

Report of Indian productivity team

*Factory building, layout
and construction in Japan,
U.S.A. and Italy*



NATIONAL PRODUCTIVITY COUNCIL, INDIA

NATIONAL PRODUCTIVITY COUNCIL

NPC activities are directed towards the objective of increasing the national wealth and the standard of living of the people by stimulating increase of productivity in various spheres of the nation's economy, particularly in industries.

The National Productivity Council is an autonomous organisation established by the Government of India. It has on it, representatives of the Government of India, organisations of employers, workers and various other elements interested in the productivity drive. Established in 1958, the Council conducts its activities in collaboration with other organisations and institutions, interested in industrial productivity. It is carrying the productivity drive to the plants through the Local Productivity Councils which have been established in industrial centres all over the country.

The purpose of the NPC is to stimulate productivity consciousness in the country ; to maximise the utilisation of all available resources ; to wage war against waste ; to help secure for the people a better and higher standard of living. To this end, it disseminates information about techniques and procedures, organises a number of programmes. It arranges conferences, study groups, lectures and training courses, an Advisory Service and Technical Enquiry Service, publications, films and exhibitions for propagation. Through these media it seeks to carry

NPC stimulates productivity in the country by organising in-plant visits and inter-plant visits. It lays the greatest emphasis on programmes of productivity to suit different levels of productivity. It aims at developing appropriate attitudes of workers and management.

NPC sponsors productivity engineering, industrial management and industrial productivity teams abroad for studies in general and in specific subjects of individual industries.

Reports of these Teams are published by NPC. This is the seventh report in the series. The first six were : (i) Productivity in industries of USA, West Germany and United Kingdom (ii) Small Scale industries in USA, West Germany, Sweden and Japan (iii) Road Transport Industry in West Germany, UK and USA (iv) Plastics Industry in USA, Italy & Japan (v) Cotton textile industry in USA, Japan, West Germany, France & Switzerland, and (vi) Industrial Management Organisation and Training in West Germany, UK & USA. One more Report on Coal Mining Industry is in the press and will be available shortly. NPC is publishing these Reports so that industrial managements in India may gain the necessary knowledge for maximising productivity within their concerns.

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*Factory Building,
Lay-out & Construction in
Japan, USA & Italy*

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THE EXECUTIVE DIRECTOR,
NATIONAL PRODUCTIVITY COUNCIL,
NEW DELHI.

Sir,

We, the members of the Indian Productivity Team for Factory Buildings, Layout and Construction, forward herewith the report of our study of Factory Buildings and allied structures in Japan, the United States of America and Italy.

The subject of the study is a vast one—full of complexities. The time at the disposal of the team for the study of such a complex problem was short. We have, however, made an attempt to record in our Report all the salient features we have observed regarding planning, designing and construction of factory buildings and allied structures in the countries visited. We hope that our observations and recommendations would be of help to all engaged on factory construction, both in the public and private sectors. The translation of some of the recommendations into practice would lead to reduction in construction costs.

Yours faithfully,

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Introduction

Origin of the team

A tally made by the Committee on Plan Progress has shown that the allotment of building construction accounts for nearly a thousand crores of rupees in the tally of Rs 4,800/- in Second Five Year Plan. Roughly, a third of this amount may be attributed to factory building construction—both big and small. With the accent on industrialisation, the investment in factory building construction in the future Plans is bound to be considerably higher. In such large items of expenditure, the desirability of economy, consistent with functional efficiency is obvious. A knowledge of the experience of industrialised countries is, no doubt, useful.

It was, therefore, decided that in order to derive benefit from the experience of other industrialised countries, a team may be sent to study the subject of factory layout and construction embracing the techniques of design and execution of works, factory-made building materials and latest methods of administration and management at site.

The team set out on tour on 1st November and completed its assignment on 20th December, 1959.

Terms of reference

The team gave attention in all their visits and discussions to the following subjects :

- (a) Broad features of modern design
- (b) Layouts
- (c) Space utilisation
- (d) Types of structures adopted
- (e) Design and material problem relating to framing, clabbing and roofing
- (f) Design problems connected with seismic forces, especially for tall structure
- (g) Adaptability for future expansion
- (h) System of lighting
- (i) Flooring
- (j) Agency for designing, tendering and construction
- (k) Building material situation in general and price-control
- (l) Wage structure and conditions of employment of labour
- (m) Special features conducive to economy and speedy construction
- (n) Standardisation and degree of pre-fabrication, and
- (o) Mechanisation and use of power-driven hand tools

Team organisation

Prior to its departure, the team met once in India for laying down the lines of study and the process of collection and collation of information during the tour. Preparatory visits to industrial centres within the country were not considered necessary as the members of the team already possess adequate background of the design principles and practices adapted in the country.

Itinerary

It was decided that the team should visit Japan, the United States of America and Italy. The inclusion of UK and West Germany in the itinerary provided for visits to industrial establishments, research centres, and discussions with consultants, architects and labour organisations. In all, the team visited 19 industrial establishments, seven technical and research institutions and had discussions with 16 organisations. A detailed list is given in Appendix I.

Limitations

Though the main object of the study was factory layout and construction, it was considered feasible to divorce from the study the general trends in building construction. Visits to some of the building material centres, multi-storeyed buildings and teaching and research institutions proved useful in providing the necessary background for properly assessing the merits of various designs, structural techniques and organisational methods.

It is rather unfortunate that none of the itinerary in the three countries visited was received sufficiently in advance. Even for Japan, the first country that was visited, the broad itinerary was received only a day prior to the departure of the team. As a result, the team, on arrival in the country, had to ask

for some changes. Although the authorities in charge were willing to accommodate, it was not found practical to make eleventh-hour change. To enable a team to ask for necessary changes with a view to fulfilling the objects of study more effectively, it is necessary, if not essential, that itinerary should, as far as possible, be received at least a month in advance of the departure of the team.

We further found that the time available for the study of a complex problem like factory building construction was insufficient and the programme was so crowded that it was difficult to assimilate the information depending upon the nature of a pre-arranged assignment, there should not be more than one or two visits during a day. There should be suitable breaks for the drafting of notes.

Acknowledgments

The members of the team are grateful to the National Productivity Council for affording them this opportunity for the study of the important subject in the three countries. The team also places on record its thanks to the International Cooperation Administration of the USA, the Japanese Productivity Council and the Council for National Productivity of Italy, who were responsible for the organisation of the tour in their respective countries. The team would specially like to express its appreciation as also for help received from Mr Leslie W Parker of the ICA, Washington, and Mr Semoto of USOM, Tokyo, who had made all arrangements for our visits. The team is thankful to the managements of the various factories, research organisations and contractors' organisations for their kindness and courtesy in supplying us all information asked for and unreservedly discussing with the members of the team problems of common interest.

The members also had an opportunity to meet the people of Japan and the USA in their homes. These contacts gave them an insight into their way of living.

Layout of the Report

As the subject of the study is vast and many-sided, the team decided, in the first instance, to divide itself into four groups, each one dealing with a specific subject, viz. (a) planning and layout, (b) design and

research, (c) materials, and (d) organisation for construction. The report of the team is accordingly divided into five chapters: the introductory chapter deals with the general background of the construction industry in the three countries visited, and the remaining four with the four subjects mentioned above. The team's conclusions and recommendations are set out at the end of the Report.

CHAPTER I

General background

Japan

In the post-war period, Japan has witnessed a mass scale building construction, unprecedented either in magnitude or speed. In 1956, the amount of building construction was placed roughly at 505 billion yens, while in 1957 it rose to 646 billion yens. Figures for 1958 are not available but it is reliably estimated that the expenditure on building construction would be higher than in 1957.

There are, in Japan, 40,000 registered contractors, out of which 30,000 are corporations. Nearly half of these are members of the contractor's organisations.

In recent years, the production of building materials has risen by a remarkable degree. In 1957, 15,000,000 tons of cement, 8.2 million tons of steel, 44.6 million cubic meter of timber were produced.

The density of population in Japan has reached a figure of 245 persons per square mile. With the rise in population the shortage has become acute and has been further aggravated by reduced activity in this line during the Second World War. In the period from 1945-48, 5.7 million houses were constructed

of which 1.8 million units were built by means of steps taken by the Government and the remaining 3.9 millions by private enterprise. In the course of these years, however, increased demand has been created by the rise in population and destruction caused by fire, floods and typhoons. The housing shortage in April, 1959, was estimated at 1.8 million units.

A major change in the Japanese building industry has been mechanization, the introduction of earth moving equipment, concrete mixing and emplacement plants and hoists and cranes. The labour, compared to Western countries, being cheaper the progress in mechanisation is limited to cases where high efficiency is required and to locations where mass scale work is not possible by manual labour. With the demand for fast construction, the attitude towards mechanization however, is gradually changing.

Almost all the construction work in Japan is being carried out on the contract system. The general contractor system is ordinarily adopted. The sub-contractors contract only for their particular trades. Interpretation of drawings, specifications and consultation with the designers on the site are all carried out by

the primary contractor who also decides the techniques of trades to be adopted by the sub-contractor.

The United States of America

An industrial survey recently carried out in the USA has shown that the construction industry is the largest single industry in the country. It is well organised and is supported by a powerful organisation known as the Associated General Contractors of America. This body has contributed in no small measure to the success of building industry. It works in close liaison with labour associations and technical institutions such as American Society of Civil Engineers and the American Institute of Architects. It has been instrumental in raising the standard of performance of the contractors and has improved their status. It also actively participated in the training of craftsmen.

A large amount of industrial expansion is taking place in the Western States. The construction industry in the United States is highly mechanised and there is increasing adoption of pre-cast and pre-fabricated construction.

Multi-storeyed buildings are a common feature. Even in the severe seismic regions of California, buildings upto 20-storey height are common.

There is a wide range of manufactured building materials available in the country. Synthetic flooring tiles, panelling materials, builder's hardware, plastic and asphaltic materials are some of the items which are abundantly available in different varieties. Pre-fabricated structural components such as floor and roof deckings, roof girders are also available for a wide range of spans and loading conditions. Erection of buildings has become easier and quicker with the use of pre-fabricated elements.

Though steel is still the predominant building material, concrete is coming into greater use. Hyperbolic paraboloids and folded plates are also coming into use.

Labour in the USA being very costly, labour saving devices are adopted to the utmost possible extent. This accounts for the high degree of mechanisation and the increasing use of pre-cast and pre-fabricated elements. Labour in the building industry is well-organised and the labour organisations have done valuable work in keeping up the standard of workmanship in different trades by focussing attention on proper training of artisans.

Most of the civil work in the USA is executed on contract basis. The general contractor system is in vogue. There are a large number of sub-contractors specialising in different trades.

Italy

In the post-war period construction work in Italy has been taken up on a vast scale. There was an acute shortage of essential materials like steel and cement. Yet the works were carried out with remarkable degree of success mainly because of the ingenuity of the engineers and architects in evolving new techniques of design and construction which could reduce to the minimum, the use of scarce materials. Shape engineering techniques developed successfully by Prof Nervi, greater use of clay products for structural purposes and advancement in the technique of pre-stressing may be cited as important developments. The construction work is normally done through the agency or contractors. The contracting firms possess well-organised design offices and are in a position to give competitive quotations based on their own designs.

In Italy the team observed that in addition to the Central and

Regional offices of Public Works, they have got a Superior Council of Public Works which is the highest consulting organisation on technical matters in the country and is directly responsible to the Minister of Works. This Council consists of scientists, technicians, technical teachers and even private consultants and the President of this Council is one of the top ranking engineers in the country. At times, engineers and architects who are specialists in their own line are also requested to attend the meeting by special invitation. This Council meets every month and gives advice direct to the Minister on all projects costing more than 200 million liras and

also on complicated and important projects. Under this Council there are the following six sections :—

- (1) Housing and building materials
- (2) Roads, hospitals etc
- (3) Hydraulic works, soil reclamation and irrigation
- (4) Dams and power plants
- (5) Railways and shipping, and
- (6) Town planning.

The heads of these sections are also all technical men.

Conversion Table for Currency

| | | |
|------------|---|---------|
| 100 lire | = | Rs .76 |
| 100 yen | = | Rs 1.32 |
| One dollar | = | Rs 4.73 |

CHAPTER II

Layout and planning of industrial buildings

Planning

The importance and careful planning of industrial buildings and their layout to achieve higher productivity needs no special emphasis. *Land and buildings* are as important as *equipment, man-power* and *raw materials* for an industry, forming the principal resources at its disposal for the production of goods or services. The effective utilisation or maximum productivity, of land and buildings, helps cost reduction not only when new factories are built, but also when existing enterprises are expanded. Economy in land and buildings can be effected by proper planning and laying down standards for space and land utilisation, and the consequent saving in capital can either be released for greater investment in equipment or to achieve overall saving in the capital investment in the industry. This saving in land and buildings in turn leads to lower maintenance costs and consequently reduced operational cost of the plant. Careful study of the production process and space requirements is necessary to secure maximum economy in large investment on buildings.

Design of industrial buildings depends to a great extent on the

technical processes adopted in a particular industry and on methods of handling the materials in the production process. Industrial structures, therefore, differ considerably from one industry to another. Broadly speaking, however, these structures can be grouped under the following categories :

- (i) Buildings for heavy industries (manufacture and servicing)
- (ii) Buildings for light industries (manufacture and servicing)
- (iii) Manufacturing laboratories and food processing plants
- (iv) Packing, storing and distribution plants
- (v) Warehouses
- (vi) Refineries and chemical plants, and
- (vii) Power plants.

Excepting structures of a specialised nature required for power plants, refineries and some chemical industries, buildings for the rest of the categories mentioned above have certain basic common characteristics, detailed studies of which can lead to economies in construction material and cost. Location of industry and its orderly

growth are of concern not only to the industry, but also to the local community and the Government, as unplanned and haphazard industrialisation brings in its wake socio-economic problems, some of which may prove well nigh impossible of solution except at great cost to the nation.

The following important aspects of Planning and Layout of Industrial structures should, therefore, receive careful consideration of not only the industry, but the Government as well.

Location

The site selected for the location of an industry, apart from its impact on the local community, has a direct influence on the smooth running of the industry and its ultimate efficiency and hence it deserves utmost thought. Apart from considerations such as proximity to raw materials and marketing centres, suppliers of components and accessories, local climate, transportation facilities such as easy access to arterial roads and railways always play a deciding role in the location of industries.

In the USA since the last war, there has been a definite trend towards decentralisation and dispersal of industries. This trend towards dispersal in organised industries is not solely due to security reasons. The development of a highly organised road transport system in the United States of America has been the major factor in the gradual movement of the industry to the more favourable climate of the West coast and to the countryside and suburban locations. With big open plots available in such locations, the industry is free to locate the plant in any desired alignment and to lay out the ancillary structures to suit the production process. Arrangements for expansion on account of future changes can also

be provided for, without restrictions on account of limited land areas.

