nails and screws shall be sunk and puttied or dealt with as instructed.

Posts and beams shall be free from sap wood, large or loose knots, shakes, cracks, etc. These shall be properly dressed, fitted and fixed as designed. No beam is to be scarfed or joined in the middle unless shown in the drawing. All parts of timber in contact with masonry shall be coated with tar, etc. Clear spaces of about 4.0 cm to 5.00 cm in width shall be left on each side of beams that are to be embedded in masonry built in lime mortar.

Timber buried in the ground shall be charred and tarred. Woodwork exposed to the weather should be tarred or painted if the wood is seasoned; *otherwise it should be allowed to remain unpainted until seasoned.*

Timber sections shall be cut to correct lengths, and measured with a steel tape. A great accuracy shall be adopted in the fabrication of various members so that these can be assembled without being unduly packed, strained or forced into position.

Frame work of a roof does differ with respect to different forms of roof. Roofs may be flat, sloped or inclined. Supports for flat roofs are simple in construction, ***but it is limited to small spans as sound timer longer than 6.0 m (20 ft) are rarely procurable, and even when available, are too heavy and expensive.*** Sloped roofs are suitable and economical for all spans. By various arrangements of timber pieces (posts, scantlings, beams, etc.) in fabricating a frame work, and by special devices of fixing beams and supports, great spans can be covered in buildings. Steel frame work is more common particularly where timber is costly or not easily available.

Sloped Roofs

Sloped roofs gabled or hipped are also in use. In the former the roof is formed by the intersection of two planes which slope upwards from the wall plates at the side of the building, meeting at an angle at the ridge, the end walls forming the gable. In the second case, the roof is formed by planes sloping up from the sides and the ends of the building to the ridge forming hips, the wall plates being on the same level all round.

Couple roof frame work is formed by the meeting of two beams on rafters fixed at an inclination. Their feet are nailed or notched on a wall plate embedded on the top of the wall and their heads meet upon a ridge board to which these are secured by nails. ***Such a frame work is suitable for small spans upto 4.25 m – (14 ft).***

Couple close roof is an improvement on the couple roof, and is formed by connecting the feet of the rafters by a tie beam, that prevents them from spreading and thrusting the walls out. ***It is economical for spans up to 5.5 m (18 ft).*** If the tie beam has to support a ceiling it may be held up by an iron rod (termed *king rod*), from the ridge.

Collar-beam roof is a variation of the couple close roof where a greater headway is required, the tie beam being raised half way up the rafters. However, it is a bad form of construction as the rafters bend in the middle and the thrust is borne by the walls. The situation can be improved by adding a tie beam or tie rod at the foot of rafters. This roof could be used only for small buildings not exceeding ***5.5 m in span.***

King post roof (truss) has a frame work consisting of rafters, king post, struts and tie beam known as ***King Post Truss***. These are used for spans up to 9.0 m (30 ft). In this truss, rafters are supported at the middle by means of props (termed braces or struts) – thus, their effective spans being reduced to half. Thus, the rafters are able to bear twice the load that these could carry otherwise. The heads of the struts are *tennoned* into the rafters and their feet into the foot of the king post. In order to guard against any cross strain coming under the rafters, the heads of the struts shall be fixed almost immediately near the purlins.

Queen post roof (truss) is best suited upto a span of about 14.0 m (≈ 45 ft). If the span is more than 9.0 m, the tie beam shall require more than one support – this is provided by means of two *Queen* posts. The queen posts, between them, carry about two-thirds of the weight of the tie beam and any addition of load brought upon the tie beam. The heads of the queen posts are kept apart by a straining beam and this feet are tennoned into the tie beam and prevented from moving inwards by a straining sill.

For spans greater than 14.0 m, roof trusses shall be designed by various combinations of posts and struts – however, then steel trusses prove economical.

Once the pitch (inclination of rafters to vertical) is known, the length of principal rafters can be ascertained by drawing the arrangement on a sheet. For too long rafters, it is appropriate to divide them into portions about 2.5 m (8 ft) long, placing a strut under each point of division. In actual practice, trusses shall be set up along the building, about 2.5 m to 3.00 m apart, and across these trusses (principals) are laid purlins, which fix them to their positions.

First a full-size truss diagram (as per drawing) shall be drawn on a levelled platform. From this full-size diagram, templates of all joints (as for tennons, mortices, scarfs etc.) shall be made to be used in guiding the fabrication work. Templates of corresponding truss members shall also be made – plate holes for screws and bolts shall thereafter be marked on these and drilled. These templates shall later be laid on wooden members, and the holes for screwing and bolting marked on them. The ends of the wooden members shall also be marked for the purposes of cutting. The base of RCC columns and the position of anchor bolts shall be carefully set out. Individual truss members must be first (before the final fabrication) assembled together to ensure close abutting or lapping of the surfaces of these various members.

After the trusses are fabricated, these shall be hoisted and placed in position very carefully. Trusses shall be screwed to walls by means of holding down bolts – hoisting having been done by using hoisting equipment. Trusses shall be stayed temporarily till these are finally secured permanently in position, and then purlins shall be laid connecting the trusses with each other.

Woodwork shall be measured for finished dimensions. Length of each piece shall be measured overall to the nearest cm – it takes care of projections for tennis, scarves or mitres. Width and thickness shall be measured to the nearest mm. Unless otherwise specified, iron fixtures (such as bolts and nuts, MS plates, holding down bolts) and staining, priming, painting or polishing of the trusswork shall be paid for separately.

