BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

MANPOWER AND MATERIALS REQUIREMENT IN RESIDENTIAL BUILDINGS

Introduction

An estimate of manpower and materials is generally required for buildings prior to the start of actual construction. Rough calculations for the quantities of important materials are usually based on certain percentage of the total cost. These can be misleading as it remains constant only when there is a proportionate increase or decrease in the cost of all materials whereas in practice this rarely occurs. A detailed bill of quantities is drawn up after the building plans are ready, and the quantities of manpower and materials are calculated by using certain constants. This method of detailed estimating, though accurate, is time-consuming

In this digest, an attempt has been made to obtain the required information with the help of simple equations which make it very speedy. The quantities of materials and labour required for a building are directly computed for a given plinth area with the help of certain empirical equations. The analysis has been made for the building portion of single, double and four–storeyed residential buildings excluding the services. For single and double-storeyed buildings, load bearing wall construction has been taken while framed construction with infill panels has been taken for four-storeyed buildings.

Specification and Plinth Area

The quantum of materials and labour required for any building mainly depends upon its plinth area while the type of materials and labour depends upon the specifications which are to be adopted in various building elements. Different specifications are sometimes used for the same element of the building. Therefore, to form the basis for calculation of materials and labour, a study of the specifications adopted in various organizations has been made and the most common specifications have been selected for the analysis (Appendix 'A').

It has been observed that generally residential buildings rarely have plinth area less than 30 square metre. Hence buildings of different shapes and plinth areas varying from 30 to 300 m^2 for single and double storeyed and from 30 to 100 m^2 for four-storeyed framed buildings have been taken in this study.

Material and labour constants for various items of work in buildings vary from organisation to organisation. In this study, average constants for various items of work have been taken.

Basis of Calculations

To arrive at an accurate quantity of materials and labour, the analysis has been based on completed buildings. The quantities of work were collected from the final bills of contractors for all items in each building. The total quantum of different materials and labour required for various items of work in buildings of different plinth areas was then calculated by using the materials and labour constants for each item. The quantity of materials and labour required is a function of the area, shape, height, fenestration and type and depth of foundation etc.

Depth and width of foundations for single-storeyed houses as excuted were normal and the same have been taken in the analysis Based on the quantities of materials and labour computed for different plinth areas, relationships were established statistically for the individual material and labour against the plinth areas. For double-storeyed constructions, the established equations for single-storeyed buildings have been adjusted, wherever required, on the basis of data collected. The equations for materials and labour are listed in Tables 1 and 2 respectively for both single and double-storeyed buildings.

In the case of four-storeyed framed buildings, either footings or piles are used for foundation and besides this the depth also varies. Relationships have therefore been established separately for superstructure (Table 1 and 2) and sub-structure (Table 3). In the case of sub-structure, pile foundations being a specialised job, the relationships have been established for column footings having a depth of 2 m below the ground–level. However, for adjusting materials and labour requirement for other depths, additional relationships per metre depth have been established and are given in Table 4.

Relationships have not been given for rainwater disposal and door and window fittings. However, a study of different roof areas has shown that, for about every 37 m^2 of the roof area of the building, one rain-water pipe with necessary fittings is required. Since fittings for doors and windows can be of various types, no attempt has been made to derive relationships. But the same are listed in Table 5 for different plinth areas.

Certain items such as shuttering and scaffolding do not form part of the building but are required during the course of construction. As far as the shuttering is concerned, the requirement of timber (planks)

and 'ballies' has been established and is given by statistical relationships (Table 1). For scaffolding, the labour content involved has been reckoned and for materials an expression as given below has been worked out for assessing their cost :

Scaffolding Material cost = $0.008\ A\ (0.03x+2y)$

where A is the plinth area in m^2
x is the cost of planks per m^3
and y is the cost of 'ballies' 3.6 m long and 13 cm diameter.

In working out the above expression, it has been assumed that the scaffolding material will have 500 reuses.

Certain types of housing units are built in a row or are semi-detached. The quantities for such constructions are expressed as a function of the plinth area for the individual unit. In computing the quantities for row-houses, data should be obtained for the plinth area of the individual house and quantities required for a row are obtained by multiplying with the number of tenements in the row. In the case of double and four-storeyed buildings, the requirement of any individual material/labour is calculated by putting the plinth area of the single tenement at the ground level. The quantity thus arrived at is multiplied with the number of quarters whether these are semi-detatched or one above the other.

Uses

The information regarding materials and labour requirement for a building is useful for preparation of building cost index, materials budgetting, computation of building cost etc. To illustrate its use, the present cost index at Roorkee based on 1967 C.P.W.D. schedule of rates has been worked out for double-storeyed constructions based on the requirement of materials and labour for a medium-sized building having 39 m^2 plinth area. This is shown in Appendix B and is self-explanatory. A study of the computation of cost index based on materials and labour for different plinth areas indicates that there is a marginal difference in them. It is therefore suggested that the cost index calculations may be based on materials and labour obtained with the help of these established equations for a medium-sized building.

