CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE-247667 (INDIA)

BUILDING RESEARCH NOTE

B. R. N. 18

MATERIAL CONSTANTS IN BUILDING WORKS

Introduction

Schedule of rates always forms the basis in preparation of detailed estimates for construction works. This is also useful in considering the reasonableness of tenders received from the contractors and for pricing the additions, alterations, omissions and substitutions in contract jobs. It is, therefore, of utmost necessity that the schedule of rates should be prepared correctly based on rationally stipulated material and labour constants. At present, the construction agencies, eg., Central-PWD, State PWDs MES, Railways, Municipal Corporations and Development authorities functioning at a place prepare their own schedule of rates and a comparison of the constants used by them has indicated that there is a large variation in them resulting in different rates for the same item of work in the same locality. A need was, therefore felt to stipulate the material and labour constants rationally in order to avoid the above discrepancy. Keeping this in view, a research project on material constants in building works was taken up in the Institute with the objective of establishing standard material constants on scientific basis for different items of works in building industry. This Research Note brings forth the work done in this direction and the material constants (without wastages) for various trades/items have been brought out.

Mortar and Concrete

The constants for mortar and concrete mixes have been arrived at by studying their yields, which may be defined as the volume of compacted mortar of concrete obtained by mixing known quantities of binder, aggregates and water. This information is necessary to work out the quantities of various materials required to make a unit volume of mortar/concrete. The yield studies have been carried out adopting the density method as recommended in IS : 1199-1959, Method of Sampling and Analysis of Concrete. In this method the weight of a certain volume of freshly mixed mortar or concrete is taken to determine its density. The total weight of the ingredients to produce the mix is then divided by this density to arrive at the yield per batch.

Before arriving at the actual constants the effect of the size and type of aggregate on the yield has also been studied for various mixes using different sizes and types of aggregates maintaining the other parameters constants. Yield studies to know the effect of fineness of fine aggregate have revealed that the yield is more, to an extent of 2 to 3 per cent, in case of mortar/concrete mixes when sand of maximum fineness modulus is used. Similary in case of concrete mixes the difference comes to 4-5 percent when both the fine and coarse aggregates with maximum fineness modulus are used. The gradings of the aggregates for the study were taken as per relevant Indian Standards. The effect of the type of aggregate has been studied using rounded aggregate (shingle) and crushed aggregate in cement concrete mixes. It has been observed that there is variation to an extent of 5 to 7 per cent (5 per cent for lean mix viz 1 : 6 : 12 and 7 per cent for rich mix. viz., 1:2:4), the yield being more in case of

concrete with rounded aggregate.

Based on yield studies, constants have been worked out for various types of mortars/mixes commonly adopted by construction organisations. These are shown in Table 1. Similarly, constants have been worked out for cement and lime concretes. In case of cement concretes, the constants have been obtained using rounded aggregate and, for lime concrete, brick ballast alongwith lime surkhi mortar has been used. For cement concrete, coarse sand (F.M. 2.87) alongwith shingle-20mm nominal gauge, has been used for all rich mixes up to mix proportion of 1:3:6 since these mixes are mostly used for RCC works. While for all other mixes, fine sand with fineness modulus of 1.26 has been used alongwith shingle (40 mm nominal gauge). All the materials used conform to the respective IS Specifications. Constants per cu.m. of concretes as obtained from the yield results for various mixes are shown in Table 2.

Reinforced Cement Concrete

In reinforced cement concrete works, an additional factor of finishing the exposed surface is also involved in obtaining the standard constants. The quantity of mortar required for finishing various RCC members depends on the type of shuttering used during casting. It has been observed that 6-8 mm thick plastering is needed where an average quality of timber is used for shuttering. Since most of the departments permit 6 mm thick plaster on the RCC work, the same thickness has been taken for computing the constants. The consumption of mortar has been calculated separately for different RCC members by considering an average section and applying reasonable weightage to various members in an item. Standard material constants for all RCC items derived with the help of Tables 1 and 2 are shown in Table 3.

