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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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SOME ASPECTS OF THE CONSTRUCTION OF INDUSTRIAL PROJECTS IN DEVELOPING COUNTRIES - BASED ON HUNGARIAN EXPERIENCE 1/

by

[illegible]. Csorba*

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* Division Director, Hungarian Institute for Building Science, Budapest, Hungary.

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CONTENTS

I. Introduction

Common factors

/Prefabricated Building/

II. Conditions leading to prefabrication

Scarcity on forces and material

III. Status of /industrialization/

Heavy industry limited little steel, plenty of cement - occupation lack of timber lack of experience - lack of funds

IV. Basic conditikons for and realization of r.c. prefabrication

Revised design - block-building - standardization - typification prefab on the site mehhanization twofold dry-connections proper organization

V. Favourable results of r.c. prefabrication

Stated as stop-gap, but prevailed, since:

Saving in scoffolding

Easy control

High quality

Reduced weights and loads

Sophisticated cross-sections

Ordered site and planned output

Reduced labour

Reduced time

Not seasonal

VI. Factory based prefabrication

VII. Monolithic

Up to date technology

Crane-supported scaffolding

VIII. Other aspects

Climate sun-protection - materials - corrosion - colours ventilation

SOME ASPECTS OF THE CONSTRUCTION OF INDUSTRIAL PROJECTS IN DEVELOPING COUNTRIES - BASED ON HUNGARIAN EXPERIENCE

I. INTRODUCTION

The need of developing countries for developing the industrial construction sector and obtaining technical assistance to achieve this objective in the fastest and most effective way is a well known fact.

Though there is a big variety in the conditions of various developing countries in different parts of the world, certain common factors appear in almost all cases:

- There is usually a lack of skilled labour at all levels.
- A shortage of foreign currency hampers imports.
- Due to lack of heavy industry, no or not sufficient steel or steel products are produced locally.
- In many cases timber for shuttering has also to be imported.
- The need of rapid industrialization calls for an increased speed in the construction of industrial projects.

Many of these factors were characteristic for Hungary in the past three decades also, and therefore it might be helpful to see what could be used from the Hungarian experience in this field.

II. CONDITIONS LEADING TO PREFABRICATION OF REINFORCED CONCRETE COMPONENTS.

1. Following World War II a speeded up industrialization has been started in Hungary. Being primarily an agricultural country with insufficient heavy industry, there was little experience in the erection of industrial plants: forces to planning and building were few. We did not have enough basic materials of industrial investments, chiefly rolled steel and wood for the shuttering of monolithic reinforced concrete constructions. We had to omit the intermediary stages of industrial development, as observed elsewhere and the demands of a growing industry had to be met by immediate action.

2. In these circumstances, the attention of Hungarian architects and engineers had been directed -- perhaps for the first time in the history of architecture - towards precast r.c. structures. We developed in the course of the last 25 years the structural types of industrial buildings of prefabricated r. c. These results are largely quoted by technical papers and are internationally well known.

III. THE STATUS OF INDUSTRIALIZATION

1. Hungary possessed a heavy industry before the war, but the shortage of coal and ore deposits hindered its development.

2. The difficulties of the building industry are determined by the deficience of the heavy industry, namely in two respects. Firstly, there is not enough disponible rolled steel. The limited stock of rolled steel and of sheet metal are needed in other fields. Building has to reckon with rolled bars of reduced quality, an inavoidable final product of the steel industry. Meanwhile, should cement production stay below a suitable level, there is enough raw material to raise the output. These facts pinpoint r.c. as the principal material of industrial architecture.

3. Due to the initial lack of the heavy industry, scores of industrial buildings are needed for it, for power production and for plants of basic material production, with shops equipped with gantries of considerable spans, etc., therefore the tasks are diverse, and complicated. There are no means to learn by stages, how to build: simple jobs appear intertwined with complex ones. The situation is aggravated, as the exigencies of the speedily developing industrialization are differentiated, even within local aspects. To reach a balanced occupation of all inhabitants, from territorial point of view and also a well proportioned progress, industrial centralization has to be considered, though slightly in the beginning.