Formwork for RCC – Floor, Beams, and Columns

If the reinforcement is adequately designed and appropriately placed a reinforced concretework never fails after construction. However, during construction, chances are there for the collapse of the work due to faulty design/construction of the forms. Thus, a meticulous design of the formwork is a pre-requisite for the trouble free construction of an RCC work. These days reputed firms specialize in this job. A responsible engineer must ensure the proper design and construction of formwork.

In order to construct a satisfactory concretework, the forms shall have to be durable and rigid, and well braced to prevent bulging or twisting. Forms shall have the required strength to take the oncoming loads. Horizontal members (like, floor-sheathing, joints, etc.) should withstand the weight of raw concrete and loads coming during the construction activity, and the vertical members (wall-sheathing and supporting studs) must be able to resist the hydrostatic pressure developed in the raw concrete it supports.

All the timber pieces (members) shall be of the best quality that is available. They shall be sound, straight grown, free from sap, shakes, loose knots, worm holes, etc. *Thorough seasoning is of great importance but partially seasonal timber is the best material for formwork* – too much dry timber tends to swell due to the absorption of moisture from green concrete; and, green timber tends to dry out and shrink in hot weather, causing fins and ridges on the concrete.

Different boarding thickness shall be used with various slab depths, live load being taken about 3.6 kN/m^2 (≈ 75 lbs per square foot). Bending moment (M) can be calculated as $M = \frac{w\,l^2}{10}$, and the deflection being limited to about 3.2 mm (≈ 1/8 of an inch). For sheathing planks, under vertical loads, these values do apply. Generally, for joists and beams (carrying joists) also deflection shall not exceed 3.2 mm for the dead loads and a live load of about 2.0 kN/m^2 (40 lb per ft^2).

Wooden forms shall be dressed equal in depth to the thickness of the slab at the sides. Forms shall rest on stakes driven into the ground within 30 cm of each end of each separate piece, and at intervals of not greater than 1.5 m elsewhere. Forms shall be held by stakes (driven into the ground along the outside edge) at intervals not more than 1.8 m, two stakes being placed at each joint. These shall be nailed firmly to the side stakes, and shall be appropriately braced, wherever needed, to resist the pressure of concrete/impact of the tamper (or vibrations of the electrical vibrator as the case may be). Forms shall be capped along the inside upper edge with 5 cm angle irons.

Metal forms (if used) shall comprise shaped steel sections, like as channels, etc. They should be at least 3.0 m in length for tangents and for curves having radius 45 m and above. Smaller pieces upto 1.5 m can be used for curves having radius less than 45 m. The depth of the forms shall be the same as the thickness of the slab – using adequate number of bracing pins or stakes to prevent any displacement of forms due to pressure of the concrete slab or impact of tamper, etc.

Forms shall be set to the exact alignment (and grade) at least 30 m in advance of the point where concrete is to be deposited. Before the setting of forms, these shall be thoroughly cleaned. After setting is done satisfactorily, forms should be thoroughly oiled prior to placing concrete against them. Forms, when in place, must be subject to checking, and correction of alignment and grade from time to time. It is important that forms shall be rigid: an essential condition for the even running of the intended finished surface.

No forms shall be removed until at least 24 hours have elapsed after the placement of concrete against them; and every care shall be taken while removing them ensuring no damage to concrete. Forms need be cleaned thoroughly before any reuse. [All the considerations discussed in Section 2.5.2 about formwork do apply along with the points discussed ***herein***.]

Where metal forms are used, all bolts and nuts (that go with this arrangement) shall be counter sunk, and well ground to provide a smooth, plain surface.

Chamfers, bevelled edges and mouldings shall be shaped in the form itself. Openings for fan clamps and other such fittings shall be provided in the shuttering as required. As far as possible the clamps shall be used to hold the forms together – wherever the use of nails is unavoidable, minimum number of nails shall be used, and these shall be left projecting so that these can be withdrawn easily. Use of double headed nails should be preferred.

For special type of locations – for tall structures, etc. – the use of moving/climbing forms shall be resorted to.

In long spans, suitable camber shall be given to the horizontal members – to counteract the effects of deflection under dead load, etc. Assembly of the formwork shall be so done as to allow the desired camber to the provided – say, bottom boards of beams require a camber of about 6.0 to 7.5 mm for a span of 1.5 m, i.e. $1/24^{th}$ of the spans, i.e., about 4 to 5 mm per meter (1 in 250). For cantilevers, camber at free end shall be $1/50^{th}$ of the projected length or so.

Temperature and humidity of air, and the nature of stress to which a member is subjected to (direct compression as in columns; flexure as in beams and slabs), and the relative proportions of dead and live load – all do influence the time required to keep the formwork in position. In cold (wet) whether, hardening of concrete is retarded and the forms must be kept in position a little longer. Also, wherever bending stresses (flexure) do occur, (as in slabs and beams) forms are kept longer than where direct compression acts (generally columns). Moreover, if the ratio of dead load to live load is quite high, the member has to bear a greater proportion of load immediately after the forms are removed – thus delayed removal is desirable.

As has been said earlier in a slab and beam construction, sides of beams shall be stripped first, and next follows the removal from under the slabs, and lastly from the under-sides of beams. Thus, one more aspect of the design of formwork consists in allowing an ordered removal of its components, such as :

(a) First, non-load bearing members (shutters to vertical faces) : column boxes, sides of beams, and wall forms,

(b) Next, shutters of soffits to slabs; horizontal, and inclined members : i.e., those carrying light loads – slabs, roofs, floors, canopies, etc.,

(c) Lastly, soffit shutters carrying heavy loads – beams, and girder bottoms.