India is now in the throes of industrial expansion on a large scale and it would, therefore, be appropriate at this stage to give careful thought to the location of industries in urban countries vis-a-vis suburban and rural areas. The main lesson that we can draw from the industrial growth of western countries is that industrialisation should not result in further concentration of population in urban centres which brings in its wake a train of social problems as overcrowding, creation of slums etc. In India, the growth of slums in industrial centres is due to the haphazard location of industries and lack of interest by the local bodies in control of land use. The Buildings Projects Team of the Committee on Plan Projects have drawn particular attention to this aspect in their report on Slum Clearance and have suggested certain remedial measures. One of the measures suggested is to carry industry to the people than carry people to the industry. This can be done successfully if industries are located near groups of villages which will give an opportunity to villages for employment without creating housing problems or slum development. The village housing can be improved and amenities, such as, water supply and electricity can be provided at such cheaper rate by using other funds available for the purpose instead of drawing upon the capital earmarked for the project. A small township will be necessary near the project only to house the managerial staff and other skilled labour imported from other cities. As this will lead to considerable reduction in the outlay in the development of townships in the various industrial undertakings, we would recommend that greater attention is given towards exploring the possibility of locating industries in rural areas. If in

certain circumstances, this is not possible, the next best alternative is to locate the industries round-about small towns with a population of about 50,000. These towns have normally all the facilities for setting up industrial plants and land in the suburbs of such towns is also less expensive. Another alternative is to create self-contained satellite towns.

Zoning for Industries

A survey conducted by the Buildings Research Institute under the Ministry of Construction, Japan, in 1958 revealed that approximately 90% of all enterprises in Japan are medium or small enterprises having less than 30 employees each and most of the factories operated by them are concentrated in urban areas. In large cities such as Tokyo and Osaka, the distribution is of very high density, being more than 600 factories per sq kilometer. In such large cities, it becomes difficult to acquire new land in industrial areas for further developments, and the price of land continues to rise sharply. The factories there have, therefore, recently started encroaching upon the inner and suburban residential areas and this has resulted in greater factory nuisance such as smoke, dirt, dust, and noise. The conclusion of this study is that in order to prevent deterioration of living environments caused by mixed existence of factories and residences and to prevent factory nuisance, it is necessary for the City Planning and Building Administrations to have more detailed zoning and to adopt measures for its strict enforcement.

In the USA, zoning has important features like exclusion of business and industry from residential districts. Heavy industry is permitted only at considerable distance from urban areas, while even packaging and distribution centres nearer the city have restrictions imposed on them in respect of

smoke, fumes, etc, with the result that the residential and business localities are comparatively free of such factory nuisance.

In this connection, it is to be borne in mind that the phenomenal development of road transport facilities, and its impact of life in these countries notably the USA, have made it possible to restrict the location of heavy industries at considerable distances from residential localities. This facility of rapid transport available to the workers is one of the dominant factors in industry not providing housing colonies for their workers. The team observed that it was usual in the USA for workers to come to the plant from long distances in their own transport.

In an underdeveloped country like ours, transport of labour is a major consideration which should influence the zoning for industries. In this connection, an extract from the proceedings of the Symposium on Housing and Building Materials conducted by the National Buildings Organisation, India, in 1956 would be relevant.

“Zoning of habitation units in other countries have been generally of the *dispersed* type, which entails much wasteful use of land and distances from site of work, when transport problems and attendant costs in daily life are the most important factors to be considered. In this, light zoning of habitation units should be such that it will permit development of a concentrated unit of mixed uses round the centre of maximum development and land value. Such concentrated units of business and mixed areas ringed by residential areas should be ringed by open green and relaxation areas, and further ringed by light industry areas, interspersed at regular intervals by concentrated smaller residential units, which can feed on the light industry areas. For larger cities, second ring or

zone of heavy or medium industries will be thrown off on the outlying parts, similarly, interspersed by concentrated smaller residential units, thus having alternations of zones and green belts. While it is appreciated that special areas have special problems, such zoning in principle will conduce to shortening of transport loads, and place the population closer to their work, and under *special planning* for each sub-zone or sector of development conduce to improved application of Housing Codes and Building Laws. The Central concentrated unit may again be divided into belts or sub-zones, beginning from core belts of highest land value with maximum expression of vertical expansion, tapering off to outer sub-zones, of lesser land values and lower expression of vertical expansion. One great advantage of such zoning is its capacity of maintaining, more or less, uniform density rate on fixed volume per person basis per sq. yard of land, while maintaining maximum concentration of population at the point of greater business concentration."

With large scale industrial expansion of the country, a detailed study of the proper type of zoning to be adopted is a vital matter to the country and it is, therefore, recommended that the Government of India should immediately undertake the study of the subject with a view to formulating the basis for an adequate workable Zoning Code with the help of specialized agencies such as the Institute of Town Planners, and the Industrial Development Corporations at the Central and State levels.

The responsibilities and problems of setting industry are so great that they require a regional approach to ensure maximum benefits to a locality with minimum of disturbances to its traditional character. To this end, regional surveys, followed by regional planning

integrated on the national and on the local planes will be necessary.

Layout

Layout of a factory is the disposition of the various working and storage areas or departments in a factory relative to one another including offices, staff facilities, etc., and the external services such as roads, railway sidings etc.

In the large plants visited in the USA and Italy, the team noted that the practice in such plants is to group the various workshops in a factory invariably in one large hall under single roof. Such an arrangement may not be wholly suitable to our climate. In colder countries, where winter is severe, much of the technical effort is expended on how to keep buildings warm during major part of the year and at the same time preserve the freedom and flexibility of modern open plan. In our country, the problem is to insulate buildings against external heat and it is not so difficult.

A layout providing for separate groups of buildings with plenty of inter-shop space for free ventilation would be more desirable in our case. Such grouping of separate buildings has, in addition, inherent flexibility for future expansion as, in such a design, the plant can be extended on any of its four sides without the need for reshuffling the existing layout. In the colder countries also of late there has been some rethinking on this subject and figure 1 (on page 11) illustrates the reasoning behind this logical development of the *Group of Building* layout for inherent flexibility.

With such a layout of separate buildings, the operations in each building can expand in two directions as occasion demands and this expansion can be independent of other nearby buildings. Office areas, laboratories, etc. can be kept apart from manufacturing buildings

FIGURE 1

STEPS IN THE DEVELOPMENT OF LAYOUT FOR A MANUFACTURING PLANT FOR BABY PRODUCTS AND DRESSING EQUIPMENT.

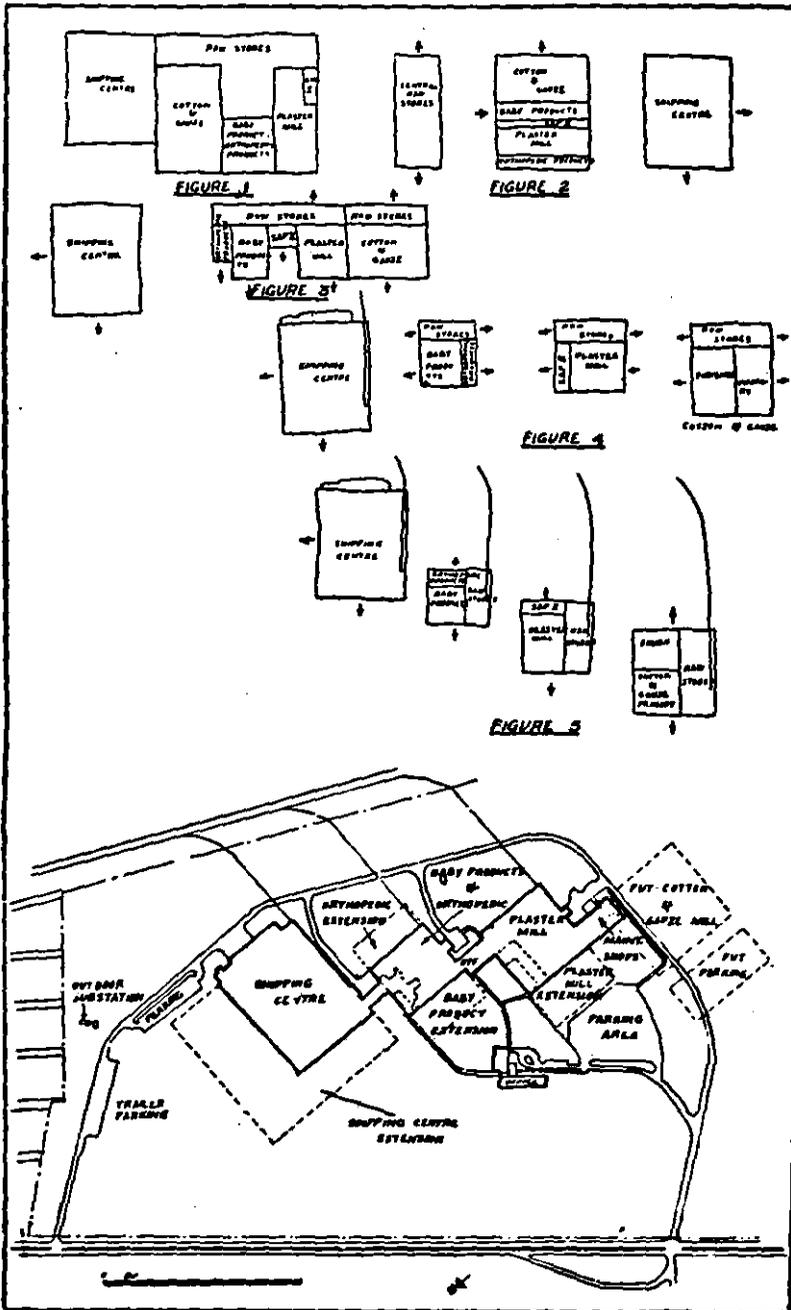


FIGURE 1 REPRESENTS THE ARRANGEMENT OF DIFFERENT AREAS, UNDER ONE LARGE HALL. EXPANSION OF EACH DEPARTMENT RESTRICTED, WITHOUT DISTURBANCE TO NEIGHBOURING AREAS.

FIGURE 2 IS AN ATTEMPT AT SEPARATE BUILDINGS WITH CENTRALIZED RAW STORES AND BETTER POSSIBILITIES OF EXPANSION FOR EACH DEPARTMENT WITHOUT AFFECTING ADJACENT AREAS.

FIGURE 3 IS AN ATTEMPT TO KEEP RAW STORES NEAR TO MANUFACTURING AREAS TO MINIMIZE HANDLING, GOOD FREEDOM TO EXPAND MANUFACTURING AREAS, BUT RAW STORES EXPANSION WILL BE AWAY FROM MANUFACTURING EXPANSION.

FIGURE 4 PARALLEL EXPANSION OF STORES AND MANUFACTURING AREAS POSSIBLE, STILL KEEPING THEM TOGETHER. RAILWAY SIDINGS INTO STORES AREAS, STILL A PROBLEM

FIGURE 5 BUILDINGS TURNED BY 90° TO SUIT RAILWAY SIDINGS INTO STORES AREAS TO FACILITATE DIRECT RECEIPT OF STORES AND MINIMIZE HANDLING. BUILDINGS STAGGERED TO CONNECT DEAN AND CONVEYOR SUITABLY.

FINAL LAYOUT

FROM "BUILDINGS FOR INDUSTRY" 1937 PUBLISHED BY F.W. DODGE CORPORATION, U.S.A.

and, while they are close to operations, they can be kept out of the way of future changes in layout.

Further advantage in this *Group of buildings layout* is that it provides plenty of materials stacking areas around the shops, so that heavy raw materials which can be stored out in the open, can be stacked close to the respective shops and issued for processing in convenient lots as and when required, cutting out wasteful haulage from a central raw materials stores. In industries involving handling of heavy steel sections, billets, timber logs, etc., group of such buildings could be connected externally by an open gantry area for direct receipt of raw materials from trucks or wagons. A single gantry crane could then serve for loading and unloading all the materials and stacking them close to the respective shops. Such an arrangement serves to mechanise the material storage and handling problem economically. If the layout should demand more than one open gantry, the logical development would be to use the same spans for all the open gantries to facilitate interchange of gantry cranes by adjusting suitably the open space between adjacent buildings.

Beside the technical considerations mentioned above the following factors also should be kept in view to ensure better working conditions :

- (a) ease of access to the various shops of the plant
- (b) adequate parking facilities for the employees' conveyances such as cycles etc.
- (c) short walking distance from parking space to the place of work or the time clock.

It was observed that except in special industries like chemical or light manufacturing, single storeyed buildings are the universal choice

for industrial plants in all the three countries visited. This is a logical solution to facilitate modern materials handling often by means of conveyors monorails, lift trucks, etc., and for efficient arrangement of production lines. It has been estimated by the Austin company that 96% of the space in a single storey plant is usable compared to 82% usable area in a six storey plant, the difference being the result of loss due to columns, outside walls, stairs, elevators, and approaches. In addition, the single storey building is cheaper to build and operate. The single storey plant has other advantages, not the least of which is increased flexibility and, for most manufacturing, improved flow and decreased material handling cost. The only factor favouring the multi-story plant is land cost.

In any layout, materials handling, whether of raw materials or process stores of finished products, should receive detailed consideration, as handling of materials represents most of the physical activity in any plant, absorbing many man-hours and even curtailing space utilisation and output. This basic material flow determines the aisle patterns, storage area stacking methods and ceiling heights, all of which determine the size and shape of the workshop structure.

As cost of paved road is a substantial proportion of the development cost of the site, the length and width of such roads should be kept to the minimum consistent with functional requirements. The team would like to cite the example of the two industrial estates visited by them in Texas where a good deal of study had gone into the planning of the layout. In one case the sellable area of the estate was as much as 75% of the total area. This was possible because of the careful provisioning of traffic lanes.

Space planning

The ideal arrangement in any plant is for the raw materials to come in at one end of the production belt, pass through all the manufacturing processes and get out as finished product at the other end. Existing factory buildings with fixed column spacings must inevitably restrict the choice of machine layouts and flow of work whenever changes are contemplated. But when constructing new factories, the machine layout is prepared first and buildings are designed around the production belt in such a way as to achieve the most economical space utilisation.

It is the natural desire of almost every industry to have as much clear and unobstructed floor space as possible with the maximum spacing of internal columns and wide working bays. However, from considerations of economics of the structure, a compromise has to be effected between column spacing and construction costs.

In American experience, the economic column grid, for most medium industries, is between 25' x 25' and 25' x 33' for simple steel construction. Where wider bays are required, for working considerations a width of 54' is usually adopted. In special cases, however, bays are even wider than this.