4. The insufficiency of timber for the building industry is world wide and increasing. The international market price of lumber is in constant rise. The deficiency compels the methodically planning architect to forego to traditional means of erecting industrial buildings of monolithic structure. Today, even in countries richest in wood turn - later, but just like the others - to the prefabrication of r.c. structures. Finland and Sweden - which are richest in timber production - use precast building methods on a large scale. The U.S.S.R. increased its production of industrially precast r.c. elements in a period of six years twentyfold.

5. Considering the building industry of developing countries, an important factor has to be faced, i.e. they are in most cases unprepared to meet the speedily increasing demands: they lack skilled forces for the erection of industrial construction, there is a general lack of experience.

6. Prefabrication of r. c. elements is carried out on special plants, or, as we will detail, on the building site. The more developed stage of prefabrication belongs undoubtedly to the specialized plant, able to handle high qualities of concrete and steel, utilizing their ultimate strength. We have to consider simultaneously, that countries in the course of industrial development are in general - due to their relative lag - deficient in funds. Their status becomes somewhat strained in this stage of progress, being compelled by the establishment of a balanced and sufficient basic industry to erect in the same period many industrial plants of most varied kinds. These circumstances sollicit heavily all resources. Thus, relatively limited resources are left to develop the building industry, which is a means and not the goal of industrialization. Therefore the strictest economy has to be maintained in this branch: there are no means for large investments, as for fully equipped prefabrication plants with specially designed machinery. Full amortization of investments for building industry plants are among the longest, as it is widely known. But the prefabrication on the site - contrary to industrialized prefabrication

serving the entire building industry - requires only inconsiderable investments. Their initial exigencies are primarily lifting devices of relatively small cost, largely differing from the producing and conveying machinery of industrialized plants.

IV. BASIC CONDITIONS FOR AND REALIZATION OF R. C. PREFABRICATION

1. To begin with, traditional methods of projecting industrial architecture have to be revised. At the planning of the technological procedure the exigencies of building construction have to be taken more in consideration Prefabrication, even on the site, assumes and expects a certain amount of serial production. The possibility of creating identical elements has to be ensured by grouping building and by housing different technologies in the same group, as well by prevailing principles of mass-shaping, concerning the whole plant. Uniting structures, possibly into a single block is - as we have experienced technologically just as advantageous, because internal delivery becomes shortest and facilitates later regroupments and new technologies. Increased standardization of structural dimensions is necessary for the repeated use of building elements. We have to regulate the dimensions of spans, widths, and heights of all main structural parts of the building, in accordance with previously established principles In Hungary we achieved by this method of standardization of portals, regularized spans of 6, 9 and 1[illegible] metres, and this implied the thorough standardization of roofing structures, i.e. of their dimensions. Typification of elements, as a result of standardized dimensioning is the major requirement of prefabrication, which becomes a high grade and economical method by the single means of serial production.

2. Judged from the point of view of progressive industrialization, prefabrication of r.c. elements on the site is an intermediary stage between monolithic construction and industrialized prefabrication. But prefabrication of the site type is - contrary to the industrialized - very flexible with respect to the **weight-limit** of the units: all main parts of load bearing structures can be cast on the site, as they need no transportation. In most cases their weight is under 10 metric tons.

Smaller elements, of 1- metric tons can be produced in the proximity of the site, by a temporarily erected plant, equipped for serial production and preferably roofed, protected from adverse weather.

3. The mechanization of the construction has to be twofold. Concrete mixers, woodworking and welding machines, simpler kinds of gantries are necessary for the aforesaid production on the site. This small mechanical equipment is of low cost and of short amortization. Cranes for building purposes are of established types. In the first place we need "universal" cranes - not bound to tracks - on wheels or of the caterpillar type, of 5-10 m.t. capacity. In special cases - for large lifting capacity, for instance at power plants, so-called lifting towers or rigs convey up to 50 metric tons. When necessary, pulley equipped primitive wooden constructions suffice. By this method were erected the prefabricated r.c. structures of the Machine Tool Factory in Korea.