However, the golden rule always remains that under no circumstances the forms shall be struck until the concrete (RCC) attains a strength of at least twice the stress to which it may be subjected at the time of striking.

Leaving formwork longer in position helps in curing the work and is a good policy. Section 2.5.2 gives a Table that must, at least, be followed while striking the formwork.

The method of measurement of formwork is based on IS Code 1200 Part V. *The actual surface of any type of formwork*, described herein later on, and rates of payment depend on the type, classification, etc. of the formwork) *in contact with concrete or any other material requiring form work shall be measured in* m^2 *and paid for accordingly*. Where the formwork is required to be lined with some material – wall board, hard board, polyethylene sheet or paper lining, or to be coated with a liquid or lime wash – such a formwork shall be so specified (described) and measured separately, for appropriate payment. Further, whenever a lining of well board, or asbestos cork slab, etc., is of a permanent nature, and is to be left in, it shall be measured separately for appropriate payment.

It is a general practice not to make any deductions for openings up to 0.4 m^2. Raking or circular cutting, and moulded or rounded edges shall be measured in running meters, and paid accordingly as per rates decided upon (after due rate analysis). Moulded stoppings shall be enumerated – i.e. paid by numbers.

Formwork of secondary beams shall be measured up to the sides of the main beams – however, no deduction shall be made from the formwork of the main beam where the secondary beam intersects it. Similarly, no deduction shall be made from the formwork for stanchions (or columns) casings at the intersections with beams.

Every formwork needs supports, braces, wedges, struts (Figures 4.1 and 4.2), and also mud sills, piles and/or any other suitable supports to achieve rigidity and stability. Also bolts, wire ties, clamps, spreaders, etc. are needed to keep the sheathing together. It also includes filleting to make up chamfered edges or splayed external angles (not more than 20 mm wide) to beams, columns, etc.; and, includes raking or circular cutting.

If found necessary, temporary openings in the formwork shall be allowed to admit pouring of concrete, inserting vibrators. Holes can be incorporated to clean/remove dirt, etc., from the inside of the sheathing prior to concerting. Necessary arrangements should be in place for dressing the formwork with oil in order to prevent adhesion of concrete to the formwork.

Formwork should be so assembled as to provide due allowances for overlaps (if needed); allow providing splayed edges, notching, battens, strutting, nailing/bolting, wedging; and, above all allow smooth easing, striking, and removal after the due time period is over. All formwork will include the necessary working scaffoldings, ladders, gangways, etc.

Generally, formworks are measured and paid for as per the given classifications, such as :

(a) Formwork for foundations, footings, base of columns, etc.

(b) Formwork for flat surfaces – soffits of floors, roof slabs, landing, etc. However, for floors that exceed 20 cm in thickness, heavy forms are required, and, hence, the formwork shall be measured separately specifying the floor thickness.

(c) Formwork for vertical surfaces – say, walls, partitions, etc., (including associated pilasters, buttresses, etc).

(d) Formwork for curved surfaces of a given radius, type of curve being taken into account.

(e) Formwork for battered (or sloping) surfaces.

(f) Formwork for the sides of columns, piers, and stanchions.

(g) Formwork for staircase, etc.

This list can be extended to cover other items of civil engineering works.

Moreover, the rates of payment for the formwork shall depend on the nature of the material used, and its make-up, such as :

(a) Wrought iron formwork – sheathing presenting planed surfaces.

(b) Sheathing of steel sheets, plywood sheets, moulded plaster, or sheathing made of tongued and grooved boards.

(c) Specially lined sheathing for ornamental surfaces.

4.3 CASE STUDIES : RCC FORMWORK

With a view to gaining access into the so-called intricacies of estimating the quantities of various items of a given RCC formwork (already designed for withstanding the expected loads during the period of the construction activity) following solved examples are presented as an introduction to this aspect of the job of an estimator.

Example 4.1

Figure 4.1(a) and (b) give the typical details of a formwork for the given RCC work – several halls having columns, beams, and slab.

Estimate the quantity of wood (Teak) required to be paid for (for constructing its various components) with respect to one beam (5.5 m span), one column, and slab of one hall.

Figure 4.1(a) : Details of RCC Formwork (Slab, Column and Beam) : Example 4.1 (Not to Scale)

Figure 4.1(b) : Section [Along A-B : Figure 4.1(a) – (i)] giving Details of Formwork (Not to Scale)

Solution

Before making a conventional bill of quantities, preliminary calculations are necessary to arrive at the needed dimensions, as shown below :

Length to be Covered

Length of slab to be covered = 6.0 – twice half-beam width

$$= 6.0 - 2\left[\frac{0.25}{2}\right]$$

$$= 6.0 - 0.25$$

$$= 5.75 \text{ m}$$

Breadth of slab to be covered $= 5.5 - 2\left[\frac{0.25}{2}\right]$

$$= 5.25 \text{ m}$$

Length of ballies (with reference to the slab of the hall) to be used in the formwork

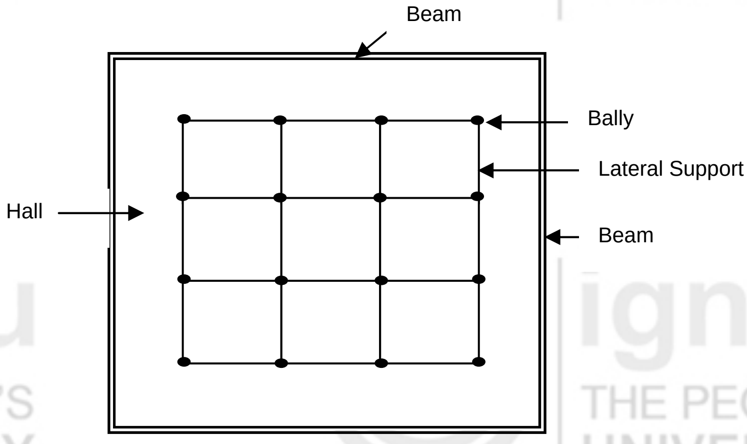
= (3 × 1.2 + 0.65 = 4.25 m) – 0.075 m at top – 0.075 m at bottom

= 4.10 m

[A gap of 7.5 cm at the top is shown in the Figure, and is needed to conveniently place the ballies in position, and the bottom gap (0.75 cm) is needed to accommodate the base plate and the wedges.]

