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Dombrovskaya, M. E.

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NEW METHOD OF DETERMINING THE EXTENT OF PREFABRICATION OF CONSTRUCTION

BY

M. E. DOMBROVSKAYA

FROM
STROITEL' PROM. (4): 23 - 26, 1955

TRANSLATED BY

G. BELKOV

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PREFACE

In its housing research studies, the Division of Building Research is naturally guided by corresponding study of house costs. There is all too little information on the basic factors such as man-hours for different types of housing operations available for use in such studies.

Accordingly, the Division welcomes the opportunity of publishing this translation of a paper from the U.S.S.R. which gives a summary of useful statistics obtained from Russian studies of prefabrication. Although methods of construction differ so widely, in some respects, between the U.S.S.R. and Canada, it is thought that the figures given by M.E. Dombrovskaya will still have much value in a comparative way in relation to Canadian cost studies.

The Division of Building Research is indebted to Mr. G. Belkov for the translation.

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R.F. Legget,
Director

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Author: M.E. Dombrovskaya

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NEW METHOD OF DETERMINING THE EXTENT OF PREFABRICATION OF CONSTRUCTION

The wide application of prefabrication is one of the most important conditions for increasing the rate of construction and decreasing costs.

Up to the present time no method has been developed for determining the extent to which a building may be prefabricated and usually it is determined from a ratio of the cost of prefabricated parts to the total cost of all materials either with respect to a single building or a building project.

This method is highly conditional since all changes in sale price of materials and prefabricated units change the relationship to the total cost.

For example, let us assume that the total cost of material is 1 million rub. and the prefabricated parts cost 200,000 rub. In this case the extent of prefabrication according to cost is 20%. If the cost of the prefabricated parts decreases to 100,000 rub. as a result of variation in sale price the extent of prefabrication will decrease although the physical volume of work and effort in assembling the parts remains the same.

Moreover the cost index of individual structural elements does not correspond with the amount of work involved in assembling them. Thus for example the cost of a single reinforced concrete flight of stairs is about 1,000 rub. and requires about 0.07 man-days for erection. On the other hand, the expenditure of labour on the erection of 1 m^2 of partition panel is 0.02 man-days and its cost is 32 rub. Thus in decreasing the cost by the factor of 30 the reduction in erection labour is only by the factor of 3.

The basic factor in determining the degree of prefabrication of a construction is the reduction of labour at the construction site by transferring part of the operation in manufacturing the prefabricated units to the factory. Therefore we usually determine the extent of prefabrication of a construction by the ratio of the amount

of labour saved in man-days to the total amount of labour spent at the building site for making the same structural unit or in carrying out the work in the usual manner of construction without prefabrication.

Consequently the extent of prefabrication is determined by the formula:

$$\text{Ex. prefab.} = \frac{A - A_1}{A} 100,$$

where Ex. prefab. is the extent of prefabrication of a unit in %;

A is the expenditure of labour at the building site under ordinary construction without prefabircation (in man-hours or man-days);

A_1 is the expenditure of labour in using prefabrication.

As is known, the quantity of labour saved and consequently the extent to which prefabrication may be used depends on the extent to which modern techniques are used in prefabricated construction. The more advanced the construction the more amount of labour will be saved at the building site and the greater will be the extent of prefabrication.

For example the amount of labour spent in building 1 m^2 of partition wall is:

(1) Wooden partition built of boards assembled vertically with plastering on both sides — 0.22 man-days;

(2) Wood panel partition with plaster on both sides — 0.16 man-days;

(3) Gypsum-slag large panel, plaster finish — 0.03 man-days, etc.

If we take the labour consumption in the first example as a standard, then in the use of a panel partition labour is reduced by 0.22 - 0.16 = 0.06 man-days and for the gypsum slag slab it is 0.22 - 0.03 = 0.19 man-days. Hence the extent of prefabrication in the first case is

$$\frac{0.06 \cdot 100}{0.22} = 27.2\%$$

and in the second case

$$\frac{0.19 \cdot 100}{0.22} = 86.4\%.$$

Thus in a general form the extent of prefabrication can be represented by the formula

$$\text{Ex. prefab.} = \frac{A - A_{1,2,3,\ldots,n}}{A} 100,$$

where $A_{1,2,3,\ldots,n}$ is the consumption of labour taking into account the use of prefabricated construction depending on the degree of modernization.

In determining the extent of prefabrication one can use as a standard the following types of construction and types of work involved in non-prefabricated construction (Table I).

To illustrate our suggested method a determination is made of the extent of prefabrication in the construction of the following six parts where the work was organized for a standardized building project (Table II).