In workshops provided with extensive overhead cranes, the economical spacing of internal columns along working bays is about 40'-0". With this spacing gantry girders are not unduly deep and at the same time a free working space is secured. The width of bays can also be 40'-0", as it is ideal to have a square column grid so that it gives flexibility in machine layout. However, a width of 50'-0" for the working bays gives a structure consistent with flexibility and economy. While allowing room for installation of two rows

of machinery and elbow room for a pathway in the centre, installation of a third row of machinery is possible, if found necessary, at a later date

Considerable study has been made of the best column spacing for warehouses as the aim here also is always to have as much clear space as possible economically, 25' x 33' bay is more commonly adopted in the USA as this gives economical overhead sprinkler head spacing and spans and is also suitable for maximum palletized storage.

For palletized storage, the distance between columns across the building should be a multiple of the pallet width plus distance between adjacent rows of pallets. For most common sizes of pallets, a column spacing in multiples of 3' (1 meter) should satisfy this condition. The column spacing along the buildings should be a multiple of two pallet lengths, plus an aisle space between racks. Column spacing as multiples of 7' or 2 meters should be satisfactory as this provides for manoeuvring of fork lift trucks.

With the continual improvements of materials handling devices, both mechanical and procedural, notably the extensive usage of fork lift trucks and palletization, warehouses, in all the three countries visited by the team, are invariably single storeyed structures with high ceilings, so that vertical stacking is utilised to the maximum extent, combined with ease of handling. In the spare parts division of the FLAT factory in Italy the team saw an interesting example of space utilisation in modern warehousing, where the height of stacks was 10 meters with the spacing of 2 meters between stacks and 4 meters cross streets at intervals. A bank of vertical transporters operating in the 2 meter spacing between stacks facilitates handling of materials in the stacks (photo 1 on page 14.)

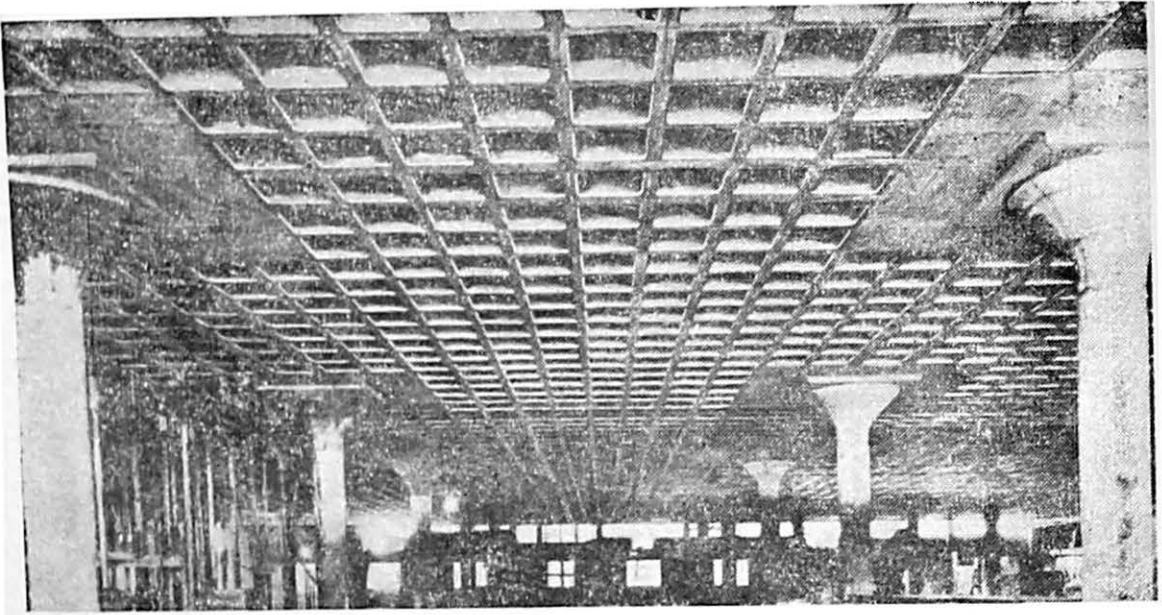


Photo 1 Material handling device, using bank of vertical transporters, in Italy.

Factory buildings

All progressive industries accept the principles of *Work Study* in their management technique towards increased productivity and such study often dictates changes in the layout of existing machinery. Change in the product due to introduction of newer models, variety reduction etc., can also affect the machine layout. Apart from this, with fast changing technology, industrial machinery and tools become rapidly obsolete. With rising labour cost, there is also a tendency to evolve multi-purpose and automatic machines, bigger and more powerful than the simple machine tools they replace. The experience in the countries visited has been that in a competitive world, plants in industrial establishments go in for modernisation to keep manufacturing costs down. In the designing of buildings for industry, therefore, a certain fluidity of manufacturing operations has always to be catered for. The buildings, therefore, should be open

and flexible in design, and the column spacing has to be fairly wide even at the risk of some increase in cost for most industrial establishments. In the USA the trend is in favour of lighter buildings with shorter life to achieve greater flexibility and expandability.

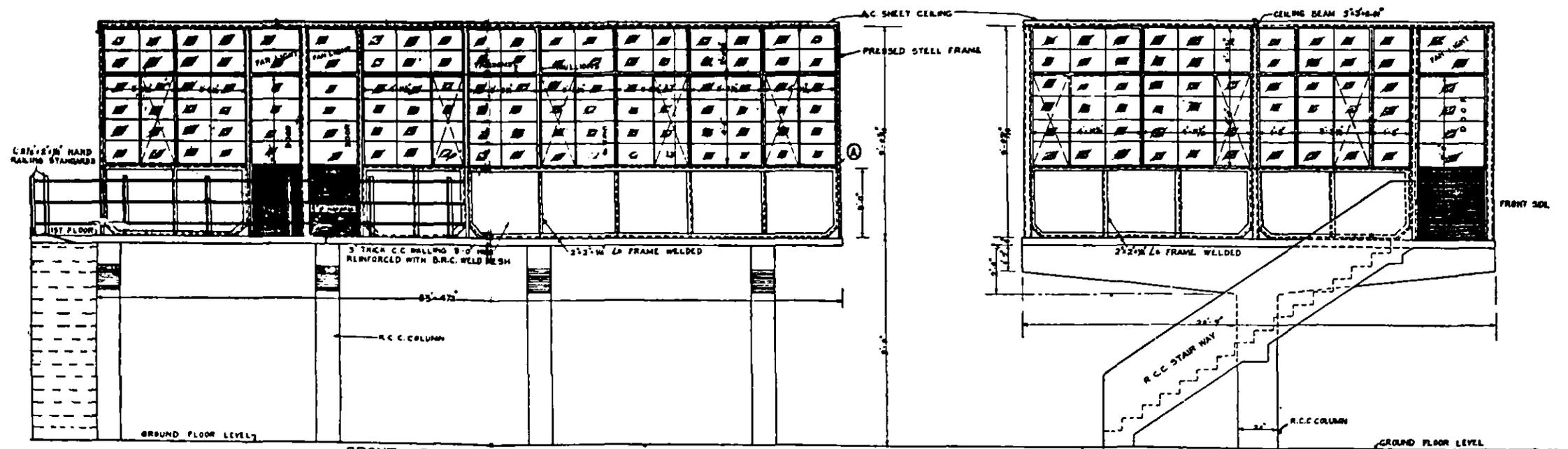
Steel construction is much in evidence as it is eminently suitable for fastness of construction and flexibility. In the countries visited by the team, preformed and pre-fabricated construction materials are abundantly available and this has greatly affected the style of buildings.

As a result of their study of factory buildings, new and old, in three countries visited, the team wishes to highlight the following salient features of industrial structures, where cost reduction can be obtained :

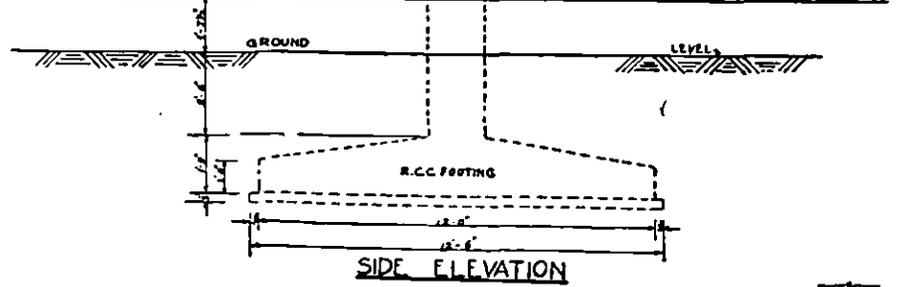
- (i) The building should be as open as possible in plant and arrangement of processes.

ELEVATED FOREMEN'S OFFICE

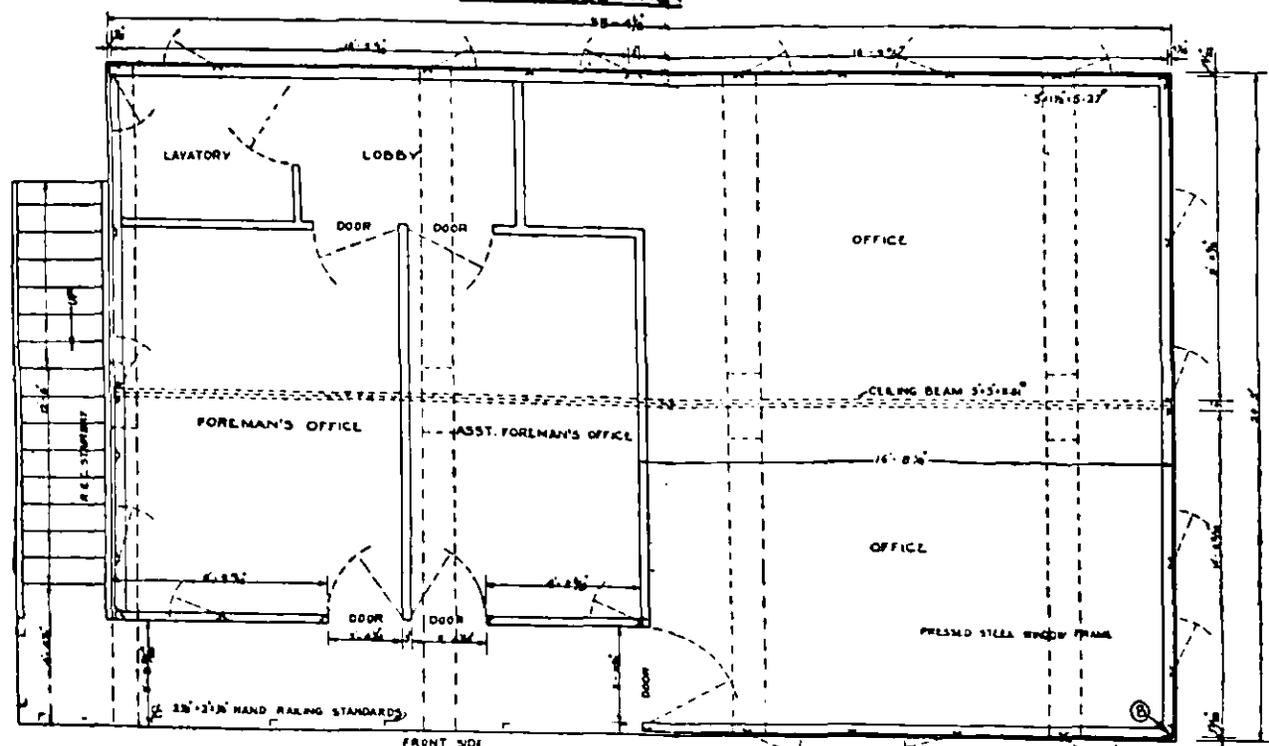
SCALE - 1/8" = 1'-0"



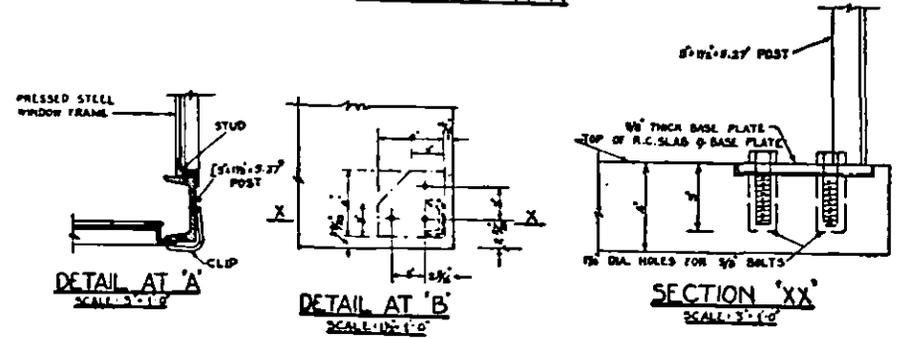
FRONT ELEVATION



SIDE ELEVATION



PLAN



DETAIL AT 'A'
SCALE - 1/2\"/>

DETAIL AT 'B'
SCALE - 1/2\"/>

SECTION 'XX'
SCALE - 1/2\"/>

- (ii) In our country, saw-tooth roofing has been generally in vogue so far for most workshops. This arrangement of roofing is generally costlier by 10 to 15% over the normal gable type roof and, therefore, may not be warranted in a large number of cases unless dictated by the superior day lighting conditions obtained in this type of roofing. The use of this type of roofing should, therefore, preferably be restricted to machine shops and to areas where precision work and manufacturing operations requiring better visibility are undertaken. The general trend in America is to use mostly flat roofs. Such roofs avoid costly valley-gutters, rainwater down pipes and corresponding underground drains through the building and this arrangement is economical on the structure also. This arrangement of roof is eminently suitable for the use of rolled steel beams or standard open web or bar joists commercially available in suitable lengths in that country. Site fabrication, therefore, is completely cut out resulting in a most economic building. Similarly, the columns for the building is also of rolled structural sections or pipe columns. It was claimed that such flat roofs with gentle roof slopes could be used for buildings upto 300' width even in an area where the annual rainfall was of the order of 30", fairly well distributed over the whole year. In view of the economy offered, it will be worthwhile to try this type of roofing on an experimental basis to see if it proves suitable to the arid regions.
- (iii) For flexibility, partition walls inside the building should only be used as a last resort. In the USA, partition walls are very rarely used even to isolate section of dusty or noisy processes. The aim there is always to clean up a dusty process rather than to isolate it. So minimum partitioning more than preserving flexibility becomes an urge to orderliness and good house-keeping.
- (iv) Foreman's offices and other shop offices and employees' facilities such as locker space etc., may be situated on mezzanine floor inside the shop, so that the valuable shop floor below is not wasted. Plate 1 (opposite this page) gives details of a type of prefabricated foreman's offices that can be tried. The space below the raised RCC cantilever platform can be used to house tool issue counters and stores. In the case of servicing industries, it would be better to have the elevated platform of prefabricated type, so that it could be shifted about to suit the change in the work flow.
- (v) In all heavy industries and where materials are handled by fork lift trucks and similar surface transports, the shop floor should be preferably at the same level as the crown of the road outside the shops. In other cases too, provision of a plinth for the shop floor may be rarely necessary for manufacturing shops, except in positions where loading and unloading facilities may be required direct from railway wagons or road trucks.
- The paved shop floor should have as few joints as possible, as each joint is a source of weakness. The team observed in one instance a factory floor under construction by alternate bay method with width of 20' and undivided lengths of 300' at a stretch. Junctions of adjacent bays were strengthened by 3' long dowel bars and the floor

was nominally reinforced. In some cases, bay sizes of 75' x 50' were also common.