Cross-section of a *bally* $= \frac{\pi}{4}(0.10)^2$

$$\approx 0.008 \text{ m}^2$$



(Web of Ballies and Lateral Supports – at One Level)

Number of *ballies* needed for one hall = [No of rows of *ballies* perpendicular to 5.5 m-side @ 1.2 m c/c] × 4 (i.e., along 6.0 m-side, as shown in the Figure)

$$= 4 \times 4 = 16$$

Number of lateral supports needed for *ballies* at one level in one hall = 12

Number of lateral supports needed for *ballies* at three levels (Figure 4.1(b)) in one hall = 3 × 12 = 36.

Beam to be Covered

Vertical length of 2.5 cm thick vertical planks

$$= 53 - 15 - 2.5 = 35.5 \text{ cm}$$

Horizontal length of 2.5 cm-thick horizontal plank

$$= 25 + 2 \times 2.5 = 30 \text{ cm}$$

Vertical length of laterals = 53 – 15 – 2.5 + 2.5 = 38 cm

Number of these laterals in one beam (on two sides)

$$= 2\left[\frac{6.0\,\text{m}}{0.9} + 1\right] = 2\,[6.6 + 1] \approx 2(7) \approx 14$$

Number of tapering blocks on every base beam

$$= 2 \text{ (i.e., on both sides of the beam)} \times \left(\frac{5.5}{1.2} + 1\right)$$

$$= 2 \times [4.5 + 1]$$

$$\approx 2 \times (5) = 10$$

Similarly, number of base beams = 1 × 5 = 5.

And, number of struts (on both sides of the beam) – with each base beam = 2 × 5 = 10.

Length of a ***bally*** under the beam = 4.25 – 0.405 – (0.075 + 0.10)

$$= 3.67 \text{ m}$$

[where, 53 – 15 + 2.5 = 40.5 cm = vertical length from bottom of slab to top of base beam; and, 0.075 + 0.10 = (height of base plate and wedges) + (thickness of base beam)].

Number of these ballies = 5 (as explained alone)

Area of this ***bally*** (0.1 m ϕ) = 0.008 m^2 (as explained earlier also)

Number of base plates (as is obvious) = 5

Column

Vertical length of column to be covered = 4.25 m

$$\text{Number of laterals} = 2\left(\frac{4.25}{1.2} + 1\right)$$

$$= 2\,[3.5 + 1] \approx 2\,[4] \approx 8$$

Now an estimate of quantities is presented below in the usual format :

Estimate of Quantities for Formwork for RCC Item (Example 4.1)

Sl. No	Description of Item	No.	Measurements			Quantity	Total
			L (m)	B (m)	H/D (m)		
1.	*Woodwork for the formwork of one slab (i.e. for one hall)*						

	(i) Planks (2.5 cm thick)	1	5.75	5.25	0.025	0.755 m^3	
	(ii) Beams (10 × 4 cm) – each is 5.5 m long, and their total number is 4 (one on each centre line in the plan)	4	5.50	0.10	0.04	0.022m^3	
	(iii) Ballies (10 cm ϕ)	16	4.1	0.008 m^2	–	0.525 m^3	
	(iv) Lateral supports (10 × 5 cm @ 1.2 m c/c)	36	1.2	0.1	0.05	0.006 m^3	
	(v) Base plates (30 × 30 × 5 cm)	16	0.30	0.30	0.05	0.072 m^3	
							1.38 m^3
	(vi) Pairs of wedges (This minor item can be expressed in numbers)	16				16 Nos.	16 Nos.
2.	*Woodwork for one RCC beam formwork*						
	(i) Planks						
	(a) Side plank	2	5.5	0.025	0.355	0.0986 m^3	
	(b) Bottom planks	1	5.5	0.30	0.025	0.041 m^3	
	(ii) Laterals (5 × 4 cm) @ 0.9 m c/c	14	0.38	0.05	0.04	0.011 m^3	
	(iii) Tapering blocks on base beams – 23 × 5 × 7.5 cm. (the last dimension is perpendicular to paper)	10	0.23	0.075	0.05	0.0086 m^3	
	(iv) Base beams (10 × 7.5 cm) @ 1.2 m c/c	5	0.48	0.10	0.075	0.018 m^3	
	(v) Struts (below base beams) – 5 × 5 cm, 0.30 m long	10	0.3	0.05	0.05	0.0075 m^3	
	(vi) Ballies (10 cm ϕ)	5	3.67	0.008 m^2	-	0.15 m^3	
	(vii) Base plate (30 × 30 × 5 cm)	5	0.3	0.3	0.05	0.023 m^3	
	(viii) Blocks (a minor item – allowing, say, 0.03 m^3)	-	-	-	-	0.03 m^3	
							0.39 m^3
	(ix) Pair of wedges	5				5 pairs	5 pairs
3	*Column (one) woodwork for its formwork*						
	(i) Planks (2.5 cm thick)						
	(a) In *x*-direction	2	4.25	0.3	0.025	0.064 m^3	
	(b) In *y*-direction	2	4.25	0.35	0.025	0.074 m^3	