Brick Work

The consumption of materials per unit volume of brickwork depends upon the size of the bricks, thickness of joints and size and position of frog. There is a great variation in the size of traditional bricks being used in various parts of the country. Investigations have shown that most common size of the bricks being used in northern India is 22.9 × 11.4 × 7.6 cm. (9" × 4½" × 3") nominal. Similarly, there is a variation in the thickness of joints ranging from 6 mm to 12 mm as specified by different departments. About the position of the frog, it is specified by most of the departments that bricks should be laid with frog up, whereas IS : 2212-1962, Code of Practice for Brickwork, specifies that bricks can be laid either frog up or frog down.

In order to arrive at the standard constants for brickwork, actual observations have been taken at various live projects at residential and office buildings, both framed and load bearing constructions. The observed values, when compared with the theoretically computed values have shown that the observed consumption of mortar is less (to an extent of 5 percent) as compared to the theoretical value. The probable reason for the difference may be that the joints are not entirely filled while laying the bricks. Constants have been arrived at based on the theoretically calculated consumption in order to arrive at the realistic figures. In case of traditional bricks the actual size of brick has been taken as 22.9 × 11.1 × 7 cm (9" × 4⅜" × 2¾"), thickness of joint 1 cm and size of frog 12.7 × 5.1 × 10 cm, while, in case of modular brick work the respective figures are 19 × 9 × 9 cm and 1 cm and 10 × 4 × 1 cm The consumption of materials per m^3 of brickwork works out to be 473 bricks and 0.203 m^3 of mortar using traditional bricks while, the respective figures are 517 Nos. and 0.186 m^3 using modular bricks. Further, an allowance in the quantity of mortar should be added if the bricks are laid with frogs up. This allowance works out to be 0.031 m^3 and 0.021 m^3 of mortar per m^3 of brick work with traditional and modular bricks respectively.

The consumption of materials per 10 m^2 of half brick work was computed on similar bases. The consumption is 520 bricks and 0.188 m^3 of mortar in case of traditional brick work, and 506 bricks and 0.139 m^3 of mortar in case of modular brick work. Extra allowance of mortar for

frog up position works out to be 0.034 m^3 and 0.020 m^3 respectivaly.

The overall standard constants for brickwork in terms of various ingredients have been derived using the information given in Table 1. These are shown in Tables 4 and 5 for traditional and modular brickwork respectively.

Flooring

There are various types of specifications being adopted for flooring. The common types are Indian Patent Stone, Marble Chips Floor and Marble Stone Floor. Material constants have been derived for Indian Patent Stone flooring (cement concrete floor) and marble chips flooring only. In case of cement concrete flooring, the constants can be computed with the help of figures given in Table 2 for any thickness of floor and an additional quantity of cement for the floating coat of neat cement has to be included, where specified. Observations have, therefore, been taken for the floating coat of neat cement in case of concrete floor finish.

The observed data indicated that, on an average, 0.43 bag of cement is required for 10 m^2 of the floor area. Material cnnstants for this type of flooring for various thicknesses have been arrived at including floating coat of neat cement and are shown in Table 6.

Constants for marble chips flooring have been worked out for 40 mm thick floor and are given separately for underlayer and top layer. The specifications regarding mix proportions and thickness of underlayer and top layer have been adhered to as per IS : 2114-1962, Code of Practice for Laying In-situ Terrazzo Floor Finish. These are given in Table 7.

Plestering

The consumption of mortar in plastering over brick walls mainly depends upon the thickness of plaster, unevenness of surface and dimensions of the raked joints which are generally specified in all jobs. Field observations have been taken for plastering over brickwork at construction sites with regard to the actual thickness of plaster, average size of raked joints and, uneveness of the surface, in order to know the difference in quantity of mortar actually being used in the field as well as the theoretically computed values. The two values indicated that, on an average, the actual consumption is always higher by about of 3 per cent. The difference might be probably due to the breakage of the edges of bricks during raking of joints which had not been taken into account in the theoretical calculations. Quantity of mortar for plastering has been worked out taking into consideration the thickness of plaster, dimension of joints and an allowance of 3 per cent (as mentioned above). In case of traditional brickwork, the 1 cm (3/8") thickness of joints has been taken, and raked depth 1.3 cm ($\frac{1}{2}$") as specified by most of the construction departments, while the respective figures for plastering on modular brickwork are 1 cm each. Finally the standard constants have been computed for various thicknesses (average) with the help of Table 1 and the results are shown in Table 8