For assessing the cost of construction, the quantities of the various materials and labour thus obtained are multiplied by the prevalent market rates. To the cost thus obtained, 2½ per cent is to be added for water charges and sundries. A further addition of 10 per cent for overheads and contractors' profit gives the total cost of construction excluding services. Computation of quantities of materials, labour and cost for a single-storey residential building of 100 m plinth area has been made at the prevailing market rates at Roorkee (January, 1972) and are given in Appendix 'C'. The total cost, excluding services, works out to Rs. 187.70 per m^2 which is in conformity with the one prevalent in Roorkee.

Concluding Remarks

The method proposed in this digest is simple and straight-forward. It provides sufficiently accurate estimate of manpower and materials requirement. The cost computation is more rational than the present practice of adding adhoc percentage over the schedule. The method indicated can be used with advantage for preplanning of materials and labour requirement in a building project and for the computation of building cost index.

Table 1—Equation for Materials Requirement (A is the plinth area in m^2)

Material	Equations		
	Single Storey	Double Storey	Four Storey* (R.C.C. Framed)
Bricks (% Nos.)	2.26A + 66.8	2.15A + 63	−26.2 + 2.56A − 0.0096 A^2
Cement (Tonne)	0.153A + 0.57	0.145A + 0.54	0.182A − 0.35
Steel (Kg)	21.3A − 314	21.97A − 305	−1491 + 92.0A − 0.36A^2
Sand (m^3)	0.47A − 7	0.376A − 5.6	0.361A − 0.38
Coarse aggregate			
(i) 20 mm and down (m^3)	0.176A − 0.21	0.178A − 0.21	0.295A − 0.75
(ii) 40 mm and down (m^3)	0.145A + 1.5	0.075A + 0.78	0.45 + 0.0027A + 0.0001A^2
Brick Aggregate (m^3)	0.113A − 0.83	0.056A − 0.42	0.021A + 0.01
Timber frames and shutters (m^4)	0.019A + 0.23	0.019A + 0.23	0.02A + 0.11
Timber shuttering (m^3)	0.0042A	0.0042A	0.009A − 0.03
Ballies (m)	0.504A	0.504A	0.90 A − 2.41
Lime (quintal)	0.145A − 0.35	0.073A − 0.17	0.063A − 0.08
Surkhi (m^3)	0.052A − 0.37	0.026A − 0.18	0.01A
Bitumen (Kg)	1.836A − 9	0.918A − 4	0.357A + 0.14
Glass (m^2)	0.064A − 0.73	0.064A − 0.73	0.056A − 0.06
Primer (Lt)	0.068A	0.068A	0.061A + 0.56
Paint (Lt)	0.108A + 0.27	0.108A + 0.27	0.085A + 1.93

*Equations for super-structure only. For sub-structure refer Table 3.

Table 2—Equations for Labour Requirement (A is the plinth area in m^2)

Labour	Equations		
	Single storey	Double storey	Four storey* (R.C.C. framed)
Mason (days)	1.335 A + 28	1.355 A + 26	1.67A–2
Carpenter (days)	1.184A–9	1.194 A–9	1.61A
Painter (days)	0.089 A	0.089 A	0.09 A
Blacksmith (days)	0.269 A–4	0.274 A–4	$-16+1.01$ A–0.004 A^2
Mazdoor (days)	4.769 A + 32	4.91 A + 33	5.49 A–9.2

*Equations for superstructure only. For substructure refer Table 3.

Table 3—Equation for Materials and Labour Requirement for Substructure in Four-Storyed (R.C.C. framed) Building

Materials/Labour	Equations
Materials	
Cement (tonne)	0.0204 A–0.014
Sand (m^3)	0.036 A
Coarse Aggregate	
20 mm and down (m^3)	0.071 A–0.01
Steel (kg)	$-171+10.46$A–0.041 A^2
Timber-Shuttering (m^3)	0.0007 A
Ballies (m)	0.036 A + 0.06
Labour	
Mason (days)	0.023 A
Carpenter (days)	0.05 A
Blacksmith (days)	$-1.6+0.1$ A–0.0003 A^2
Mazdoor (days)	0.343 A

Table 4—Equation for Materials and Labour Requirement for Additional one Metre Depth of Foundation