4. For connecting the elements lifted into place fully developed methods have been established. Characteristic are the so-called "dry-connections", i.e. those with immediate load bearing capacity, whereby lifting and placing call for little time, and by rational assembly the demand for lifting devices remains small. For instance ten year ago, the relatively highly developed building industry of Hungary produced satisfactorily with 40 caterpillar-cranes, though 80 % of our industrial buildings were erected by prefabrication.

5. Because of serial production, mechanization, less skilled workers and speeded output, the method described above requires a more carefully scheduled organization. Construction and design have to be strictly coordinated. One has to reckon with initial difficulties, but as is proven by Hungarian experience, the new method was adapted within one or two years and became an indispensable factor of the building industry.

V. FAVOURABLE RESULTS OF R. C. PREFABRICATION

1. As stated above, prefabrication on the site started as a reasonable stop-gap. Circumstances motivating prefabrication lessen sooner or later, according to the progress of the given countries, but experience proves that this method remains in widespread use. Prefabrication has many advantages compared to monolithic and shuttered construction. The comparisons result in the following conclusions.

2. With prefabrication, scaffolding becomes superfluous, particularly at levels above 5 meter, for the placing of reinforcement and of concrete. Scaffolding requires considerable material, careful execution, skilled labour: it is costly, as a method. As it is well known, the quality of monolithic r. c. constructions depends mainly of a correct scaffolding, which has to be kept during 40-70 % of the entire constructional period. Important scaffoldings require especially skilled workers.

3. With prefabrication, the construction of the moulds is also advantageous. The average shuttering can be utilized at best 3 to 5 times. Though moulds for prefabrication are somewhat costlier than average wooden shutterings – being sheet-iron clad wooden structures or made of concrete – and are built stronger but by previously designed construction and by more careful maintenance they last much longer and can be utilized at least 30-50 times. As they are placed at soil level, they are easy to reach, and further, their construction and dismounting does not cause losses. By prefabrication the needs for scaffolding and shuttering material decrease by 80-90 % compared to monolithic and shuttered methods.

4. As the placing of reinforcement and of concrete takes place at soil level, the operations and control are easy. The product is of greater precision, consequently the needed tolerances are less.

5. Due to the former reasons we are in a position to utilize materials of higher quality. The quality of concrete depends mainly on the agregate, the cement and the water coefficient but the circumstances of placing and of vibrating, i.e. the accessibility of the formwork is by no means indifferent, or secondary. With prefabrication, work and control becomes easy. To indicate the resulting economy, we mention as an example, that the dead load of a main roof truss of 12 m span decreases by 50 % when made of a concrete of 420 kg/cm2 cube strength, instead of a concrete of 140 kg/cm2 cube strength. This also becomes a fundamental consequence regarding lifting devices and the dimensions of all load bearing structures.

6. With monolithic structures, because of difficult circumstances of erection, we have to adher to cross-sections of tmost simplicity, while in the course of prefabrication we are enabled to adopt elaborate cross-sections, in the most advantageous and systematic form, as derived from statical computations. Thus, by the building technique we obtain the practical I and T sections, as well as moulded and latticed girders trusses. At the traditional monolithic method the fully guadrangular section is solely employed, in our demonstrating figures the more subtle and latticed forms prevail only. These slender and light structures are also becoming factors of spatial composition, they can compete in many cases with the aspect of steel structures.

7. The organization of the prefabricating plant is an easy task and we reach without difficulties an ordered working site and planned output.

8. By prefabrication, the total number of workers decreases. compared to the traditional methods: this holds good especially to skilled workers. We can dispense largely of carpeaters and scaffolders. These, perhaps the most skilled and most valuable men of the building industry should be employed as foremen of prefabricating units.

9. The constructional time-schedule can be considerably shortened because of a better organization, simultaneous job-distribution and mechanization.

Also, the prefabrication diminishes to a certain extent the seasonal character of the building industry, results in a more even employment of workers and acts indirectly by a further cut on time-schedules.