	(ii) Laterals (6.3 × 5 cm) @ 1.2 m c/c	8	0.53	0.05	0.063	0.013 m^3	
	(iii) Blocks – allowing 0.012 m^3					0.012 m^3	
							0.163 m^3
	(iv) Bolts (1.25 cm ϕ) (with nuts, etc.)		4	2		8 sets	8 sets

Example 4.2

Figure 4.2 details out a formwork (designed by a civil engineer for dead and live loads that may act while the construction activity proceeds) for an RCC beam (10 cm-dia bolts with washers are used in this work – 40 cm long). Estimate the quantity of various components and the total woodwork required, so that whenever needed this data is used to calculate the rate of payment that can be fixed on a rational basis.

[**Note :** *The length of beam (8.00 m) may be taken as including both side bearings – though no bottom plank cover can be laid over the walls that bear the beams. Nails are included in the rate for woodwork.*]

Solution

Nails are included in the rate for woodwork.

Bill of Quantities

Sl. No.	Description of Item	No.	Measurements			Quantity	Total
			L (m)	B (m)	H/D (m)		
	Word work in the given form work						
1.	Side planks – 2.5 cm thick, 50 cm wide.	2	8.05	0.50	0.025	0.20 m^3	8.0 + (2 × 2.5 cm) = 8.05 m
2.	Bottom planks – 5 cm thick	1	7.8	0.35	0.05	≈0.14 m^3	30 + 2 (2.5) = 0.35 m; & 8.0 – 2 × bearing on either side = 8.0 – (2 × 0.1) = 7.8 m
3.	End planks – 2.5 cm thick	2	0.55	0.35	0.025	≈ 0.01 m^3	50 + 5 = 0.55 m & 30 + (2 × 2.5) = 0.35 m
4.	Side stiffeners – 4 cm thick, @ 1.0 m c/c	2 × 9	0.55	0.10	0.04	0.072 m^3	$\frac{8}{1} = 8 + 1 = 9$
5.	Bottom supports	9	0.50	0.10	0.05	0.023 m^3	
6.	Brackets – 5 × 5 cm	2 × 9	0.50	0.05	0.05	0.023 m^3	
7.	Prop braces – 5 × 10 cm	2	7.8	0.1	0.05	0.078 m^3	Length = 8 – 2 (0.1) = 7.8 m
8.	Bearing plates for props	9	0.3	0.3	0.05	0.041 m^3	
9.	Wedges	9	0.2	0.15	0.08	0.022 m^3	
10.	10 cm – dia, ballies (i.e. props)	9	2.5	0.008 m^2	–	0.18 m^3	Sectional area of a *bally* = $\frac{\pi}{4}(0.1)^2$ = 0.008 m^2

Note : *Sometimes ballies are paid for in Nos when dia and length are specified.*							
						Total	$= 0.789 \text{ m}^3$ $= 0.80 \text{ m}^3$ (say)
1.	*Bolts and Washers* 10 cm - ϕ tie bolts (40 cm long) with washers	10 (say)	–	–	–	10 Nos.	

Figure 4.2 : Formwork (Centering + Shuttering) of RCC Beam (Part of a Roof) – Example 4.2 – Not to Scale

For the sake of a rate analysis, about 5% of 0.80 m^3 can be added to the total wood required (= 0.8 + 0.04 = 0.84 m^3) as wastage to arrive at the grand total. After the total cost of the timber work is arrived at, about 20% of that cost can be taken as the salvage value of timber and ballies when the set up becomes unserviceable – assuming that the setup becomes unserviceable after using it 20 times over. This salvage value gets deducted from the total cost of timber and ballies. And, the remaining net amount can be divided by 20 to get the cost figure for using the set-up once – to this figure, the cost of labour and sundries gets added to arrive at the total material and labour cost of the set-up. Adding 10% of this amount as contractor's profit, and dividing the sum (x, say) by the volume of the beam gives the rate of formwork per m^3 of the RCC work.

Surface Area of the Shuttering in Contact with RCC in this Example

$$= 2\,(8 \times 0.5) + (8.00 - 2 \times 0.10) \times 0.3 + 2\,(0.5 \times 0.3)$$

where, 0.10 m is the bearing of the beam on either side.

$$= 8.0 + 7.8 \times 0.3 + 2 \times 0.15$$

$$= \mathbf{10.64\ m^2}$$

Hence, the rate per m^2 (which is the standard unit of measurement for payment in the case of formwork used) $= \dfrac{x}{10.64}$

= Rs. y (say).

4.4 CASE STUDIES : TRUSSES (TIMBER AND STEEL)

Following solved examples are presented with the aim of making the student familiar with the various components of the two types of trusses (timber and steel) and different types of quantities that need be estimated.

Example 4.3

A godown measuring 18 ×10.5 m is having a pitched roof – consisting of Queen-post trusses (at 3.0 m c/c), purlins, common rafters with battens and Mangalore tiles (Figure 4.3). **Short walls of the godown are provided with gables.**

Estimate the quantities of the following :

(a) Woodwork in each truss, and all the trusses,

(b) Woodwork in purlins, and common rafters,

(c) Woodwork in eaves boards, and barge boards,

(d) Area of tiled roof,

(e) GI sheet eaves gutter, and

(f) Concrete bed blocks.

Figure 4.3 : Queen Post Truss (with Wall of Godown Included) Section – Example 4.3 (Not to Scale)

Specifications are as follows :

(a) Queen-post truss shall be of second class country cut teak wood. Its rate shall include joinery, iron straps, and oiling with 3 casts of double boiled linseed oil, including erection into position, and complete in all respects.