In such wide floors, as heaving of the sub-grade below is the most common cause of failure, the floor slab is of a minimum 6" thickness, founded on 6" to 8" thick soling below and 3/4" to 1" wearing coat laid monolithically on top. In the case of smithy floors a flexible paving using stones set in bitumen is satisfactory to withstand the vibration to which the floor is subjected from drop hammers.

- (vi) Roof-gutters and rainwater down pipes in asbestos products can be used in preference to pressed steel gutters and CI rain water down pipes, as these asbestos products have proved successful in our country. In locations, where the bottom stretch of the rain water down pipes may be subjected to damage from movement of materials, the bottom length of 8' to 10' may alone be replaced with CI pipes with suitable adapters.
- (vii) Roof purlins and gantry girders should be designed as continuous on the one hinge system with erection joints at 1/5th to 1/4th span as this effects considerable economy and also facilitates erection.

Warehouses and bulk storage

In a manufacturing plant, the building cost may vary upto one-third of the total cost. In the case of warehouses, however, the cost of the structure itself is a large part of the total operating costs and therefore it is all the more necessary to design the most economical and functional building to get the lowest operating cost.

In the USA the typical warehouse is built with masonry bearing walls, light open web long span joist roof

with steel or reinforced concrete interior columns. They are usually built on raised platforms fed by rail on one side and a truck dock on the other, the height of the warehouse floor being generally about 3'6" above ground level to suit direct loading into and unloading from railway wagons or road trucks. The ceiling heights to the bottom chord of the roof carrying elements are generally not less than 18' and with modern material handling and stacking equipment, the stacking height is progressively on the increase. The ceiling height is usually determined on the basis of 2' clearance between the maximum stacking height and the sprinkler head below the ceiling. A hard wearing and highly finished floor space is considered essential for successful warehousing and this is provided by 5" or 6" thick concrete flooring with an integral wearing coat.

Lighting and ventilation

In the USA there is a school of thought preferring artificial lighting in industrial plants to natural day lighting, as the control of artificial lighting is comparatively simpler. It is also argued that the production schedules of most factories include night shifts, for which adequate artificial lighting has in any case to be provided. The same lighting should also do for the day shift employees. However, though the lighting industry is constantly at pains to make out light produced by artificial sources as natural and as smooth as day light, workers react unfavourably to working long hours under artificial lighting during day time. Psychologically, men need to be in contact with nature outside. While, therefore artificial lighting may supplement daylight, it should never be made to supplant the same.

In a country like ours blessed with abundance of day light, it would be desirable to take advantage of the

same and avoid recurring costs on artificial lighting.

For industrial structures day lighting is generally obtained by roof glazing, as windows are not of much value in lighting interiors of large halls. The objective is to produce a uniform distribution of daylight of high intensity and free of glare with minimum of costly glazing area. The principal methods adopted for such glazing are :

- (i) double pitched or curved roofs with glazing distributed along the roof slopes
- (ii) north-light or saw-toothed roofing where the glazing is normally arranged in one direction only
- (iii) monitor in conjunction with sloped roof where glazing is arranged in opposed vertical strips.

Studies conducted at the Building Research Station in UK on the comparative merits of the above three systems of roof glazings have indicated that for the same extent of glazing area provided (expressed as a percentage of the covered floor area) the double pitched roof is the most efficient as it gives the maximum intensity of light of fairly uniform distribution. Next comes the saw-toothed roof, while the monitor roofing is the least efficient of all, giving only about 30 to 60% of the light obtainable from double pitched roof.

In the case of the double pitched roof, the glazing should be provided immediately adjacent to the centre of the sloping sides to obtain uniform illumination over the whole span. In the case of saw-toothed roofing a larger number of small north lights per span is preferable to comparatively fewer lights having the same total glazed area. Monitor roofing will give satisfactory and uniform lighting if a succession of such monitors is used per span.

In any such roof glazing, the strongest contrast and glare are usually to be seen around the sources of light such as the view of the sky through the roof glazing when the area of the wall or roof around the opening is dark. This reduces the efficiency of lighting and causes discomfort. The cure for this trouble is to ensure that the brightness differences are reduced by surrounding the windows with light coloured and well-illuminated surfaces. From this point of view, the north light glazing and monitor roofs are less glaring than other types, as the underside of the roof and the surrounding areas can be illuminated directly from the sky or by reflection.

However, compared to the ordinary double pitched roof, the north light roof is about 10 to 15% costlier and, therefore, indiscriminate use of this type of roof may not be warranted in most cases. For majority of industrial plants, packing and distribution centres, ware houses, chemical plants, etc. the monitor type of roof lighting with strip glazing along the side walls at the eaves level supplemented with windows and artificial lighting as required, may be an economical solution. Even where considered necessary north lighting should be restricted only to those particular buildings in the layout which need it; the rest of the buildings may have less expensive type of lighting.

The amount of illumination to be provided for comfortable working conditions differs for various occupations. In the past, the extent of vertical glazing in north light roofing in Indian workshops was as high as 40 to 45% of the floor area covered. This high percentage has to be attributed to the practice of western countries where it is necessary due to weather conditions. In India, such high percentages tend to produce excessive glare in the summer months and portions of the

glazing have to be blanked off or painted over to reduce the glare. An effective glazing area of about 25 to 30% of the floor area gives a reasonable standard of lighting for our climate consistent with economy. However, as glazing is a costly item and as all possible economy should be effected to keep the cost down, it is essential to decide more precisely the extent of such glazing to be provided to give just adequate lighting for various occupations.

The team, therefore, considers that this would be a fit subject for study by research organisation in view of the scope for considerable economy in this direction.

In the countries visited by the team, ventilation of the factory premises was not so much of a problem as exclusion of the outside weather, artificial control of indoor temperatures and insulation for retention of indoor heat. In our country, the problem is to provide protection against outside heat and promote ventilation for comfort. In our present state of economy, air-conditioning of the interiors, as many American plants do, cannot be thought of. The design for comfort in our factories, should, therefore, be on the lines of taking advantage of natural breeze for ventilation, resorting to forced or mechanical ventilation only in exceptional circumstances.

In the hot humid regions of India the main factor that controls design for comfort is adequate ventilation, as air movements enable the body to lose heat by evaporative cooling. In such climates the windows and permanent openings should be placed sufficiently low to ensure thorough ventilation. In plants where dust, noise, etc. are to be avoided, external walls may be required to enclose the working area. Such external enclosures may be of masonry upto 12' height with aluminium or corrugated asbestos sheet

side cladding above, as an economical solution. To provide adequate ventilation through the enclosure the aluminium or AC sheet side cladding above the masonry walls should be in the form of wide sheeted louvres as in Plate 2 (opposite this page). This, together with precast concrete louvres below the window sills in the masonry side walls, preserves the openness of the shops, while providing the requisite enclosure. In the case of foundries, forges and heat treatment shops no such external walls in masonry may be required if the factory, as a whole, is fenced or enclosed by a compound wall. The aluminium or AC sheet side cladding may be provided starting from a height of 6' to 8' above the floor level to provide free ventilation.

In arid regions, the louvres in the side sheeting and the precast concrete louvres in the masonry wall below should be eliminated to prevent the ingress of dry hot winds during the summer months and cold breeze during the winter.

As most manufacturing operations would require a ceiling height of not less than 14' to 16' below the bottom chord of trusses, single layer asbestos or aluminium roof should be sufficient in our country to keep down the effect of radiant heat.

Services

In most of the factories visited, the team was impressed by the good house-keeping on the factory floor. Work places were remarkably clean and the employees seemed to be conscious of their individual responsibilities. This should be attributed in no small measure to the psychological effect of well finished floors and cheerful disposition of the men.

Service pipes such as water supply, compressed air, etc., when run above ground, at roof level or between

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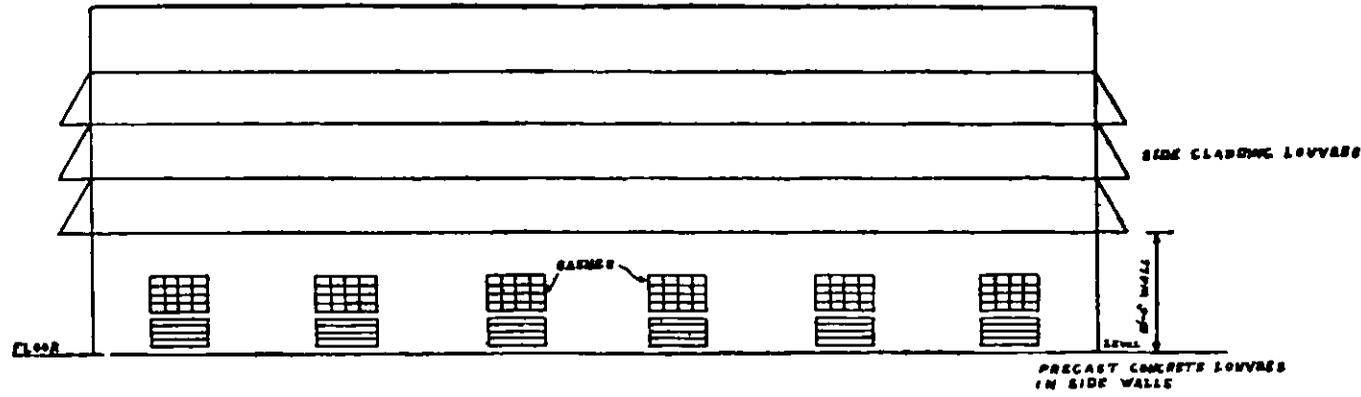
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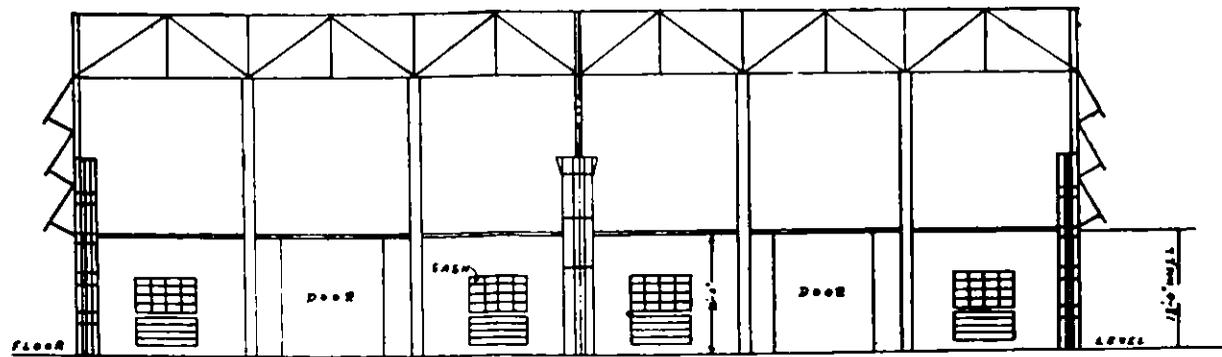
Service pipes such as water supply, compressed air, etc., when run above ground, at roof level or between

DETAILS OF LOUVRES IN SIDE WALLS AND CLADDING

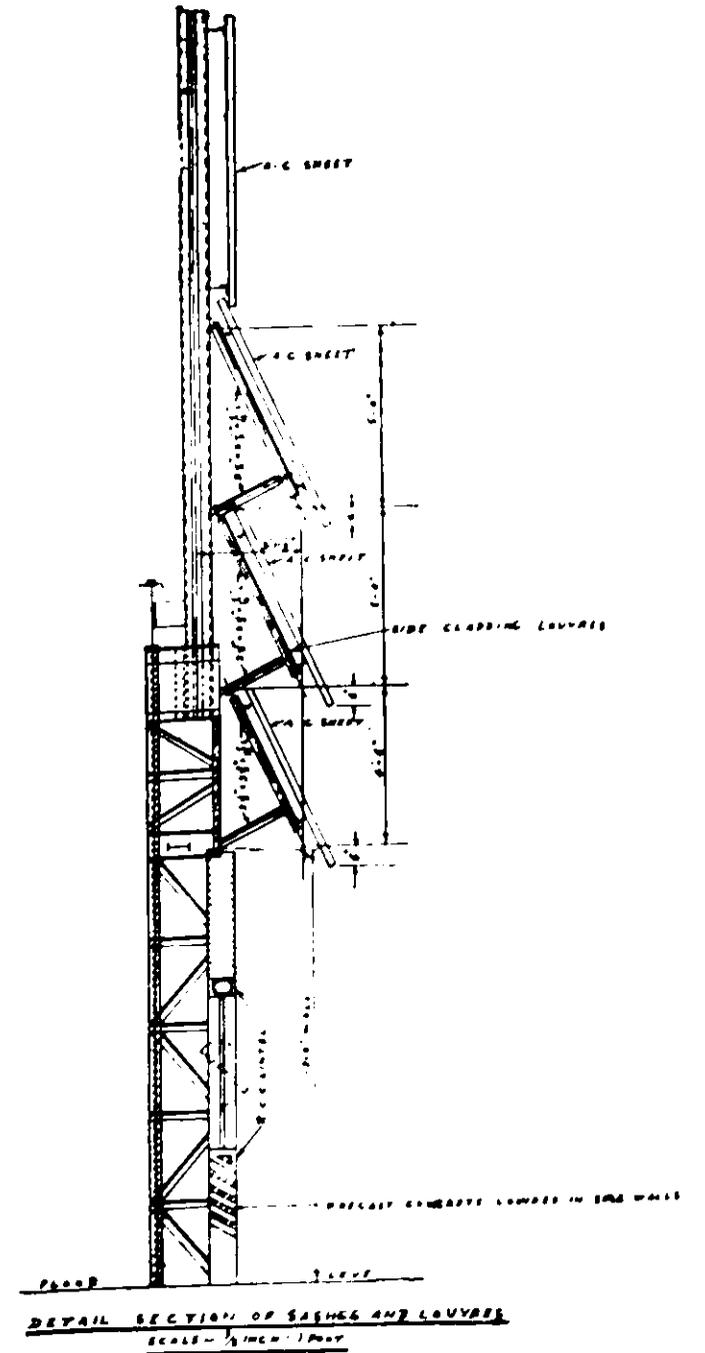
SCALE - 1/8" = 3'-0"



ELEVATION



SECTION



column tops, detract from the general appearance of the work places. Moreover such pipes collect dust, cobwebs, etc., in our climate and cannot be kept clean. The use of compact floor trenches, covered with steel chequered plates, for accommodating such services has much to commend itself. While permitting easy access for repair and maintenance, the shop floor is left free and unobstructed.