Materials/Labour	Equations
Materials	
Cement (tonne)	0.0022 A + 0.002
Sand (m^2)	0.0031 A + 0.015
Coarse Aggregate	
20 mm and down (m^3)	0.0053 A + 0.02
Steel (kg)	$-17.9+1.118$ A—0.004 A^2
Timber-Shuttering (m^3)	0.0002A
Ballies (m)	0.018 A + 0.05
Labour	
Mason (days)	0.006 A
Carpenter (days)	0.024 A
Blacksmith (days)	0.006 A
Mazdoor (days)	0.086 A

Table 5—Actual Consumption of Door and Window Fittings

Fittings	Plinth Area in m²						
	31-40	41-50	51-70	71-100	101-150	151-200	Above 201
Butt Hinges 100 mm	12	18	24	30	37	46	55
75 mm	26	36	42	58	62	75	88
50 mm	12	18	22	28	38	53	60
Sliding Bolt 250 mm	2	4	6	8	11	12	14
Door Latch 250 mm	2	4	6	8	—	—	—
Tower Bolt 250 mm	6	8	10	12	14	23	35
150 mm	14	20	24	30	38	45	60
100 mm	6	8	9	13	17	20	23
Door Handles 100 mm	8	12	16	20	25	32	37
Cup Board Knob	2	2	2	4	4	4	5
Ball Catcher 10 mm	2	2	2	4	4	4	5
Hook and Eyes 100 mm	16	24	28	36	42	47	52
Chain and Hooks 300 mm	2	3	4	5	6	6	7
Hasp and Staples 115 mm	1	1	1	2	3	4	4
Fan light Catch 14 mm	2	3	4	5	6	6	7

APPENDIX A

Specifications Adopted

Element	Specification Adopted In	
	Single and Double Storey Construction	Four Storey (R.C C. Framed Building)
Foundation	Excavation in ordinary soil, cement concrete (15 cm thick) 1:5:10 in beds, brick work in cement mortar 1:6, 38 mm thick. DPC consisting of cement concrete 1:2:4 with bitumen coating on top, and sand filling (10 cm thick) in plinth.	Excavation in ordinary soil 2 m deep, R.C.C. 1:2:4 column footings with cement concrete 1:4:8 in beds, R.C.C. 1:2:4 plinth beams finished smooth with 6 mm cement mortar 1:3, brick work in cement mortar 1:6 sand filling (10 cm thick) over stone bedding (12 cm) in plinth.
Frame	—	R.C.C. 1:2:4 columns and beams finished smooth with 6 mm thick cement mortar 1:3 including neeru finish.
Walling	Brick work in cement mortar 1:6 (23 cm thick load bearing and 11 cm thick partitions), RCC work 1:2:4 in lintels, beams and chajjas.	Brick work in cement mortar 1:6, R.C.C. work 1:2:4 in lintels, beams and chajjas.
Floor	38 mm thick cement concrete 1:2:4 laid over cement concrete (11.5 cm thick) 1:5:10.	38 mm thick cement concrete 1:2:4 laid over 11.5 cm thick CC 1:5:10 in ground floor and over R.C.C. slab for upper floors.
Roof	R.C.C. slab with lime concrete terrace(Average 11 cm thick) with bitumen coating underneath.	R.C.C. slab with lime concrete terrace (Av. 10 cm thick) with bitumen coating underneath and top finished with 40 cm CC 1:2:4. Brick work in cement morter 1:6 in parapet finished with CC 1:2:4 coping.

Joinery	Timber frames 100 x 75 mm, 38 mm thick panelled shutters for doors and fully glazed shutters for windows.	Timber frames 100 × 75 mm, 38 mm thick timber panelled shutters for doors and fully glazed shutters for windows.
Finishes	Levelling top of wall surfaces with cement mortar 1:3, 12 mm thick cement plaster 1:6 on smooth sides of walls and 20 mm thick cement plaster 1:6 on rough sides of walls, 20 mm thick cement plaster (1:3) skirting and dado, internally white washed and externally colour washed, painting woodwork with an oil paint.	12 mm thick cement plaster 1:4 on internal faces of the walls and 20 mm thick cement plaster 1:3 on external faces of walls, internally white washed and externally colour washed, painting wood work with an oil paint.
Stairs	R.C.C. stairs in double storey.	R.C.C. stairs
Fittings and Fixtures	Precast R.C.C. shelves, M.S. round bars in windows, raised cooking platform.	Precast R.C.C. 1:2:4 shelves, M.S. round bars in windows, timber cupboards, raised cooking platform.