(b) Tie beam shall be in 3 pieces (4.11 m each) – full-span tie (in one piece) is not possible to obtain. Material for three pieces and due wastage makes up the total quantity.

(c) Queen post = 2.3 m (finished dimension) long.

(d) Principal = 4.4 m long.

(e) Strut = 2.21 m long. Straining beam = 3.8 m long.

(f) Straining sill = 3.05 m long.

(g) Common rafter = 7.2 m long.

(h) Concrete bed blocks = 50 × 60 × 19 cm.

(i) Rate for purlins covers providing and fixing in position. Woodwork shall be of second class country cut teak wood, including joinery, and three coats of double boiled linseed oil after fixing in position.

(j) Rates for eaves board and barge board include – providing and fixing. These shall comprise first class country cut teak wood; and the rates shall also cover oiling with three coats of linseed oil, and painting with three coats of green oil paint as per detailed specifications.

Note : Rates for all woodwork are per m^3.

(k) Rates for Mangalore tiled roof cover : providing, and laying of the best quality (as specified) of tiles, includes teak wood battens of 3.75 × 1.9 cm section at 26.5 cm distances apart; also included is oiling with three coats of linseed oil, etc. complete. Rate for roof tiles is per m^2.

(l) Rate for eaves gutter covers: providing and fixing half round GI sheet gutter, 15cm dia., including iron brackets; fixing these in position, etc; complete in all respects. Rate for this is per m.

(m) Rates for concrete bed blocks (1: 2 : 4 mix) includes centering, and cutting and finishing sides smooth, etc., and complete in all respects. Rate is per m^3.

Solution

Common rafters are placed @ 53 cm c/c, thus their total number

$$= \frac{18.38}{0.53} = 34.67 \approx 34 \text{ (say) } + 2 \times \text{(one at each end)} = 36.$$

And, number of trusses = 5 (Figure 4.3) – because there are two gables : one at each end of the godown.

The required bill of quantities is tabulated as under :

The Bill of Quantities – Example 4.3 – in Queen Post Truss

Sl. No	Description of Item	No.	Measurements			Quantity
			L (m)	B (m)	H/D (m)	
1	*Woodwork in one Queen Post Truss – providing and fixing as per given specifications.*					
	(i) Tie beams	3	4.11	0.125	0.125	0.193 m^3
	(ii) Queen posts	2	2.3	0.125	0.15	0.043 m^3
	(iii) Principals	2	4.4	0.125	0.18	0.20 m^3
	(iv) Struts	2	2.21	0.10	0.075	0.032 m^3
	(v) Straining beam	1	3.8	0.125	0.15	0.071 m^3
	(vi) Straining sill	1	3.05	0.125	0.15	0.057 m^3
					Total (one truss)	= 0.596 m^3
					Total Woodwork for Five Trusses (5 × 0.596)	= 2.98 m^3
2	*Woodwork in Purlins and Common Rafters* – providing and fixing as per specifications.					
	(a) Purlins	6	18.38	0.125	0.15	2.07 m^3
	(b) Common rafters	2 × 36	7.2	0.10	0.075	3.89 m^3
					Total	= 5.96 m^3
3	*Woodwork in eaves boards and barge boards* – providing and fixing as per specifications					
	(a) Eaves boards	2	18.38	0.025	0.15	0.138 m^3
	(b) Barge boards	2	18.38	0.025	0.23	0.211 m^3
					Total	= 0.349 m^3
4	*Mangalore tiled roof* – providing and laying as per specifications	2	18.38	7.2	-	264.67 m^2
					Total	= 264.67 m^2
5	*Eaves gutter* – providing and fixing as per specifications	2	18.38	-	-	36.76 m
					Total	= 36.76 m

6	*1 : 2 : 4 mix concrete bed* – providing and laying as per specifications *(there being 5 trusses)*	2 × 5	0.60	0.50	0.19	0.57 m^3
					Total	= 0.57 m^3

[**Note :** After working out the cost (for any given set of rates for various items), one can express the cost of this roofing per 10 m^2 of the area covered.]

Example 4.4

A galvanized corrugated iron roof is to be installed over eight trusses, from end-to-end of the godown shed (Figure 4.4). The roof covering will be 22 BWG galvanized iron with 20.5 cm gutters at the eaves.

Figure 4.4 : A Steel Roof Truss : Example 4.4 (Not to Scale)

The trusses will be made of steel throughout, anchored down the side walls, and put at 2.9 m c/c spacing. The roof covering shall project 0.9 m from the last truss at both the ends of the shed.

There will be 4 down pipes on each side – each one 6.10 m in length, including bends and elbows.

All the steel work in trusses and purlins will be given three coats of ready-mixed superior oil paint of approved shade (or colour).

The detailed drawings (not given here) show 6 sheets of corrugated iron – each 2.10 m long – and 2 sheets of 3.00 m length along the width of each slope of the roof. The usual width of a sheet may be assumed 0.81 m, and the overlap be taken as 2 corrugations of 8.5 cm each.