In the matter of electrical service also, modern plants frequently utilize feeder conduits buried in the floor. This not only improves the appearance of the plant but frequently reduces the cost, as the runs are shorter. But this system of distribution is quite inflexible and may not suit subsequent changes and re-location of equipment. Overhead busbar distribution is adopted widely in many modern plants on account of flexibility of the system. This system, however, suffers from the disadvantage that the appearance of the interior of the factory is marred by a series of crisscross individual drops to the machine from the overhead busbar. This system, in the opinion of the team, should be considered only if it becomes otherwise unavoidable.

At the Huntington Beach Steam Plant near Los Angeles, the team saw an interesting example of ocean water being directly used for the cooling system. The use of ocean water does lead to marine growth inside the cooling tubes. Once a month the water is heated to 100°C and pumped through the tubes to kill the marine growth. To prevent corrosion, the tubes are made of arsenic aluminium brass. The team was told that in some of their sister steam plants elsewhere they had to use plastic paints and chemical coatings for the tubes to prevent corrosion. However, in their opinion, the use of ocean water is ultimately cheaper even with the cost of protective arrangements for the tubes

and eventual replacement of the tubes themselves. The comparative cost of using ocean water vis a-vis the use of cooling tower was given out as 1 : 2. It seems, therefore, worthwhile for the Indian industry, located along the sea coasts, to investigate the economics of this ocean conduit system, wherever large quantities of cooling water are required.

In all the three countries visited by the team members, it was noticed that the steel structure of the factory buildings was not fire-proofed by concrete encasing. The fire-proofing of industrial structures, it was said, was not a major consideration in the USA, as the difference of insurance rates between various fire ratings is not large enough to promote better class of buildings and fighting devices. The normal fire protection arrangements consisted of fire extinguishers and, in some cases, of fire alarms inside the building with exterior underground fire mains and fire hydrants at strategic points supplemented by overhead sprinkler system in areas of greater fire hazard. Warehouses were invariably provided with sprinkler system with a 100% coverage.

The team feels that fire risk to factory buildings is minimised considerably by the adoption of *Group of buildings* layout as recommended earlier. In large halls the provision should be made for wide fire aisles, well marked and always kept clear to sectionalise the plant and prevent the spreading of fire.

Landscaping

During the tour of the USA, the members of the team were particularly impressed by the prominence given to landscaping in the layout of factories and industrial estates or districts. To their thinking, simplicity and beauty of plant and facilities as well as good house-keeping are basic essentials in

industrial management. Not only as a gesture of goodwill but even as a business proposition, it is being increasingly recognised that anything that contributes further to the efficiency of the men at work and anything that makes the plant a more desirable place to work should readily justify its cost within a reasonable margin. It is also based on the realisation that anything that can evoke in the employee a feeling of pride and personal attachment towards the plant, pays rich dividends in better labour relations. This incidentally impresses the general public also and serves as an advertisement in itself of the efficiency of the plant. From this consideration also, location of the plant in open country is being preferred.

Landscape treatment includes the use of suitable walls, screenings, terraces, fountains, pools etc. to demarcate areas, roads and parking spaces. Treatment of the site may be in the form of grass lawns, shade trees for parking areas, roadside arboriculture, dividing hedges etc. Such landscape treatment is contemplated not only as a relief in environment but also to better the working conditions by providing shade for buildings, reducing thereby heat and glare, and to provide a wind brace in exposed locations. For pleasant surroundings nothing is more inspiring or cheaper to maintain than natural grass and trees. Artificially maintained lawns should be judicially planned.

Offices

These should be situated within easy access of the various working areas of the factory. In general, the best layout seems to be of the central corridor type with a corridor width of about 6'—8' with rooms of 16' to 18' on one side and deeper halls on the other side. The orientation of the buildings should be such as to avoid long exposure of occupied rooms, to eastern or western sun.

The factors that should be kept in view to achieve economies in the design of multi-storeyed buildings for offices are enumerated below :—

- (i) The percentage, of lettable space or carpet area (i.e. total floor area minus sanitary accommodation, circulation space for lifts, staircases, corridors, entrance halls, etc.) should be in the neighbourhood of 65 to 75% of the plinth area.
- (ii) The floor to floor height of 11' for air-conditioned buildings should be adequate. This will give a headroom of 8' in the corridors after allowing room required for air-conditioning ducts, etc.
- (iii) From fire safety point of view, the number and location of staircases should be considered in terms of travel distances and for office buildings this should not exceed 150', of which not more than 100' should be along the corridor. The travel distance is measured from the farthest point under consideration to the nearest staircase.
- (iv) The area occupied by horizontal circulation space including corridors, passages, etc., should be 12 to 14% of the plinth area and the area of vertical circulation space i.e. lifts, staircases etc., should be 4 to 5% of the plinth area.

Staff amenities

In Japan, USA and Italy considerable attention is paid to the designing and equipping of staff canteens, and cafeterias, and managements take pride in setting up better and better examples.

Proper canteen, lunch and rest room facilities should, as a rule, be planned separately. Such facilities should be close enough to the

working areas so as to minimise walking distance and should be of sufficient capacity to cater to all the staff who may patronize these facilities, without undue delay. The number employed on the largest shift, the location of their place of work and the duration of their place of work and the duration of their luncheon period should determine the size and location of the dining rooms and its connected equipment. The total number of employees in all shifts should determine the size of the kitchen and its store rooms.

In the design of cafeterias there must be enough counters to eliminate long waiting lines. In properly designed serving counters, 5 to 6 persons per minute could be served and in large installations where greater service speed is required, the provision of free flow self service counters with counter-lengths of 40 to 70' should be considered. Such counters, where food dishes are kept ready, in sectionalized compartments, are successfully in use in the USA, even for public cafeterias.

In staff canteens, the dining rooms lie unused for major part of the day. To cater to increased staff strength it would, therefore, be uneconomical to increase the dining area correspondingly. Wherever feasible, it is desirable to stagger the lunch period of the different sections in a plant provided this does not lead to complications.

Amongst other facilities to be provided for employees mention may be made of parking facilities for their cycles. Plate 3 (opposite this page) shows a good design for cycle stands. This type requires only 4.5 sq ft of covered accommodation per cycle and is easily removable.

Housing and medical facilities

The team noted that in the countries visited, the general

practice in regard to workers' housing was to leave this field to private enterprise, cooperatives, Government or municipal authorities. The industry rarely undertook this responsibility for the workers, although in one or two cases in Japan and Italy, big firms provided part of their workers with houses.

In Japan, the team saw an interesting example of providing housing in dormitories for the single employees of the Matsu Shita Electric Co. The dormitory recently built to house 212 such employees was an efficient and interesting example of space planning. The rooms, 5 meters square, are allotted to 4 occupants with sleeping bunks at two levels. Furniture such as cupboards, shelves and tables add to the convenience giving maximum comfort in minimum area. The sleeping bunks are so disposed and screened as in a train that one can read at night without disturbance to the other three occupants of the room. Another instance of good planning is a hostel for the employees of Messrs Obayashigoomi at Osaka. The hostel has 71 single-seater rooms and the proportion of total built-up area to room area is of the order of 1 : 8. This is due to the judicious planning of circulation and other ancillary space.

In the FIAT and OLIVETTI factories in Italy, health clinics are attached to the factories and to the training schools as part of the welfare measures. In these modern clinics the team saw facilities provided for indoor sun bathing during the winter, by means of ultra violet ray equipment and for corrective exercises to improve physical fitness.

Training for employees' children

The FIAT and OLIVETTI factories have a programme of training for their employees'

children. The facilities afforded to the trainees in the schools at Tunis which has well equipped workshops are very good. 250 boys are admitted every year for its three-year course. It was reported that all of them got

absorbed in the various factories under the Fiat Management. Though there was no compulsion for a trainee to enter a Fiat concern after the successful completion of his training, yet invariably one and all chose a Fiat Service.

CHAPTER III

Design and research

General trends

The development of design techniques in any country has to be viewed against the background of the availability of materials and other factors such as seismic forces etc. which influence the design. In Japan and the USA steel is available in abundance. Greater emphasis, therefore, is laid on steel construction, whereas in Italy due to the scarcity of steel in the post-war years certain other techniques of design had to be developed with a view to avoiding totally the use of steel or restricting its use to the minimum extent possible. Of late, however, the position with regard to steel has improved on account of the European Common Market and this has necessitated some rethinking on the subject. In USA also, there is a recent trend towards the adoption of concrete structures such as hyperbolic paraboloid, folded plates etc. as these are found to be as economical as other structure.

Of particular interests to the team, was the development of *Steel Skeleton Reinforced Concrete Construction* in Japan to resist seismic forces in which both structural and steel sections and mild steel bars are used as reinforcement. Equally

interesting are the light gauge steel structural sections of different patterns, pre-cast light weight reinforcement concrete components and light gauge deckings of different types. All these have been developed to a marked extent in the USA. Advancements made in pre-cast construction in Italy, especially by Prof Nervi, are very impressive and show clearly how buildings designed with a view to getting maximum structural efficiency can at once be economical in cost and architecturally pleasing.

Steel Skeleton Reinforced Concrete Construction

As mentioned earlier, this type of construction has been developed to a great extent in Japan. Its development is mainly due to the fact that reinforced concrete does not possess adequate ductility to withstand earthquake forces while a purely steel structure is "poor in resistance against the high heat caused by after shock fires". SSR Construction, therefore, was developed as a logical solution. The structural members used in such construction are all of the open web type mostly built up of light structural sections. The steel skeleton which is erected first also helps

erection, alignment and support of form work. In addition, the columns and beams in this type of construction are smaller compared to those of RCC construction, resulting in better space utilisation and reduction of floor heights in multi-storeyed structures.

Normally, multi-storeyed buildings in Japan are not more than 100 ft high above ground level with two or three and even four floors sometimes below ground level. The provision of basements gives good anchorage for the building and at the same time provides more useful space. The sub-soil water level is quite low and the problem of underground construction has been solved by the development of special processes such as *Takinaka Caisson System*.

The development of SSRC as in Japan will be of advantage in the seismic zones in this country where at present purely concrete construction or steel construction is being adopted. The ISI should consider the problem of preparing a *code* for such construction.

Composite construction

In the USA composite construction is adopted for floors and roofs on a wide scale. Several types of shear connectors are in vogue, typical among them being the Nelson studs. These studs are welded on the top flange of rolled steel beams. It is widely known that composite construction can result in the saving of steel and reduce the over-all cost of construction. Because of these advantages composite construction has been widely adopted both in the USA and Germany in the post-war years.

This type of construction, however, has not made any headway in India. Even in cases, where encased steel construction is adopted, no structural advantage is generally taken of the encasing. In the present economy of the country

where there is the urgent necessity of saving steel and reducing construction cost, the need for exploiting this type of construction needs no special emphasis. The absence of a code of practice on the subject is a handicap to the designers. The team would, therefore, suggest that the ISI should urgently take up the preparation of a code of practice for composite construction.

Taisei Truss

For single storeyed shed type construction, several types of space trusses have been developed. One such is the Taisei truss developed by Taisei Construction Co Ltd of Japan which offers an economical means of roofing large spans upto 150 meters.

Bar-Joist construction with steel decking

In the USA several types of open web joists have been developed to support floor and roof deckings. The columns generally follow a grid of 25' x 30'. The steel decking which forms roof is of 18 to 22 gauge. The width of the deck is normally 18" and it is supplied in lengths to suit the purlin spacing.

The steel decking is carried on bar-joists which form the purlin. The bar-joist is a light open-web joist whose top chord is made up of two angles and the bottom chord of two rods. The diagonals are of single rods. The spacing of the bar-joists depends on the span and the loading. The lighter types of bar-joists weigh between 3½ to 10½ lbs per foot. The weight of the entire roof including the steel deck is usually about 2 lbs per square foot. Made of hot-rolled new-billet steel, the bar-joists are shop fabricated into the form of a Warren-type truss by the shielded arc-welding process. Every weld is inspected in the factory before shipment. All joists are manufactured with a camber which varies with the length. The wide top-chord, made

up of two light angles, provides maximum lateral rigidity and adequate bearing surface. The bottom chord consisting of two rods facilitates the easy attachment of ceiling lath, service ducts etc. This type of construction is light, economical and takes less time to erect. The bar-jolsts are all standardized and manufacturers supply tables from which the joists suitable for any spacing, loading or spans can be readily selected.

Even for multi-storeyed construction, the open web joist can be easily adopted with RCC decking. The top flange of the open web joist can be of the box type which is utilised for taking service lines such as telephone cables, electric cables etc as shown in figure. 2 on page 34.

In India there is need for similar standardisation of building components. Several warehouses are to be put up at far off places and economical construction of these is possible if pre-fabricated elements are manufactured in the country. With the increase in the steel production, it should be possible to set up factories for fabricating open web girders for different spans and loading conditions together with deckings of different sizes and patterns. This will facilitate single storeyed shed construction in industrial undertakings. It can also be adopted for the structural floor system of multi-storeyed buildings.

Pre-stressed concrete

Pre-cast pre-stressed components : Pre-stressed concrete has not made much headway in Japan in building construction though it has been increasingly used for bridges. The main reason for its slow development are (a) lower fire resistance compared to reinforced concrete and (b) the difficulty of making joints fully rigid.

In the USA there has been marked development in the field of pre-stressed concrete construction in

recent years. Two factories producing precast prestressed units were visited by the team. These are the Wailes Precast Concrete Factory outside Los Angeles city and the Texcrete Factory at Dallas.

The Wailes and Associates factory manufactures precast reinforced and prestressed beams. It has an outdoor pretensioning bed 400 feet long. The high tensile wire used is in the form of strands of 7 wires, each of 2 mm. The ultimate strength of the wire used is 250,000 pi, the wires being stressed to 80% of their ultimate strength. The cement used is rapid-hardening, the aggregate being light-weight gravel with the trade of *Ridgelite*. The products include precast RCC Channels and slabs for spans upto 22 feet, prestressed precast channels for spans upto 32 feet and T-beams for spans upto 120 feet.

The Texcrete factory produces both post-tensioned as well as pre-tensioned beams. The factory started with post-tensioning facilities as this required less investment. The pretensioning bed was added later on. The pretensioning bed is equipped with a number of 10-ton jacks, each of which tensions a single strand of 7 wires of 3/8" diameter. The jacks have an extension of 30 inches. The detensioning of the entire bed is effected by four hydraulic jacks, each of 150 tons capacity operated by a single pump. The post-tensioning is carried out by the *Prescon* button-head system wherein the anchorage is by means of button-heads forged on to the end of the wires. The plant produces double-tee sections for spans upto 94 feet. The strand in the *Prescon* system is wrapped in paper and the cable duct is not subsequently grouted.