APPENDIX 'B'

Computation of Building Cost Index* for the Year 1972 at Roorkee with Respect to Delhi C.P.W.D. Schedule of Rates. (1967 taken as 100)

Materials/Labour	Quantity	Year					
		Rate	Unit	Amount	Rate	Unit	Amount
		1967			1971		
Materials							
Bricks	14685 Nos	36.40	Thousand No.	534.53	70.00	Thousand Nos.	1027.95
Cement	6.20 tonne	170.40	tonne	1056.48	250.00	tonne	1550.00
Steel	552 Kg	0.81	Kg	447.12	1.60	Kg	893.20
Sand 45% coarse 55% fine	9.0 m^3	9.18	m^3	82.62	8.0	m^3	72.00
C. Aggregate	9.3 m^3	14.64	m^3	136.15	28.0	m^3	260.40
Timber	0·97	890.00	m^3	863.30	1050.00	m^3	1018.50
Labour							
Masons	75 W. days	5.82	W.D.	436.50	6.50	W.D.	487.50
Carpenter	38 ,,	6.40	,,	243.20	6.50	,,	247.00
Mazdoors	224 ,,	2.90	,,	649.60	3.00	,,	672.00
			Total :-	4449.50			6228.55
			Building Cost Index	100			$\frac{6229}{4450} \times 100 = 140$

*Building cost index has been based on important materials/labour which consume 2 or more than 2 per cent of the building cost.

Quantities of Materials and Labour and Computation of Cost for a Single Storey Building 100 m² in Plinth Area

Particulars	Quantity	Unit	Rate (Rs.)	Amount (Rs)
Materials				
Brick	29280 Nos.	Thousand Nos	80.00	2342.40
Brick-ballast 25 mm and down	10.47 m^3	m^3	20.00	209.40
Bitumen	174.60 kg	kg	0.55	96.03
Cement	15.87 tonne	tonne	250.00	3967 50
Lime	1415 kg	kg	0.13	183.95
Primer	6.80 litre	Litre	7.00	47.60
Paint	11.07 litre	Litre	8.00	88.56
Steel	18.16 ql.	ql.	160.00	2905.60
Sand	40 m^3	m^3	10.00	400.00
Stone-ballast 40 mm and down	16.00 m^3	m^3	24.00	384.00
Stone-ballast 20 mm and down	17.39 m^3	m^3	26 50	460.84
Surkhi	4.83 m^3	m^3	22.00	106.26
Timber for frames and shutters	2.13 m^3	m^3	700.00	1491.00
Timber for shuttering	0.42 m^3	m^3	550.00	231.00
Ballies	50.4 m	m	3.00	151.20
Glass	5.67 m^2	m^2	5.00	28.35
A C. rainwater pipe 100 mm dia	10 m	m	4.50	45·00
A.C. shoe	3 Nos.	each	2.75	8.25
A.C. head	3 Nos.	each	3.50	10.50
A.C. bend (plain)	3 Nos.	each	2.75	8.25
Door and window fittings				
(a) Butt hinges 100 mm	30 Nos.	each	0.40	12.00
75 mm	58 Nos.	each	0.35	21.30
50 mm	28 Nos.	each	0.25	7.00
(b) Sliding bolt 250 mm	8 Nos.	each	1.50	12.00
(c) Door latch	8 Nos.	each	0.80	6.40
(d) Tower bolt 250 mm	12 Nos.	each	0.80	9.60
150 mm	30 Nos.	each	0.60	18.00
100 mm	13 Nos.	each	0.50	6.50
(e) Door handles 100 mm	20 Nos.	each	0.40	8.00
(f) Cup-board knob	4 Nos.	each	1.00	4.00
(g) Ball catcher	4 Nos.	each	2.00	8.00
(h) Hooks and eyes	36 Nos.	each	0.25	9.00

Particulars	Quantity	Unit	Rate (Rs.)	Amount (Rs.)
(i) Chain and hooks	5 Nos.	each	0.30	1.50
(j) Hasp and staples	2 Nos.	each	1.00	2.00
(k) Fan light catch	5 Nos.	each	1.50	7.50
Labour				
Blacksmith	23 Nos.	each	6.00	138.00
Carpenter	110 Nos.	each	7.00	770.00
Mason	162 Nos.	each	7.00	1134.00
Mazdoor	445 Nos.	each	2.75	1223.75
Painter	9 Nos.	each	6 00	54.00
Scaffolding	100 m^2	0.008A (0.03x + 2y)		29 20
				16,647.44
Add 2½% water charges and sundries	...	...	...	416.17
			Total	17,063.61
Add 10% for over heads and profits	...	...	...	1706 36
Cost of 100 m^2			...	18,769.97
Cost per m^2			...	187.70
and x = 10 when y = 550				

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Correction

Page 7 Line 15&16	*for*	*read*
	and x = 10 when y = 550	when x = 550 and y = 10

There is a demand for short notes summarising available information on selected building topics for the use of engineers and architects in India. To meet the need, this Institute is bringing out a series of Building Digests from time to time and the present one is the 96th in the series. Readers are requested to send to the Institute their experience of adopting the suggestions in this Digest.

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