Wood Work and Steel Work

The analysis of rate for any item pertaining to wood work and steel work trades is based on the actual consumption of wood or steel in that item. However, an allowance of certain percentage is made over the actual consumption to cover the wastage which depends mainaly upon the sizes actually required and those available in the market. Constants for steel/woodwork are not given in any tabular form as these depend on the sizes and sections of the members which vary to a large extent in different construction works. It is, therefore, suggested that the actual quantity of material may be worked out for each item and an allowance for wastage may be added to get an overall consumption of materials.

Conclusions

There is a need to rationally stipulate the material constants in view of the large variation in constants being specified by various organisations. The standard constants established through the present study will go a long way in avoiding these variations. The impact of the size and type of aggregate has been studied and conclusions arrived at. This would help in the proper selection of required type of material. The item rates arrived at by adopting these constants will show a uniform trend in price movement from place to place and region to region.

TABLE 1

Material Constants in Mortars

Sl. No.	Item (Mix by Volume)	Constants per m^3 of mortar			
		Cement (bags)	Slaked Lime (m^3)	Surkhi (m^3)	Sand (m^3)
1.	Cement mortar 1 : 3 (1 cement : 3 sand)	8.48	—	—	0.90
2.	Cement mortar 1 : 4 (1 cement : 4 sand)	6.79	—	—	0.96
3.	Cement mortar 1 : 5 (1 cement : 5 sand)	5.60	—	—	0.99
4.	Cement mortar 1 : 6 (1 cement : 6 sand)	4.65	—	—	0.99
5.	Cement mortar 1 : 7 (1 cement : 7 sand)	4.06	—	—	1.01
6.	Cement mortar 1 : 8 (1 cement : 8 sand)	3.57	—	—	1.01
7.	Lime mortar 1 : 2 (1 lime : 2 sand)	—	0.45	—	0.90
8.	Lime mortar 1 : 3 (1 lime : 3 sand)	—	0.33	—	0.99
9.	Lime Surkhi mortar 1 : 2 (1 lime : 2 surkhi)	—	0.50	1.00	—
10.	Lime Surkhi mortar 1 : 3 (1 lime : 3 surkhi)	—	0.37	1.11	—
11.	Composite mortar 1 : 1 : 6 (1 cement : 1 lime : 6 sand)	4.48	0.16	—	0.96
12.	Composite mortar 1 : 2 : 9 (1 cement : 2 lime : 9 sand)	3.02	0.21	—	0.96

NOTES :—1. The fineness modulus of sand used was 1.26.

2. The sand and cement constants shall be reduced by upto 2 per cent when the fineness modulus of sand is 2.9. The grading is as per relevant Indian Standard.

3. Water cement ratios adopted are for the percentage flow of 110 ± 5.

4. When lime is used in the form of putty, the volume 'V' of slaked lime contained in one metre cube of lime putty is to be found as follows :

$$V = \frac{G\,(WP - 1000)}{(G-1)\,D}$$

Where 'G' is specific gravity of slaked lime, 'W' is weight of putty in kg/m^3 and 'D' is bulk density of slaked lime in kg/m^3.