Prestressing of slabs in two directions is increasingly being employed in the USA. The team had the opportunity of studying two such jobs.

At the Huntington Beach Power Plant, prestressing in two directions of the concrete slabs was in progress. The slabs which spanned over steel beams are post-tensioned by the *Prescon* system. The stressing is done by an electrically operated jack. It was explained that although neither the spans of the slabs nor the loading over them would have normally justified prestressing, it was employed in this instance to produce a crackless slab.

The other job inspected by the team on which two-way prestressing was employed was the office of the State Transport, California. The slabs in this instance were designed as continuous and post-tensioned by sinusoidal cables using the *Prescon* system of prestressing. The erection of the slabs was by the lift-slab method.

Shell construction

Shell construction is not much in vogue in Japan though the team visited some factories with doubly curved shell roofing near Osaka. Lack of a simple method of analysing such doubly curved shells for seismic forces was mentioned as one of the factors standing in the way of its large scale adoption. But in some of the cases where they have been tried, such as the Cathode Ray Tube Factory in Ibalaki City, it has been found quite economical. It was reported that an economy of 20% over normal construction with steel was effected by the adoption of shell roofing in conjunction with movable form work.

In the USA several types of shell structures such as cylindrical shells and hyperbolic paraboloids have been adopted for the roofing of factory sheds and warehouses. There does not seem to be any hesitation to their adoption even in seismic zones. The Union Pacific Freight Terminal at Los Angeles can be cited as an example. It is

roofed over by thirty transversely continuous barrels 104 feet long with a chord-width of 44 feet. The shells which are of 4 inches uniform thickness are cast of light-weight concrete weighing 104 pounds per cubic foot using Rocklite aggregate. The cylinder strength obtained was 4200 psi. It was reported that the structure was designed for a seismic coefficient of 0.30 gm. *Maricon*, (air entraining agent) added at the rate of 1/4 pound per cubic yard, was reported to have improved the workability and retarded the time of setting. The edge beams of the shells were deeper than normal to enable them to act as rigid frames along with columns, to resist seismic forces (Photo 2 on page 27).

Hyperbolic-paraboloids were reported to have been used to some extent to roof factories in and around Dallas. The outstanding example cited was the Texas Instrument Co. where hyperbolic-paraboloids 64'x64' were used to roof the factory. On account of the large number of identical units involved, it was reported that the cost of roofing on this project worked out to be economical. The Great Southwest Corporation at Dallas, Texas, have used 16 hyperbolic-paraboloids, each 30'x52', to enclose a total area of 32,000 square feet. By using specially designed movable formwork, the corporation was able to pour one shell per day. The cost of the shell worked out to about 1.00 per square foot. A similar structure 70'x70' which was under construction to house a filling station and a few others recently completed were visited by the team. Hyperbolic-paraboloids, which work out to be as cheap as the light bar-joist construction, is making much progress in the South Western States.

Shell construction in Italy dates back to the late thirties. A special fillip to its development was given in the post-war years when there

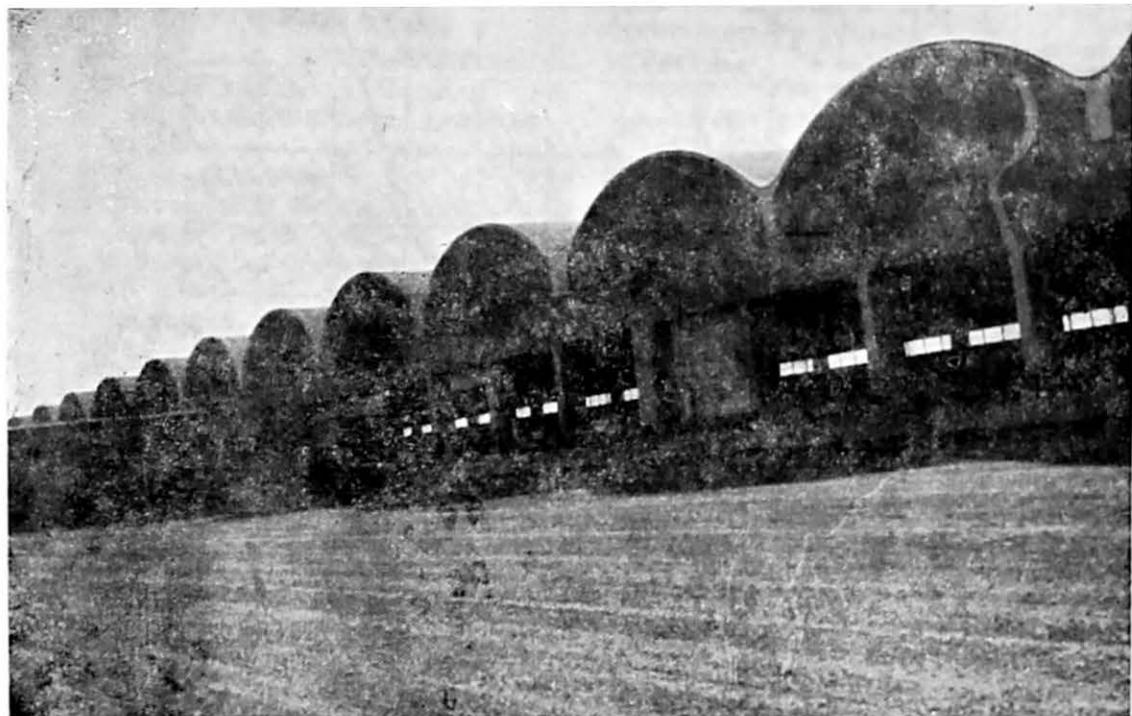


Photo 2—Cylindrical shell structure, Union Pacific Freight Terminal, Los Angeles, USA

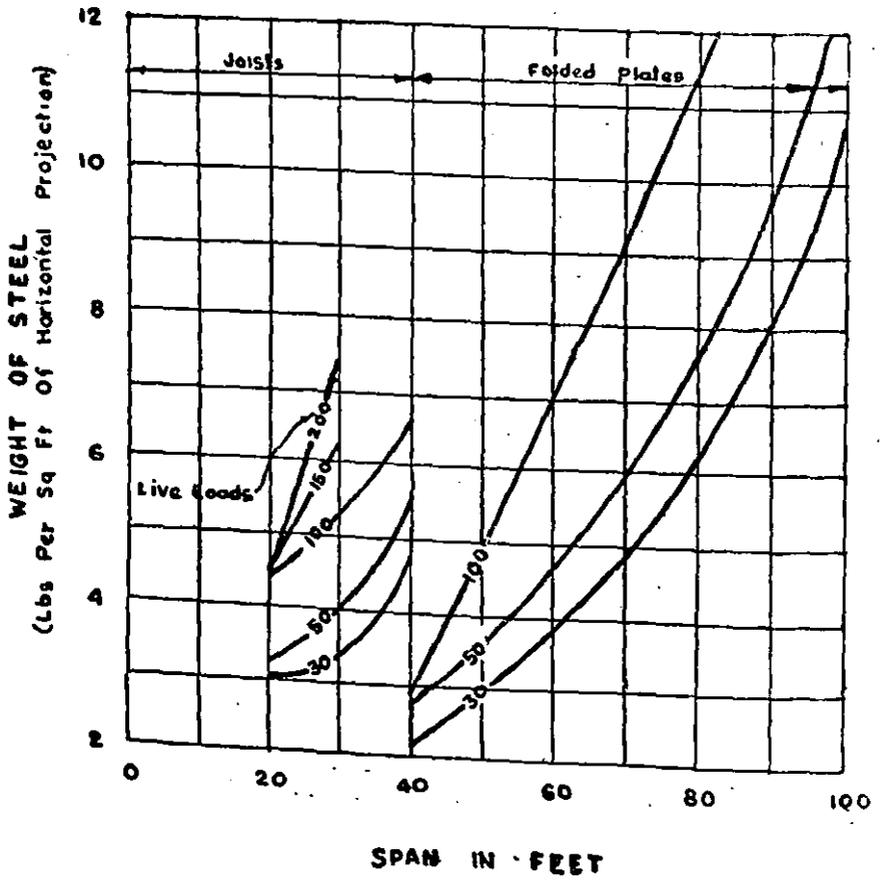
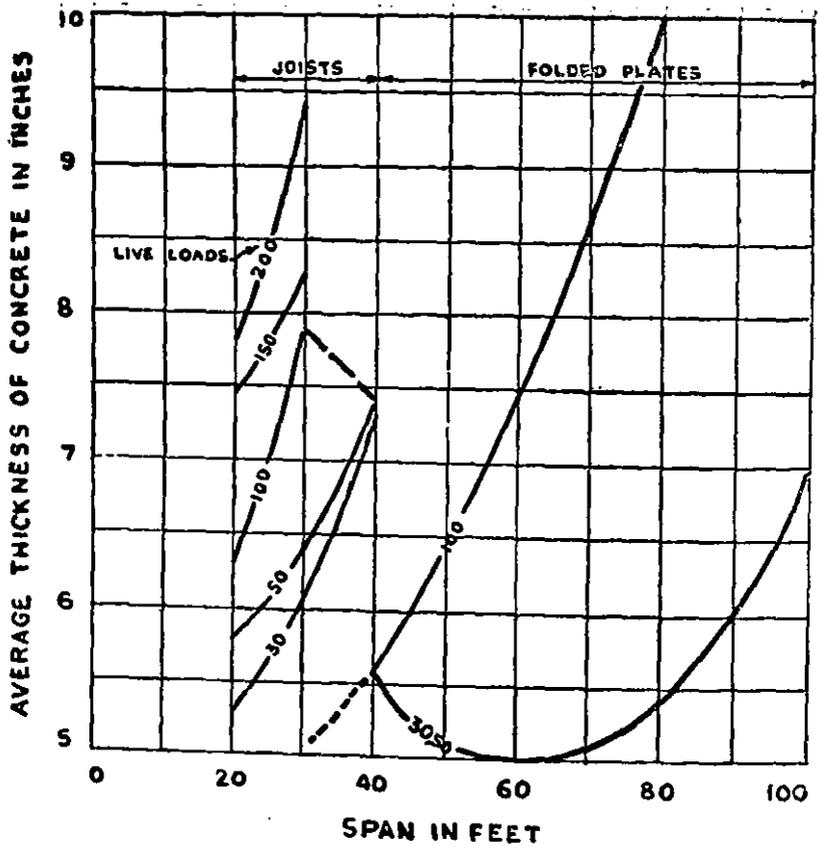
was great scarcity of structural steel. Pre-casting techniques have been adopted successfully in shell construction, reducing thereby the time of completion and cost. The exhibition hall at Turin and the Sport Place in Rome which was nearing completion at the time of the visit can be cited as examples. The latter is the most impressive structure seen by the team during the tour.

The first shell roofing was put up in Meerut as far back as in 1938. Many factories with shell roofing have thereafter been put up in the private sector. The construction organisations should see that shell designs are promoted wherever they are economical in order to save use of structural steel, which even though may available in greater quantities now should not be wasted on structures for which other alternatives are possible.

Folded plate construction

A panel of the team members had useful discussions on the subject with Mr Amman and Mr Boyd G

Anderson of the leading consulting firm of M/s Amman and Whitney, New York. It was gathered that folded plates are likely to find more extensive application in the future than even shell structures for roofing large spans. The materials involved are usually much less than those required for flat slabs or beam and slab construction and little more than what are required for continuously curved shells with the additional advantage of simpler formwork. They cited several projects, for which they had designed flooded plates. The angles are usually kept below 45° to avoid the need for top forms. The amount of steel used to cover one square foot area has been worked out to be as low as 2 to 4 pounds for spans ranging between 40 to 60 feet, and 4 to 6 pounds for spans between 60' and 80' for super load of 30 lbs per sq ft. Two graphs (Fig. 3) on page 28 are reproduced from a recent study published in the Proceedings of the American Society of Civil Engineers Structural Divisions, by Witney Anderson and Birnbaum.



Other structural forms

Flat slabs: Flat slab construction is quite popular in the USA especially for multi-storeyed garages and warehouses. A variation of the flat slab construction with a waffle-like pattern with beams running both ways is being adopted wherever wide-column-free spaces are required (Photo 3). The advantages claimed are the economy inherent

depths varying between 8 and 14 inches. The roof slabs are generally protected by 4-ply tar-felt. This type of roof is usually designed for a load of 125 pound per square foot. The slab is supported on columns with capitals as in flat-slab construction. The team saw this type of construction employed for the office block of the Union Pacific Freight Terminal at Los Angeles.

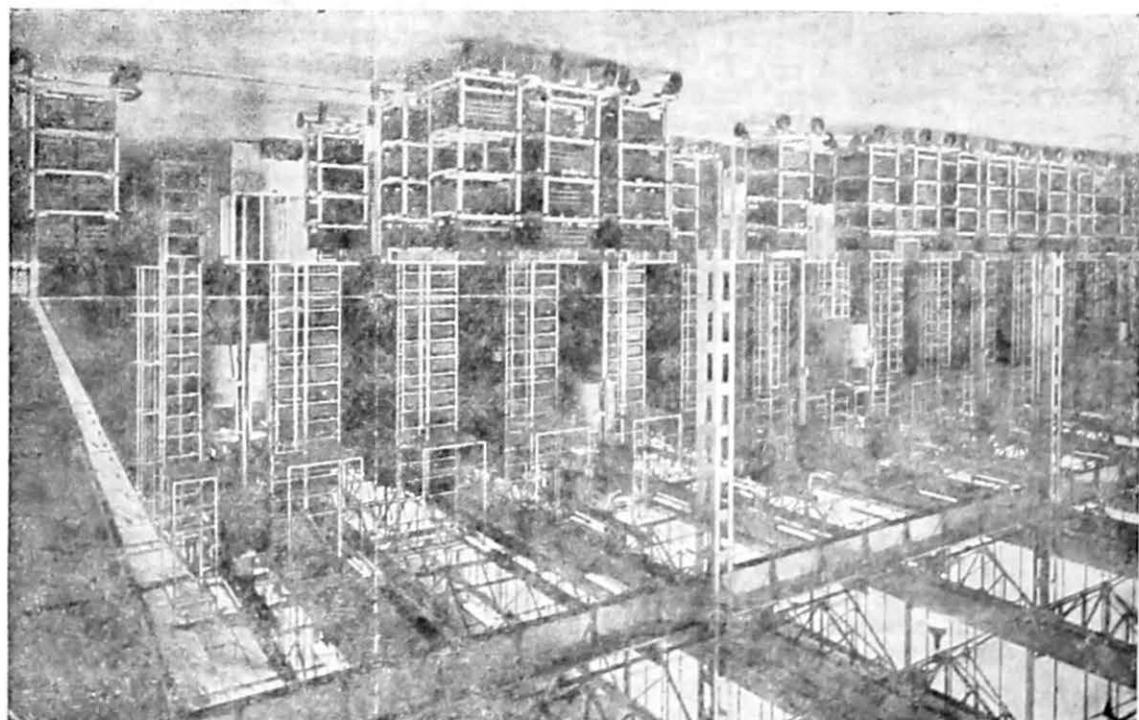


Photo 3—Variated flat-slab construction in USA

in a two-way system and the saving in dead load. Moreover, storey heights are reduced. The floor is cast on steel domes which act as the shuttering. The domes rest on runners which are in turn supported by props. The domes including the flanges measure 36"x36" in plan, the flanges being 3" wide. They are formed of 16" gauge metal. The slab cast on them is usually 2½" thick. The depth of the ribs formed can be varied by using domes of

Lift-slab construction

Lift-slab construction has successfully been tried out on a few large jobs, although its application on a very large scale to the construction of multi-storeyed buildings is far from common. Typical of such construction is the office of the State Transport, California, just nearing completion. The building consists of one ground and fourteen upper floors. The floor slabs are

150' × 300' and the column spacing is 25 feet. The building was constructed by the lift-slab method. The slabs were designed as continuous slabs prestressed in two directions at right angles. The slabs for the different floors were cast, one over the other, with Hunt's parting compound separating them. Each of the lift-slab panels measuring 75' × 150' was hoisted with the aid of eighteen 100-ton hydraulic jacks operating from the top. The post-tensioned slabs were not grouted, but their exposed ends were covered with *Hydretine*. The slabs which were temporarily secured by bolts to the columns were connected to them permanently by welding. At the time of the inspection, the construction was at an advanced stage and the slabs had already been hoisted and positioned.