Estimate the various quantities as per the details given. [***Lengths of various truss members can also be directly measured from the drawing if that is drawn to scale.***]

Solution

Total length of roof

= (No. of trusses – 1) × 2.9 + 2 × Given end projection

= (8 – 1) × 2.9 + 2 × 0.9

= 22.1 m

In ordering the roofing material for any roof the exact number of corrugated iron sheets, that would be required, shall have to be stated without any ambiguity :

No. of sheets required, along the length of the roof (considering one row) would be equal to :

$$\Rightarrow \left[\frac{22.1}{\left\{0.81 - \frac{2 \times 8.5}{100}\right\}}\right]$$

$$\Rightarrow \frac{22.1}{0.64}$$

$$\Rightarrow 34.5 = 35 \text{ Nos. (say)}$$

Hence, total number of sheets required (considering all the rows):

(a) ⇒ 6 × 35 = 210 Nos. of 2.1 m × 0.81 m

(b) ⇒ 2 × 34 = 68 Nos. of 3.0 m × 0.81 m

[**Note :** 34.5 has been rounded off to 35 – so 35 and 34 numbers are a little arbitrary; and one can always calculate exactly as per given drawings.]

The bill of quantities of various items of the truss is prepared as given below :

Bill of Quantities of Steel Truss – Example 4.4

Sl. No.	Description of Item	No.	Measurements			Quantity
			L (m)	B (m)	H/D (m)	
1.	***Steel in one truss***					
	(i) T. S. Rafters (100 × 65 × 10 mm) @ 12.2 kg / m	2	90	–	–	219.60 kg
	(ii) Brackets for gutters (L. S. 50 × 50 × 6 mm) @ 4.5 kg/m [Straight portion = 30 cm; curved portion = $\pi \times \left(\frac{20.5}{2}\right) = 32.2$ cm. Total Length = 62.2 cm.]	2	0.622		–	5.60 kg
	(iii) Knees (LS – 60 × 60 × 10 mm) for purlins, @ 8.6 kg/m [length = 100 mm = 0.1 m, to fit on TS rafter.]	2 × 6	0.1			10.32 kg
	(iv) Tie rod (F.B – 60 mm ×10 mm), @ 78.5 kg/m^2	1	15.2	0.06		71.60 kg
	(v) Sloping FB – (4) in the *legend* – 60 mm × 10 mm), @ 78.5 kg/ m^2	2	2.29	0.06		21.57 kg
	(vi) FB (60 mm × 10 mm) – (5) in the *legend* – @ 78.50 kg/ m^2	2	2.44	0.06		22.98 kg
	(vii) FB (60 mm ×10 mm) – (6) in the *legend* – @ 78.50kg/ m^2	2	3.35	0.06		31.56 kg
	(viii) FB (60 mm × 10 mm) – (7) in the *legend* – @ 78.50 kg/ m^2	1	2.67	0.06		12.58 kg
	(ix) TS vertical struts (80 × 80 × 8 mm) – (8) in the *legend* – @ 9.6 kg/m	6	1.30	–		74.88 kg
	(x) Foot plates (10 mm thick) @ 78.50 m^2	2 × 2	0.45	0.50		70.65 kg
	(xi) Gusset plates, 10 mm thick, @ 78.50 kg/ m^2					
	Item 9 in the *legend*	1	0.38	0.23		6.86 kg
	Item 10 in the *legend*	1	0.30	0.20		4.71 kg

	Item 11 in the *legend* [Foot of struts]	6	0.30	0.19		26.85 kg
	Item 12 in the *legend* [Head of lower – end struts]	2	0.23	0.23		8.31 kg
	Item 13 in the *legend* [Head of centre struts]	2	0.27	0.23		9.75 kg
	Item 14 in the *legend* [Head of struts near the kind rod]	2	0.23	0.23		8.31 kg
	(xii) Anchor plates @ 62.8 kg/m^2	2	0.45	0.45		25.43 kg
	(xiii) Rivets in trusses and knees[= 5% of sum of item (i) to (*xi*)]	$\frac{5}{100} \times (606.13)$			–	30.31 kg
	(xiv) Anchors bolts 0.025 m ϕ – @ 4.6 kg/m on the average.	2 × 4	0.66			24.30 kg
	(xv) Heads and nuts – say, $\frac{1}{6}$ of item (xiv)	$\frac{1}{6} \times 24.30$				4.05 kg.
	Grand Total for 1 Truss					**= 690.22 kg**
	Total for 8 Trusses (8 × 690.22 kg)					= 5521.76 kg
	Add 5% for wastage $= \left(\frac{5}{100} \times 5521.76\right)$					= 276.09 kg
	Grand Total For 8 Trusses					**5798.00 kg (say)**
2.	*Mild Steel Purlins* @ 8.6 kg/m	2 × 6	22.10 (total length of roof)	–	–	2280.72 kg
3.	*Steel in wind ties (3 on each side on of pitched roof, not shown in the Figure) – FB, 3.2 cm × 0.6 cm thickness - @ 47.1kg/m^2*	2 × 3	22.1	0.032	–	199.85 kg
	Total of (2) and (3)					**2480.57 kg**
4.	*Painting as per specifications in one truss* (i) Rafters	2	9.0	0.33	–	5.94 ≈ 6.00 m^2
	Surface width of T-section	⇒ 2 × 100 mm + 2 × 65 mm = 330 mm = 0.33 m				
	(ii) Brackets for LS gutters	2	0.622	0.20		0.2488 ≈ 0.25 m^2
	Surface width of L section	⇒ (2 × 50) + (2 × 50) = 200 mm = 0.2 m				
	(iii) Knees for purlins	2 × 6	0.1	0.240	–	0.288 ≈ 0.29 m^2
	Surface width	⇒ (2 × 60) + (2 × 60) = 240 mm = 0.24 m				
	(iv) Tie rods taken al1 pieces together	1	15.2	0.14		2.128 ≈ 2.13 m^2
	Surface width	⇒ (2 × 60) + (2 × 10) = 140 mm = 0.14 m				