TABLE 2
Material Constants in Concrete

Sl No.	Item (Mix by volume)	Fineness Modulus		Size of coarse aggregate (nominal gauge) mm	Constants per m³ of concrete					
		Fine Aggregate	Coarse Aggregate		Cement (bags)	Slaked lime m³	Sand m³	Surkhi m³	Shingle* m³	Brick Ballast m³
1.	Cement concrete 1 ; 1 : 2 (1 cement : 1 sand : 2 shingle)	2.87	6.50	20	9.76	—	0.35	—	0.70	—
2.	Cement concrete 1 : 1½ : 2 (1 cement : 1½ sand : 2 shingle)	2.87	6.50	20	7.33	—	0.39	—	0.78	—
3.	Cement concrete 1 : 2 : 4 (1 cement : 2 sand : 4 shingle)	2.87	6.50	20	5.84	—	0.41	—	0.82	—
4	Cement concrete 1 : 3 : 6 (1 cement : 3 sand : 6 shingle)	2.87	6.50	20	4.15	—	0.44	-	0.88	—
5.	Cement concrete 1 : 4 : 8 (1 cement : 4 sand : 8 shingle)	1.26	6.90	20	3,20	—	0.45	—	0.90	—
6.	Cement concrete 1 : 5 : 10 (1 cement : 5 sand : 10 shingle)	1.26	6.90	40	2.52	—	0.45	—	0.90	—
7.	Cement concrete 1 : 6 : 12 (1 cement : 6 sand : 12 shingle)	1.26	6.90	40	2.10	—	0.45	—	0.90	—
8.	Lime concrete with brick aggregate and 40 percent lime mortar 1 : 2 (1 lime : 2 surkhi)	—	—	25	—	0 22	—	0.44	—	1.00
9.	Lime concrete with brick aggregate and 50 percent lime mortar 1 : 2 (1 lime : 2 surkhi)	—	—	25	—	0.26	—	0.52	—	1.04

*For crushed aggregate the constants shall be increased by 5 per cent for leaner mixes and by 7 per cent for richer mixes.

TABLE 3
Material Constants for RCC Works

Description of item	Consumption of materials per m³				
	Concrete			Fair finish	
	Cement (bags)	Sand coarse (m³)	Shingle* (m³)	Cement (bags)	Sand fine (m³)
Reinforced cement concrete 1 : 2 : 4 (1 cement : 2 coarse sand : 4 shingle 20 mm nominal gauge) including finishing and plastering the exposed surface with cement mortar 1 : 3 (1 cement : 3 fine sand) of thickness 6 mm (average) to give a smooth and even surface in .					
a) Suspended floors, roofs, landings, shelves and their supports and balconies	5.84	0.41	0 82	0.44	0.05
b) Walls including attached plasters buttresses and string courses,	5.84	0.41	0.82	1.02	0.11
c) Lintels, beams, girders bressummers and cantilevers	5.84	0.41	0.82	0.70	0.07
d) Columns, pillars, posts and struts	5.84	0.41	0 82	1.12	0 12
e) Chajjas	5.84	0 41	0.82	0.87	0,09

*The material constants for concrete items shall be increased by 7 per cent when crushed aggregate is used in place of shingle.

TABLE 4

Material Constant for Brick Work using Traditional Bricks

(22.9×11.1×7.0 cm with 1 cm thick mortar joints)

Sl. No.	Description of item	Constants per m³							
		Frog up				Frog down			
		Bricks (No.)	Cement (bags)	Slaked lime (m³)	Fine sand* (m³)	Bricks (No.)	Cement (bags)	Slaked lime (m³)	Fine sand* (m³)
1.	Brickwork in cement mortar 1:3 (1 cement : 3 sand)	473	1.99	—	0.210	473	1.72	—	0.183
2.	Brickwork in cement mortar 1:4 (1 cement : 4 sand)	473	1.59	—	0.225	473	1.38	—	0.195
3.	Brickwork in cement mortar 1:5 (1 cement : 5 sand)	473	1.31	—	0.232	473	1.14	—	0.202
4.	Brickwork in cement mortar 1:6 (1 cement : 6 sand)	473	1.09	—	0.232	473	0.94	—	0.200
5.	Brickwork in cement lime mortar 1:1:6 (1 cement : 1 lime : 6 sand)	473	1.05	0.037	0.223	473	0.91	0.032	0.193
6.	Brickwork in cement lime mortar 1:2:9 (1 cement : 2 lime : 9 sand)	473	0.71	0.05	0.226	473	0.61	0.045	0.194
7.	Half brick masonry in cement mortar 1:3 (1 cement : 3 sand)	520	1.88	—	0,200	520	1,59	—	0.169
8.	Half brick masonry in cement mortar 1:4 (1 cement : 4 sand)	520	1.51	—	0 214	520	1.28	—	0,181
9.	Half brick masonry in cement lime 1:1:6 (1 cement : 1 lime : 6 sand)	520	0.99	0.035	0.210	520	0.84	0.030	0.178

*The sand and cement constants shall be reduced by 2 per cent when coarse sand (fineness modulus 2.9) is used.