RCC Trusses

Reinforced concrete trusses have been adopted extensively for the production shops of the Fiat Factory in Turin. The columns are spaced on a grid of 20m × 20m. These structures were constructed in 1939 and have given very good service for the last 20 years. The argument advanced in some quarters that RCC is not suitable for the construction of production

shops would, therefore, appear untenable.

Except in specialised types of design and construction techniques dealt with earlier, the standards adopted in India with regard to design loads, methods of structural analysis etc are comparable with those in other advanced countries.

Aseismic design

The first draft of the Japanese Code for aseismic design appeared soon after the great earthquake of 1923 which caused severe damage in the Kanto District including the Tokyo Yokohama areas. It has been revised and redrafted several times in subsequent years. The broad provisions of the current Code are summarised below:—

- (i) The lateral force F due to earthquake is arrived at by multiplying the sum of the dead and live loads and snow load in districts where heavy snow fall occurs, by a lateral load coefficient K or, $F = KW$.

The factor K itself is a product of K_0 —known as the standard seismic coefficient and two other of factors n_1 and n_2 . The standard seismic factor K_0 is taken from the below figure. The factor n_1 is taken from a map of Japan divided into three seismic probability zones

The factor n_2 which takes into account the material of construction and the nature of the soil is tabulated below :

| Subsoil condition | Wood | Steel | RCC | Masonry |
|--|------|-------|------|---------|
| Tertiary or older | 0.60 | 0.60 | 0.80 | 1.00 |
| Dealluvium or alluvium gravel | 0.80 | 0.80 | 0.90 | 1.00 |
| Normal alluvium | 1.00 | 1.00 | 1.00 | 1.00 |
| Alluvium more than 30m thick Newly reclaimed mud. | 1.50 | 1.00 | 1.00 | 1.00 |

- (ii) Earthquake and wind forces are not assumed to occur simultaneously
- (iii) An increase of 50% over the usual permissible stresses in the materials is admissible under the combined action of dead, live and earthquake loads
- (iv) An increase of 100% over the permissible bearing pressures of foundations is admissible under the combined action of dead, live and earthquake loads
- (v) The standard seismic factor K_0 for independent chimneys, water tanks and chimneys projecting over roofs is taken as 0.30. However, for the design of footings for independent chimneys, a factor 0.20 may be used.
- (vi) The Code has also detailed provisions for timber, masonry and reinforced-concrete block construction.

The question of devising a suitable code of practice for a seismic design in this country has been taken up by the Indian Standards Institution. Further research in this line is also essential. Accurate and reliable instrumentation is the first requisite of successful earthquake engineering research. A comprehensive programme of research should include (a) ground motion measurements and soil problems, (b) extensive testing of full scale model substructures, and (c) surveys and field studies after earthquakes in addition to fundamental problems and theoretical investigations. It is understood that a Research Institute for this purpose is being put up at the University of Roorkee. The team would recommend that this should be expedited.

Research

The team visited the Building Research Institute in Tokyo, the California Institute of Technology at Los Angeles and the Research and Development Laboratories of

the Portland Cement Association at Chicago. A few members of the team also visited the Kyoto University and had discussions with Dr Ban and Prof Niwa.

There are five sections in the Building Research Institute at Tokyo to deal with Town Planning and Building Economy, Building Materials, Building Structures, Execution of Building Works and Planning Design and Fire Protection. The Institute has given due weight to theoretical as well as operational research. The work of the Institute on Execution of Building Works includes studies on Light-weight Gravel Concrete, quality control of concrete in the field, construction methods using metal forms for economy, etc.

The following two research projects pertaining to earthquake engineering were of special interest to the team :—

- 1 Study of buildings actually subjected to vibrations produced by special device.
- 2 Field surveys being carried out to prepare maps showing the distribution of the earthquake hazard and providing reliable data for arriving at coefficient K .

The section for fire research has also done considerable work on the fire rating of different materials, flow pattern of fire flames and standards for fire escapes. It is understood that there is a proposal to put up a Fire Research Station in India; the details collected in this connection from Japan and the USA would be of great help.

In the California Institute of Technology the members had discussions with professors Housner and Hudson on seismic design of structures. Among the research projects which were in progress, the following deserve mention :

- (a) The machine built by the Institute for vibrating models and

actual structures to simulate the effect of earthquakes. It was explained that the machine was developed in connection with a programme for the earthquake resistant design of schools

- (b) The arbitrary function generator which can reproduce the accelerogram of any given earthquake
- (c) The analogue-computer built by the Institute to study the response of structures to any given earthquake accelerogram. The computer permits the study of structures of varying periods, degree of freedom and damping.

The subjects under investigation in the Research and Development Laboratories of the Portland Cement Association were of great interest. The Research programme that has been drawn up has the following objectives :

- (a) To support new and improved structural applications such as precast frames and bridges, shell structures, folded plates and space frames through the development of science and art of structural engineering
- (b) To extend knowledge of the structural properties of concrete, with particular emphasis on precasting, prestressing, lightweight aggregate and the use of high-strength, deformed bar reinforcement
- (c) To advance structural concrete design through improved methods and concepts such as ultimate strength design, shell theory and limit design, and
- (d) "To improve structural details in order to facilitate mechanized construction and reduce costs"

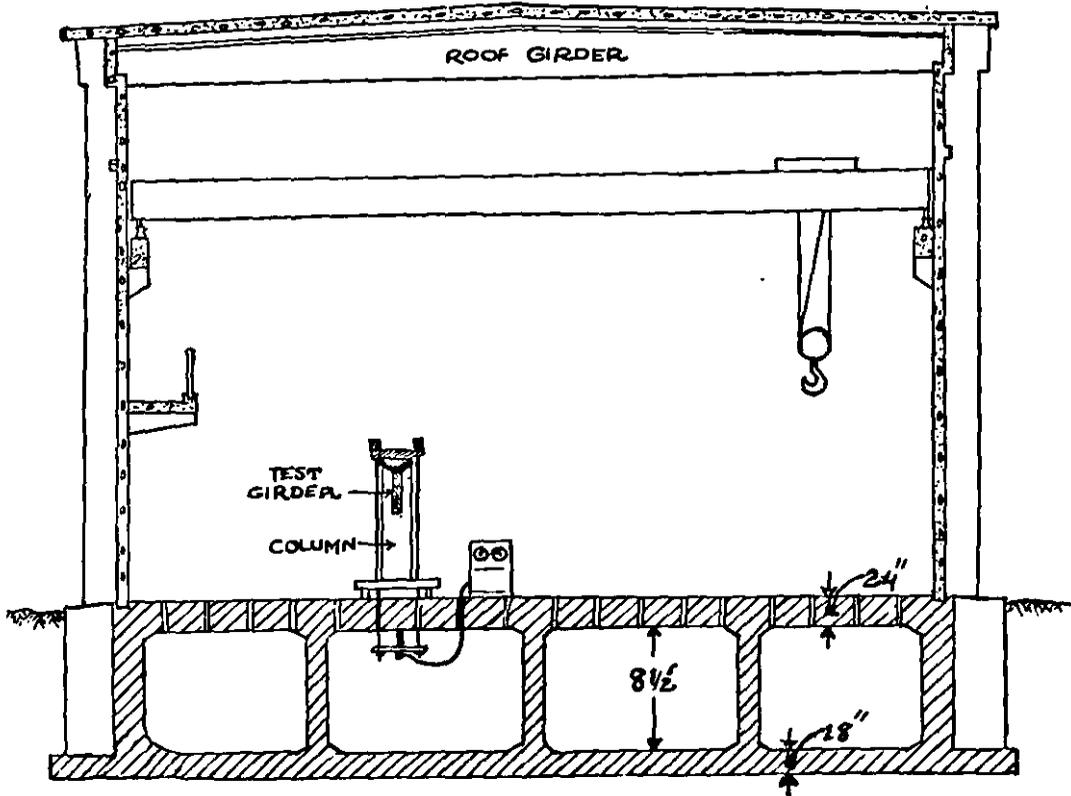
The new PCA Structural Laboratory, near Chicago, completed in 1958, is itself a giant testing machine capable of resisting over 10 million pounds. It has a heavy duty test floor 56' x 121' which is pierced by a total of 690 holes

located at 3 feet centres. Structure and specimens under test are loaded by tie rods passing through these holes. The loads are applied to the tie rods by hydraulic jacks reacting against the underside of the floors and transferring the loads to the tie-rods through crossbeams. The test floor is designed as a hollow box-girder in the longitudinal direction and as a Vierendeel girder in the transverse direction. The depth of the girder is 12 feet ; the top floor which is 24 inches thick is connected to the basement floor which is 18 inches thick by webs which are 8½ feet deep. The loading jacks are housed in the basement (Fig. 4 on page 33). The laboratory is equipped with 150 ton hydraulic rams of an inexpensive commercial variety. With the aid of these jacks, a variety of arrangements of loading on test structures is possible. At the time of the visit a hyperbolic paraboloid was being loaded by means of thirty 10-ton rams acting through 60 tie rods. The members of the team had detailed discussions with Dr Hognested, Manager of the Structural Development Division, as similar facilities are under installation at the Central Building Research Institute, Roorkee. Details were also collected of the instrumentation used at the PCA for measurement of strains and deflections, were also collected and these would be of great use for further work in the CBRI.

In Italy, the team visited the Institute Sperimentale Modelli E Structure at Bergano. The Institute undertakes model studies of buildings, dams and other structures. It is a nonprofit making organization financed mainly by leading Italian Hydro-electric engineering companies and cement manufacturers. The following are some of the test facilities available at the Institute :—

- (i) A cylindrical tower about 55 feet high and 32 feet in internal

Fig. 4



Cross Sectional View of Heavy Duty Floor

diameter. Built of heavily reinforced concrete, it has two concentric rings of columns which are stiffened by horizontal slab-rings at the various floor levels. The slabs support removable wall units which span between the columns. With this arrangement, the internal cylindrical surface of the tower can sustain a horizontal thrust in any direction. The foundation slab of the testing tower is 60 inches thick and is provided

with 128 anchorage sockets on a square grid of approximately 3 feet centres. One of the largest building models to be tested in the tower was 1/15th scale model of the 440 feet high, 32 storey pirelli skyscraper in Milan. A model of the structure in pumice mortar was tested to determine its deformations under design loading and its natural frequencies in flexure and tension when subjected to various wind load conditions.

- (ii) Facilities for the simulation of earthquake vibrations. A steel frame $13' \times 10'$ in plan has been built and this can be vibrated in the following ways :
- (a) by impact of a pendulum weight
 - (b) mechanically to produce a unidirectional harmonic vibration, and
 - (c) electromagnetically to produce the resultant vibration of two simple harmonic vibrations of varying amplitudes in two directions at right angles.
- (iii) Several spring dynamometers and hydraulic jacks for applying loads. Besides mechanical extensometers and electrical strain gauges, the Institute uses large numbers of acoustic gauges made by officine Galelio with gauge lengths varying from 0.80 to 4.7 inches.

The extensive use of model analysis in structural design which has been adopted in Italy is worthy of emulation. It is desirable that similar facilities are made available in this country.

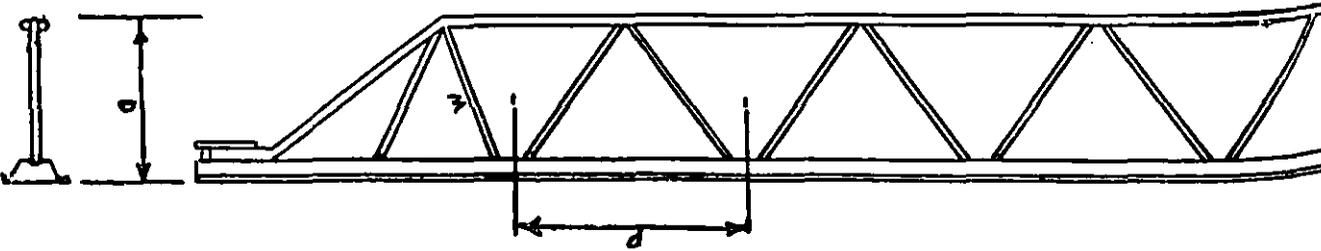


Fig. 2. Box type service lines

CHAPTER IV

Materials

General trends

In all the countries visited, the building material industry has made significant advance in the post-war years. A wide array of materials is available in abundance to suit the varying need of the different patterns of structures and the types of buildings that are coming into vogue. Light gauge steel sections, different types of deformed bars for RCC work, light weight aggregates of different grades, varieties of flooring and panelling materials can be mentioned as some of the outstanding developments in the USA and Japan. In spite of the high wage level in the USA, the building industry has been able to keep down the cost of construction by evolving substitute materials and new methods of construction. These measures have also enabled them to increase the productivity in the building industry.

In Italy, the clay products industry has registered remarkable progress in the post-war years and a wide range of products are available both for structural and non-structural uses.