The amount of labour was calculated from NiR (time and wage norms) since they give a correct determination of the amount of labour required to complete individual jobs and structural units under actual building conditions.

As seen from Table II the extent of prefabrication of these apartments and public buildings is not high and for the total construction work it is 9.3 to 19.6%. Considering the entire construction including plumbing the extent of prefabrication was 7.8 to 17.5%.

Table III gives data for calculating the extent of prefabrication of a standard apartment house.

This extent of prefabrication was determined mainly for the use of prefabricated reinforced concrete parts and also with wooden floors and slab subfloors.

The extensive prefabrication of staircases and landings does not have a large effect on the index of prefabrication of a unit on

the whole because the relative amount of labour involved is quite small — only 0.5%.

The very small amount of prefabrication involved in the walls (5.4%) is explained by the fact that in standard construction of this type of building the walls are of brick. However the use of prefabricated reinforced concrete cross beams and cornice plates has very little effect on the overall amount of prefabrication (only 0.7%).

The determination of the extent of prefabrication of building with respect to administrative units or building trusts on the whole can be carried out by the same method as for individual buildings. For this the following are necessary:

(a) To find the amount of labour saved at the building site as the result of using prefabricated construction;

(b) To determine the percentage ratio of this labour to the total amount of labour spent under conditions without prefabrication.

From the above the average extent of prefabrication as a whole considered for a construction administrative unit or a trust can be determined by the formula

$$\text{Av. ex. prefab.} = \frac{\Sigma A - \Sigma B}{\Sigma A} 100,$$

where ΣA is the expenditure of labour in man-days on the whole for a construction administration or a trust using ordinary non-prefabricated construction;

ΣB is the expenditure of labour in man-days on the whole for a construction administration or a trust using prefabricated construction.

As an example we give the average extent of prefabrication for the fixed residential and public buildings mentioned in this paper (for the total construction work) (Table IV).

The index of the extent of prefabrication of a construction on the whole by trust or construction administration can to some extent be determined by taking into account the percentage of prefabricated parts used and is calculated in the following way.

For each structural unit or type of work the percentage of prefabricated parts is established.

Then multiplying this factor by the factor of the percentage ratio of labour used on a given structural element according to the standard and dividing the product by 100 one can establish the extent of prefabrication per building as a whole.

The sum of the indices obtained constitutes the extent of prefabrication for a construction administration or a trust on the whole. For example the total amount of work on foundations of apartment buildings carried out by the construction administration was 1000 m^3 including 500 m^3 going into foundations made of large blocks; in this case the percentage of prefabricated construction is 50%. The total volume of work on the walls was 3000 m^3 including 600 m^3 of large blocks; the percentage of prefabricated construction here was 20.

In agreement with the indices given in Table VI the percentage ratio of labour involved in the foundation of a three-storey apartment building was 4.9% of the total and the walls 13.4%. Thus the extent of prefabrication of the construction is determined from Table V.

In using Table VI one should keep in mind that the volume of work involved in setting up separate structural elements in relation to the total amount of work depends on the structural features, number of stories and purpose of the buildings.

For example, with an equal floor area an increase in the number of storeys decreases the percentage ratio of work on building the foundation and roof although the total volume of work spent on these structural parts does not change.

Similarly with the same cubic space the amount of partitions (in m^2) in an apartment house would be greater than in a school.

Hence to determine the extent of prefabrication for a trust as a whole one should take into account the percentage of prefabrication used in the construction and the percentage ratios of labour consumed, shown in Table VI, for groups of similar buildings. The total extent of prefabrication of construction is determined by

summing the results of data for individual groups of buildings (schools, apartment buildings, hospitals, etc.).

Table I

Structural parts and types of work	Type of construction used as a standard
Foundations and basement walls	Foundation of rubble stone; load bearing wall type of foundation; the walls of rubble stone with a facing of brick (from the inside)
Walls	Brick walls covered with plaster
Floors of wood	Subfloors of slabs on wooden beams
Floors reinforced concrete	Monolithic concrete
Partitions	Wood laths with plaster on both sides
Roof structure and roofing	Rafters of wood with struts; roofing of asbestos cement or metal
Staircases and landings	The steps on metal string. The landings of monlithic concrete or small slabs on metallic beams
Finishing	Wet plaster including cornice plaster. Painting

Table II

Building	Extent of prefabrication in %	
	General construction work	Per building
Apartment house three storeys.....	19.6	17.5
Apartment house five storeys.....	19.2	17.2
School for 280 students.....	15.9	13.9
School for 400 students.....	14.7	12.8
Hospital with 75 beds.....	9.3	7.8
Hospital with 200 beds.....	11.3	9.6