TABLE 5

Material Constants for Brickwork with Modular Bricks

Sl. No.	Description of item	Constants per m³							
		Frog up				Frog down			
		Bricks (No.)	Cement (bags)	Slaked lime (m³)	Fine sand* (m³)	Bricks (No.)	Cement (bags)	Slaked lime (m³)	Fine sand* (m³)
1.	Brickwork in cement mortar 1 : 3 (1 cement : 3 sand)	517	1.76	—	0.187	517	1.58	—	0.168
2.	Brickwork in cement mortar 1 : 4 (1 cement : 4 sand)	517	1.41	—	0.200	517	1.26	—	0.178
3.	Brickwork in cement mortar 1 : 5 (1 cement : 5 sand)	517	1.16	—	0.205	517	1.04	—	0.184
4.	Brickwork in cement mortar 1 : 6 (1 cement : 6 sand)	517	0.96	—	0.204	517	0.87	—	0.182
5.	Brickwork in cement lime mortar 1:1:6 (1 cement : 1 lime : 6 sand)	517	0.93	0.033	0.198	517	0.83	0.029	0.176
6.	Brickwork in cement lime mortar 1:2:9 (1 cement : 2 lime : 9 sand)	517	0.63	0 044	0.201	517	0.56	0.040	0.178
7.	Half brick masonry in cement mortar 1 : 3 (1 cement : 3 sand)	506	1.35	—	0.143	506	1.18	—	0.125
8.	Half brick masonry in cement mortar 1 : 4 (1 cement : 4 sand)	506	1.08	—	0.153	506	0.94	—	0.133
9.	Half brick masonry in cement lime mortar 1:1:6 (1 cement : 1 lime : 6 sand)	506	0.71	0.025	0.151	506	0.62	0.022	0.132

*The sand and cement constants shall be reduced by 2 per cent when coarse sand (fineness modulus 2.9) is used.

TABLE 6

Material Constants for Flooring

Sl. No.	Description of item	Constants per 10 m²		
		Cement (bags)	Sand (coarse) (m^3)	Coarse Aggregate (Shingle)* (m^3)
1.	75 mm thick cement concrete flooring 1:2:4 (1 cement : 2 sand : 4 shingle-20 mm nominal gauge) finished with a floating coat of neat cement.	4 81	0.31	0.62
2.	50 mm thick cement concrete flooring 1:2:4 (1 cement : 2 sand : 4 shingle-20 mm nominal gauge) finished with a floating coat of neat cement	3.35	0.21	0.42
3.	38 mm thick cement concrete flooring 1:2:4 (1 cement : 2 sand : 4 shingle-20 mm nominal gauge) finished with a floating coat of neat cement.	2.65	0.156	0.312
4.	25 mm thick cement concrete flooring 1:2:4 (1 cement : 2 sand : 4 shingle-20 mm nominal gauge) finished with a floating coat of neat cement.	1.89	0.103	0.206

*Constants for concrete shall be increased by upto 7 per cent when crushed aggregate is used in place of shingle