	(v) Vertical struts (taking the given average length into consideration) (or, one can compute the surface area, by one by one strut)	6	1.3	0.32		2.496 ≈ 2.5 m^2
	Surface width	⇒ (2 × 80) + (2 × 80) = 320 mm = 0.32 m				
	(vi) King rod Surface width	1	2.67	0.14		0.3738 ≈ 0.374 m^2
		⇒ (2 × 60) + (2 × 10) = 140 mm = 0.14 m				
	(vii) Foot plates					
	(a) 2 (2 at each wall × 2 sides)	8	0.45	0.5		1.8 m^2
	(b) Thickness-wise	*This item could have been neglected because of extremely low value*				0.0036 m^2
[**Note :** For each plate, thickness area = 2 (10 mm × 45 mm) = 900 mm^2 = 0.0009m^2. For 2 plates thickness area = 0.0018 m^2; and, thus, for 4 plates (i.e. for both walls), thickness area = 0.0036m^2.]						
	(viii) Gusset plates (neglecting thickness-wise surfaces)					
	(a)	2 sides	0.38	0.23		0.17 m^2
	(b)	2 sides	0.30	0.20		0.12 m^2
	(c)	2 sides × 6 Nos. for one truss	0.3	0.19		0.684 ≈ 0.7 m^2
	(d)	2 × 2	0.23	0.23		0.2116 ≈ 0.21 m^2
	(e)	2 × 2	0.27	0.23		0.2484 ≈ 0.25 m^2
	(f)	2 × 2	0.23	0.23		0.2116 ≈ 0.21 m^2
	(ix) Anchor bolts (2πr = 2π × 2.5 = 15.7cm)	4 × 2 walls	0.66	0.157		≈ 0.83 m^2
	(x) Anchor plates (neglecting thickness-wise areas	2 × 2 sides	0.45	0.45		0.81 m^2
	Total painting for one truss Total painting for 8 trusses (8 × 16.65)					**= 16.65 m^2** **= 133.2 m^2**
5.	*Painting (as per specifications) for steel purlins, and wind ties.)*					
	(a) Purlins	12	22.1	0.24	–	63.65 m^2
	(width for painting)	⇒ (2 × 60) + (2 × 60) = 240 mm, neglecting thickness area				
	(b) Wind ties	6	22.1	0.076	–	10.08 m^2
	[width of painting	⇒ 2 × 3.2cm + (2 × 0.6cm) = 7.6 cm]				
					Total	**= 73.73 m^2**
					Grand Total of Painting (133.2 + 73.73)	**= 206.93 m^2**
6.	*Galvanized Corrugated Iron Roofing* Both slopes of the pitched roof (with overlaps)	2 (i.e. two slopes)	22.1	9.0	-	**397.8 m^2** (to be paid to the contractor or this area)

7.	*23 cm GI ridging*	1	22.1	-	-	**22.1 running meter**
8.	*Gutters and Down Pipes*					
	(a) Gutters	2	22.1	-	-	**44.2 running meter**
	(b) Down pipes	4 × 2	6.1	-	-	**48.8 running meter**

It is left to the student to prepare an *abstract of cost* on the basis of cost on the basis of following rates :

(a) Steel including cutting, fabricating, welding, and erection into position – Rs. 40/- per kg.

(b) Painting (as per specifications) – Rs. 10/- per m^2.

(c) GI roofing (including laying, etc.) – Rs. 100/- per m^2.

(d) GI ridging – Rs. 5/- per metre.

Add 5% towards contingency; and also suitably for tools and plants, and for work charge establishment to arrive at the total cost of the work.

4.5 ACTIVITIES TO TAKE UP FOR DEEPER UNDERSTANDING OF THE PROCESS OF QUANTITY ESTIMATION

It is in the interest of gaining the desired skill and speed in estimating the quantities involved in formwork and trusses that the student should take up the following suggested activities :

RCC Formwork

Collect the actual field data for various formworks – beams, columns staircases, roof slabs, etc. – most easily available with private (reputed) construction firms, and/or with PWD (or CPWD) engineers. The data should comprise drawings and bill of quantities that have already been prepared.

The student should himself/herself work out the data, and then compare with the details worked out by the source agency.

Design of any formwork is subject to minor variations from agency to agency – these finer points should be noted.

Trusses – Timber and Steel

The relevant data from government and/or private agencies should relate to Queen Post and King Post Trusses, and to various forms of steel roof trusses, bridge trusses (road and railway). One's solutions can be compared with the already available solutions.

This much exercise should put the student on a firm footing and make him/her on ace estimator – what is, however, needed is consistent hard work. Everything comes for a price.

Rate Analysis for the above items should also be studied as to how an agency works out these things.

SAQ 1

(a) Explain how trusses are more economical and efficient than load bearing beams?

(b) Under what conditions are pitched roofs recommended for buildings? Which regions in our country go in for trussed roofs?

4.6 SUMMARY

Trusses (timber and steel) have their own general specifications for their appropriate construction and erection, as have various formworks required for RCC items to be constructed. These specifications also guide the designer and an estimator to classify various items of these works to be paid appropriately as per the rates of payment arrived at prior to any exercise in estimation. Specifications clearly lay down the methods of measurement and the relevant units to be adopted.

It is always advantageous to work out the required dimensions (if not directly available from drawings or written data) of an item to make the procedure of preparing a bill of quantities a pleasant exercise, and avoid any ambiguities, doubts or confusions.

4.7 ANSWERS TO SAQs

Refer to relevant preceding text in the Unit or other useful books listed in section ‘Further Reading’ to get the answers of SAQs.