Table III

The extent of prefabrication of a standardized three-storey apartment house

Structural units and type of work	Expenditure of labour				Labour saved in man-days	Extent of prefabrication in %	
	Standard (bldg. code)		Standardized building				
	Total in man-days	Total ratio %	Total in man-days	Total ratio %		Structural units	Building
	I. General construction work						
Excavation and backfill.....	113	2.3	113	2.9	—	—	—
Foundation and basement walls of reinforced concrete.....	238	4.9	237	6.1	1	0.4	—
Walls.....	647	13.4	612	15.7	35	5.4	0.7
Floors.....	835	17.2	280	7.2	555	66.5	11.4
Roof structure and roofing.....	181	3.7	181	4.6	—	—	—
Windows.....	68	1.4	39	1.0	29	42.6	0.6
Doors.....	141	2.9	127	3.2	14	9.9	0.3
Partitions.....	232	4.8	160	4.1	72	31.0	1.5
Finished floors.....	234	4.8	234	6.0	—	—	—
Staircases.....	25	0.5	5	0.1	20	80.0	0.4
Inside plastering.....	1066	21.9	840	21.5	226	21.2	4.7
Outside plastering.....	243	5.0	243	6.2	—	—	—
Painting.....	509	10.4	509	13.0	—	—	—
Miscellaneous work.....	330	6.8	330	8.4	—	—	—
Total.....	4862	100.0	3910	100.0	952	—	19.6
	II. Total work per building						
General construction work.....	4862	—	3910	—	952	—	17.2
Plumbing and electric installation.	467	—	467	—	—	—	0
Transport and crane operation.....	204	—	188	—	16	—	0.3
Total.....	5533		4565		968		17.5

Table IV

Name of building	Expenditure of labour under ordinary building conditions without prefabrication ΣA in man-days	Expenditure of labour with prefabrication ΣB in man-days	Amount of labour saved $\Sigma A - \Sigma B$ in man-days	The average extent of prefabrication $\frac{\Sigma A - \Sigma B}{\Sigma A} 100$ in %
Three-storey apartment building.....	4862	3910	952	19.6
Five-storey apartment building.....	9283	7504	1779	19.2
School for 280 students.....	2624	2206	418	15.9
School for 400 students.....	3855	3288	567	14.7
Hospital for 75 beds.....	5642	5117	525	9.3
Hospital for 200 beds.....	12647	11214	1433	11.3
Total.....	38913	33239	5674	14.6

Table V

Item No.	Structural units and type of work	The percentage ratio of labour as a percentage of the standard	Total volume of work in m^3		Percentage of prefabricated parts (gr. 5 : gr. 4) · 100	Extent of prefabrication on the whole per building (gr. 3 · gr. 6) : 100
			Total per trust	Including prefabrication		
1	2	3	4	5	6	7
1	Foundations.....	4.9	1000	500	50	2.45
2	Walls.....	13.4	3000	600	20	2.68
	Total.....	100	—	—	—	5.13

Table VI

Percentage ratio of labour spent on structural units and types of work under ordinary building conditions without prefabrication (standard)

Structural unit and type of work	Schools		Hospitals		Apartment buildings	
	280 students	400 students	75 beds	200 beds	three storey	five storey
Excavation and back filling.....	2.7	3.3	3.0	4.2	2.3	1.4
Foundation and basement walls.....	8.2	8.0	5.0	6.8	4.9	4.6
Walls.....	19.6	16.1	16.8	15.4	13.4	13.4
Floors.....	18.5	18.3	9.9	11.4	17.2	17.3
Roof structure and roofing.....	5.0	3.3	2.8	1.8	3.7	2.4
Windows.....	3.0	2.5	1.9	1.6	1.4	1.7
Doors.....	1.2	1.2	1.0	1.0	2.9	3.5
Partitions.....	0.9	1.6	2.5	2.8	4.8	9.2
Finished floors.....	8.3	8.7	9.7	8.5	4.8	4.6
Ladders.....	0.5	0.6	0.5	0.3	0.5	0.5
Inside plastering.....	14.2	13.8	23.1	24.8	21.9	23.9
Outside plastering.....	8.7	7.5	8.5	6.6	5.0	—
Painting.....	7.0	10.4	13.7	14.6	10.4	12.5
Miscellaneous.....	2.3	4.5	1.6	0.2	6.8	5.0
Total.....	100.0	100.0	100.0	100.0	100.0	100.0