VI. FACTORY-BASED PREFABRICATION.

In Hungary, the development reached a further important phase in 1966-1967, when the large-scale production of typified structures started. In order to reach this, the structural variants had to be unified and their number reduced. In the preparatory phase of typification, we analysed:

- the demand on single-floor and multy-storeg industrial buildings,
- dimensional parameters
- performance requirements
- transport requirements etc.

We found that the slightly differing requirements can be co-ordinated, the number of variants reduced, thus the conditions for factory produced building technologies satisfied.

A new standard for dimensional co-ordination has been worked out, dealing with all important details.

The main dimensions of typified industrial halls are:

span/m/	12,0 - 18,0 - 24,0	
axis distance /m/	6,0 - 12,0	
height /m/	3,6 - 4,2 - 4,8	5,4 - 6,0 - 7,20

As a next step, industrial production capacity and mechanisation has been increased.

On the graph, the increase of industrial halls made by factory-produced r.c. prefabricated components is represented.

The full line /a/ shows the area covered by factory-produced halls vs the total demand in dotted line /b/.

VII. MONOLITHIC INDUSTRIAL CONSTRUCTION

1. From all what has been said previously, it might appear that we consider prefabrication as the only construction technology to be considered and recommended for developing countries. This is not the case. Our experience has shown that up-to-date monolithic construction technology can be competitive even with the most advanced prefabricated systems - and this would probably be valid for the conditions of developing countries as well. As an example I wish to give a brief description of an interesting technology which could be recommended for developing countries.

2. The system has been developed for one-storey, large span industrial halls, provided with a travelling-crane. The monolithic elliptical shell structure is supported by prefabricated columns, placed at 22,0 x 12,0 m distances. The thickness of the monolithic r.c. shell is 7 cm. The technology is as follows: First the r.c. columns are erected, than the longitudinal steel crane-girders. The mobile formwork of the 22 m span edge beams is mounted on the crane bridge. In the next phase, the steel scaffolding of the shell and of the 12 m span edge beams is supported by the previously completed 22 m span edge beams. Shell and short edge beams are poured simultaneously.

The number of the plastic skylights can be chosen according to lighting requirements. The construction time of the 66x108 m shell roof is 13 weeks.

Specific materials consumption:

B 200 concrete:	9,25 cm/m2
Reinforcement B 60.40:	10,5 kg/m2
Tie-bar C 60	1,1 kg/m2

8. Some other aspects of constructing industrial buildings in developing countries, especially in the tropics.

To comply to industrializing demands of economically underdeveloped countries, tropical building conditions are to be determined and systematized. The unusual sollicitation is due to the climate, as high air temperature, increased sunshine, tropical precipitations, further draught and abnormal air-humidity: secondary causes might be the damaging effects of vegetation and faune. To reduce harmful consequences, the effect of each element has to be considered.

On the basis of annual precipitation, the tropics may be devided into hot-dry, hot-wet and intermediate regions, with regard to buildings and to their equipment.

Protection from increased sunshine comply to some rules, to give instructions, supported by examples of correct orientation, the establishing of shielding areas, the selection of materials, as well of further important features of planning.

The building should be oblong, with an east-west main axis, possibly multistoried and of a northern or southern main facade. Direct radiation and glare may be prevented by selfshielding walls: good solutions provide full protection from 8 a.m. to 4 p.m.

At selecting materials, great care has to be given to availability and to thermal characteristics, to corrosion and to the action of funguses, insects and rodents. Heavy materials with good insulating properties suit hot dry climates, while in hot wet regions with a nearly constant temperature light materials may be employed.

Light colored surfaces are very important to reflect heat radiation. In hot and wet climate open surfaces suit well to conditions, while for hot and dry weather insulating walls and closeable frontages enable to utilize night air for cooling purposes. At plants with several buildings wind direction and ventilating conditions shall be considered. The surrounding should not shield from wind and reflect the least sunshine to the buildings. Lawns and lofty trees are to be planted in the surroundings. It should be refrained from adjacent concrete roads and paved ways as they reflect considerable radiation.

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