TABLE 7

Material Constants for Terrazzo (Marble Chips) Flooring

Sl. No.	Description of item	Constants per 10 m²					
		Under layer			Top layer		
		Cement (bags)	Sand (m^3)	Coarse aggregate (m^3)	Cement (bags)	Marble powder (kg)	Marble chips (kg)
1.	40 mm thick marble chips flooring rubbed and polished to granolithic finish under layer 35 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 stone aggregate shingle 20 mm nominal gauge) and top layer 5 mm thick white, black or white and black marble chips of size 2-4 mm (grade no. 0) laid in proportion 1 : $1\frac{3}{4}$ (1 binder : $1\frac{3}{4}$ chips-binder consists of cement and marble powder in ratio 3:1 by weight).	2.04	0.144	0 288	0.52	8 65	61.10
2.	40 mm thick marble chips flooring rubbed and polished to granolithic finish under layer 30 mm thick cement concrete 1:2:4 (1 cement 2 coarse sand : 4 stone aggregate-shingle 20 mm nominal gauge) and top layer 10 mm thick white black or white and black marble chips of size 7-10 mm (grade no. 2) laid in cement proportion 1 : $1\frac{1}{2}$ (1 binder : $1\frac{1}{2}$ chips-binder) consists of cement and marble powder in ratio 3 : 1 by weight).	1.75	0.124	0.248	1.13	18.9	118.8

TABLE 8

Material Constants for Plastering

Sl. No.	Description of item	Constants per 10 m^2					
		On traditional brickwork			On modular brickwork		
		Cement (bags)	Slaked lime m^3	Sand* (fine) m^3	Cement (bags)	Slaked lime m^3	Sand* (fine) m^3
1.	12 mm cement plaster 1:3 (1 cement : 3 sand)	1.22	—	0.130	1.19	—	0.126
2.	12 mm cement plaster 1:4 (1 cement : 4 sand)	0.98	—	0.138	0.95	—	0.134
3.	12 mm cement plaster 1:5 (1 cement : 5 sand)	0.81	—	0.143	0.78	—	0.139
4.	12 mm cement plaster 1:6 (1 cement : 6 sand)	0.67	—	0.143	0.65	—	0.139
5.	15 mm cement plaster 1:3 (1 cement : 3 sand) on rough side of one brick wall	1.48	—	0.158	1.45	—	0.154
6.	15 mm cement plaster 1:4 (1 cement : 4 sand) on rough side of one brick wall	1.19	—	0.168	1.16	—	0.164
7.	15 mm cement plaster 1:5 (1 cement : 5 sand) on rough side of one brick wall	0.98	—	0.173	0.96	—	0.169
8.	15 mm cement plaster 1:6 (1 cement : 6 sand) on rough side of one brick wall	0.81	—	0.173	0.80	—	0.169
9.	20 mm cement plaster 1:3 (1 cement : 3 sand)	1.92	—	0.203	1.88	—	0.200
10.	20 mm cement plaster 1:4 (1 cement : 4 sand)	1.53	—	0.217	1.51	—	0.213
11.	20 mm cement plaster 1:5 (1 cement : 5 sand)	1.27	—	0.224	1.24	—	0.220
12.	20 mm cement plaster 1:6 (1 cement : 6 sand)	1.05	—	0.224	1.03	—	0.220
13.	12 mm cement lime plaster 1:1:6 (1 cement : 1 slaked lime : 6 sand)	0.65	0.023	0.138	0.63	0.022	0.134
14.	12 mm cement lime plaster 1:2:9 (1 cement : 2 slaked lime : 9 sand)	0.43	0.030	0.138	0.42	0.029	0.134
15.	15 mm cement lime plaster 1:1:6 (1 cement : 1 slaked lime : 6 sand)	0.78	0.028	0.168	0.77	0.027	0.164
16.	15 mm cement lime plaster 1:2:9 (1 cement : 2 slaked lime : 9 sand)	0.53	0.037	0.168	0.52	0.036	0.164

*The sand and cement constants shall be reduced by 2 per cent when fineness modulus of sand is 2.9 and maintaining the grading as per relevant IS.

Prepared by : G. C. Sofat & Surinder Singh
This BRN Supersedes B D. 147
Revised by : G. C. Sofat
Published by :
Central Building Research Institute,
Roorkee (U.P.) India
Reprinted : Aug. 1981, May, 1995

Printed at :
Anubhav Printers & Packers, Roorkee. Ph. 71237
Copies, 2000