Steel materials

The role played by light gauge steel, barjoists, high tension bolts and

simple methods of prestressing such as the *Prescon System* have been outlined in the previous chapter. The team strongly recommends that steps be taken by Government to set up factories for the production of light gauge steel and other structural units. The team understands that a factory for manufacturing high tensile wire is being established. It would strongly recommend that the plan for this be finalised quickly.

Deformed bars are almost exclusively being used for RCC work in the USA. According to Dr Hogenstad of the Portland Cement Association, Chicago, the trend in future will be to use alloy steel deformed bars with a yield point of the order of 70,000 lbs per sq inch. Precast units reinforced with such deformed bars have already been used in the construction of the structural laboratory of the Portland Cement Association at Skokie on an experimental basis. The economy due to adoption of deformed bars in RCC construction is too well known to require any special mention. The team would recommend the manufacture of such deformed bars in the country so that they may be used in RCC work, thereby effecting economy in

cost as well as in the consumption of steel reinforcement.

High strength bolts

An important development in the field of steel construction in the USA is the extensive use of high strength bolts for field connections in place of rivets and ordinary bolts. As a result of research work sponsored by the Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, this new type of connection was introduced into structural practice in 1947. Unlike in riveted connections, the joint depends on the friction between the faying surfaces of the connected members for stress transfer. The connection employs pre-tensioned *high strength steel bolt* with hardened washers, the bolts working with a clearance of 1/16" in the holes. The bolt is made from medium carbon steel and is heat-treated, quenched and tempered. Unlike in an ordinary bolted-joint, hardened washers are used both under the bolt head as well as the nut. The heavy semi-finished hexagonal nuts are made from steel similar to that used for the bolt, but no heat-treatment is given. The hardened washers are either quenched and tempered or carburized, quenched and tempered. The bolts are given the recommended initial tension by the use of pneumatic impact wrenches. Hand-operated torque wrenches can also be used. But manual wrenching is slow, cumbersome and expensive. The recommended tensions for different diameters of bolts, the minimum bolt tension required and the equivalent torque to be applied to the torque-wrenches are tabulated in the next column from a publication of Bethlehem Steel.

At present, development of high strength bolts is not possible as the type and grade of steel required is not being manufactured in the country. The possibility of introducing this in the country needs examination.

| Bolt Size (in.) | Recommended* Bolt Tension for Calibrating Wrenches | Required Min. ** Bolt Tension (lb.) | Approximate *** Equivalent Torque for Required Minimum Bolt Tension (lb. ft.) |
|-----------------|--|-------------------------------------|---|
| 1/2 | 12,500 | 10,850 | 90 |
| 5/8 | 20,000 | 17,250 | 180 |
| 3/4 | 29,000 | 25,600 | 320 |
| 7/8 | 37,000 | 32,400 | 470 |
| 1 | 49,000 | 42,500 | 710 |
| 1-1/8 | 58,000 | 50,800 | 960 |
| 1-1/4 | 74,000 | 64,500 | 1350 |

* Approximately 15 per cent in excess of the Required Minimum Bolt Tension.

** Equal to 90 per cent of the maximum Proof Load of Bolt (ASTM A325). There is no recommended maximum bolt tension.

*** Equal to 0.0167 lb. ft. per in. bolt diameter per lb. tension for non-lubricated bolts and nuts. Values given are experimental approximations. If torque rather than tension is to be measured, the torquetension ratio shall be determined by the actual conditions of the application.

Light-weight aggregates

The progress made in the use of light-weight aggregates for insulating and structural grade concretes in the USA was of great interest to the team. These are replacing gravel aggregate to a very great extent for reinforced concrete and prestressed-concrete work, especially in the Western and South-Western United States. These are preferred on account of their lighter weight, higher insulating value and better acoustic properties.

The light-weight aggregates that are being used in the United States may be divided into :

- (i) aggregates of volcanic origin, such as Perlite, which expand on the application of heat because of the entrapped pockets of gas
- (ii) micaceous minerals such as vermiculite which expand to 30 times their original volume on

being dried, ground and subjected to a temperature of 1800°F for 4 to 8 seconds

- (iii) byproducts of industry such as blast furnace slag (foamed slag) treated with controlled quantities of water, and
- (iv) expanded clays and shales such as Haydite and Rocklite.

Of these, the first two produce a very light concrete weighing between 6 to 16 lbs per cubic foot which is suitable only for insulating purposes. Aggregates made from blast-furnace slag are mainly used in the manufacture of blocks. Those made from expanded clays and shales are the most important as these are suitable for use in reinforced concrete and prestressed-concrete work.

Although a patent for the manufacture of Hydite was granted to one Stephen Hayde, a Kansas City ceramic engineer, as far back as 1918, it is only since 1949 that there has been phenomenal development in this field. The acceptance of light-weight aggregates on a very large scale in building construction is mainly due to the research initiated by bodies such as the Housing and Home Finance Agency, the Portland Cement Association and the manufacturers themselves.

Concrete made of expanded clay and shale aggregates marketed under the trade names of Haydite, Rocklite, Ridgelite etc weighs about 100 lbs per cubic foot. Cylinder strengths as high as 8000 psi are possible and these aggregates are, therefore, suitable for reinforced-concrete and prestressed-concrete work. They effect a straight saving of 33-1/3 % in the weight which is of special advantage in multi-storeyed construction. Their Modulus of Elasticity which is only about half that of normal concrete of the same strength may be calculated from the 28 day cylinder strength by using the

formula $E = 1.5 \times 10^6 + 160(f - 1000)$. As the value of E is lower, the deflections to be expected are higher and this aspect needs special attention in the design. Laboratory and field experience indicates the need for a higher proportion of fines in the aggregates. Roughly 50 to 60% of the aggregate must pass the No. 4 (ASTM) sieve. This is because the light-weight aggregates are sharp and angular and sometimes rough in texture. It is generally desirable to add an air-entraining agent to secure better workability. The aggregates are preferably presoaked before use. The mix-design of light-weight structural concretes is discussed in the "Proposed recommended practice for selecting proportions for structural light-weight concrete" (ACI Committee 613). As some of these aggregates may absorb as much as 12% of water, the problem in mix-design is to determine the amount of surface moisture that will be available as mixing water. The usual practice is to select the cement content of the mix on the basis of the strength required and determine the amount of mixing water needed to ensure adequate workability by making trial mixes. On account of wide variations in the properties of such aggregates, it is necessary to carry out tests on each aggregate and develop procedures for mix-design. The manufacturers usually do this and supply the necessary data. The most important element in the control of quality of light-weight concretes in the field is the uniformity of gradation of the aggregate from batch to batch. This is essential as the specific gravity and absorptive properties of light-weight aggregates vary over a considerable range through the various fractions of the fine material. Again to facilitate proportioning, the moisture-content of the aggregate has to be maintained more or less constant. Hence storage and handling of the aggregates require special attention.

The team visited the Texcrete factory in Dallas which is manufacturing Haydite from a locally available blue shale which is subjected to a temperature of 2000°F. Several works using light-weight concretes were visited by the team. Some of these are :

- (i) The New Union Pacific terminal where Rocklite aggregate has been used in the construction of reinforced concrete cylindrical shells,
- (ii) Office of the State Transport of California at Los-Angeles with one ground and fourteen upper floors on which lift-slab construction has been employed. The slabs are of light-weight concrete,
- (iii) The Wailes and Associates Factory outside of Los Angles manufacturing a variety of pre-cast and prestressed products using Ridgelite as aggregate,
- (iv) The Texcrete Factory at Dallas, Texas manufacturing blocks and precast prestressed products using Haydite aggregate.

The team would urge that the possibility of manufacturing similar light-weight aggregates in India requires investigation.

Another raw material which could economically be processed into light weight aggregate is fly ash, which as a by-product of the thermal power stations is available at present in sufficiently large tonnage and with the setting up of more thermal power stations during Third Five Year Plan period, this waste material is expected to become available in still larger quantities. The process employed for manufacture of lightweight aggregate from this raw material is of recent origin and a survey conducted recently has shown that the cost of installation of the plant per ton of light weight aggregate produced from this raw material is expected to be very much less than that of

the plant required to produce light weight aggregate from other raw materials like clays or shales. Therefore, consideration should also be given for conversion of this raw material viz fly ash into light weight aggregate at places of large scale construction.

Ready mixed concrete

The uses of transit or ready-mixed concrete is common in USA. This practice has been introduced in Japan also. The idea of ready-mixed concrete originated from a desire on the part of the American engineers to centralise all the concrete making operations to achieve economy and efficiency. Ready-mixed concrete ensures uniformly high standards of mix because of the greater control on quality that could be exercised in the centralised plant. On the work site also the consumer gets a number of advantages. Some of these are mentioned below :

- (a) reduction of working capital as no concrete making machinery is necessary at site
- (b) elimination of wastage of material
- (c) reduction in supervision charges
- (d) saving of space for storing raw materials and for making concrete
- (e) elimination of all arrangements for purchase and transport of raw materials.

Two methods for this are in vogue, viz (a) transit mixing and (b) central mixing. In the former, the dry materials are proportioned at the plant, water being added and the mixing done en route to the job. In the latter, both the operations of proportioning and mixing are carried out at the central plant and the concrete already mixed is transported to the site in a truck which acts as an agitator. The central mixing has a number of advantages

as all operations are done under controlled conditions. But this would require increased capital investment. The transit mixing, therefore, should be suited to conditions in the country except where large pours are required as in major projects.

Considering the economy in the cost and better control over quality that can accrue, the team would recommend the setting up of central batching plants at least at places where there is concentration of building activity.

Materials for form work

The form work needed for RCC construction is standardised to a great extent both in the USA and in Japan. Metal forms of assembled type are in greater use as they can be applied more accurately, handled easily and erected and dismantled rapidly. With the increasing use of forms the disadvantages involved in wooden forms have been eliminated. The team would recommend the standardisation of such metallic form work for increased use in this country, as it would lead to conservation of timber which at present is in short supply.

In Japan, 2 mm thick sheets are used for face plate and 2.8 mm sheets for ribs, which are electrically welded precisely to size and exactly at right angles to each other. The shape of the forms is rectangular, length being 5 ft, 4 ft, 3 ft, or 2 ft 6 inches and width 1 ft 8 inches and 4 inches while depth of the rib for all sizes is 2½ inches. Holes for clips are punched at 6 inch intervals. In addition, there are corner forms, corner angle, column clamps, extension bars and other accessories such as L and U pins. Props for these are placed at 5 ft intervals in both directions. Any odd space occurring in arranging the metal forms can be covered up and supplemented with a wooden board

nailed on to an extension bar inserted into the metal forms.

The stripping of these forms is very easy and can be done by removing the U clips. The use of these forms arrests the leaking of concrete slurry and gives smooth surface. This will, however, make the surface so smooth that plaster may not stick on to it. Where plastering is essential an adhesive glue is painted on to the surface. Another device to serve as an adequate key to the plaster work is to have special rubber *Kiffs* attached to the form work.

Mention may be made of a type of pressed cardboard centering used for circular columns in the USA. Marketed under the name *Sonotube*, it claims to have reduced the cost of centering. After concreting, the cardboard is cut out and this leaves a pleasing pattern on the columns. Another device which facilitates easy erection and dismantling of formwork is the double-headed nail.

Different types of pipe scaffolding are becoming increasingly popular. Even for timber shuttering steel spacers and special steel fittings are used, enabling thereby large units of shuttering being put up rapidly.

Materials for roofing

Factory buildings in Japan normally have steel trusses while in multi-storeyed buildings slabs of light weight concrete are provided which are covered with insulating material like heraklith and suitably water proofed. Another type of roof that has become very common is one with light gauge steel channels. Fibre boards are fixed on the under side of these channels to provide necessary insulation. For residential construction, sloping roofs with special tiles are generally used.

In USA a variety of roofing materials such as light steel troughs

asphalt shingle tiles etc are used in conjunction with pre-fabricated steel trussed beams. This enables one to secure a very light roof construction for factory buildings and warehouses.

Materials for flooring and finishing

A variety of flooring materials are available such as asphalt tiles, vinyl tiles, glazed and mat ceramic tiles, tara cota and marble mosaic tiles. The asphalt and vinyl tiles are very light and reduce the weight on the structure. They are also capable of being laid easily and quickly. These are being increasingly used in all residential and office buildings. For factories, however, the flooring is of cement concrete finished with mechanical floats using hardening materials like ironite or rocklite.

Light partitions are very common. A variety of materials are available for such partitions. An interesting development which the team has noticed is the folding type of partitions which are quite light and easy to operate. Such partitions enables multiple uses of space.

Pressed facing bricks and glazed and mat ceramic tiles are used for the external finishing of buildings which give a colourful appearance apart from affording good amount of protection against weather.

Even in a particular class of product, say *Asbestos*, a number of varieties are manufactured such as :

Small corrugated sheets, 6 mm thick,

Large corrugated sheets,

Plain flexlble board, 4' wide and 9' long,

Flat plate of perlite board, $\frac{1}{4}$ " thick,

Acoustic tiles with perforations, and

Marblite sheets.

One surface of the plain sheets is polished smooth which in itself serves as the finished surface, with out any additional treatment. Marblite sheets have a surface very similar to marble and this is obtained by giving a special treatment with the help of resins. To have further varieties colour is added integrally to one surface which gives a pleasing appearance to the otherwise dull sheeted roofing.

Synthetic resins are also applied on plywood hard-boards, asbestos sheets to get what is called the *Formica* finish. The progress of synthetic resin group products has been remarkable. These are used for ornamentation, flooring and wall paneling.

Cladding of buildings

For cladding of factory buildings, sandwich boards are increasingly adopted because of their lightness and rigidity. One type of sandwich construction is with plain AC sheets with a corrugated sheet in between hard board, aluminium and other materials used for sandwich construction.

Because of earthquake considerations, the general tendency in Japan is to avoid the use of heavy materials not only for partitions but also for internal and external walls. Panels of light weight concrete or of lath and plaster, sheets of morblite or other types of ornamental hard boards are used for walling.

Doors, windows and fittings

Doors and windows used in factories and multistoreyed buildings are of cold pressed light steel sections while in residential houses, these are of wood with shutters of paper. The general practice is to have them to hung and sliding on small ball rollers. This helps in saving floor space. Aluminium sections are gradually replacing steel in the manufacture of doors and windows. For glazing, rippled

glass, wire-reinforced glass; colour glass and even plastic sheets are used. These materials help in getting different patterns and designs for controlling light while providing a variety of architectural expression.

The impression of the team was that both from earthquake as well as climatic considerations, the area of glass provided in Japan was excessive, but it was explained that this was done to fulfil the desire of the Japanese to be one with Nature. At one place, the team was told that the tendency now was to use less glass.

In the countries visited by the team Great advance has been made in the development of high quality fittings for doors and windows. A variety of sanitary and electrical equipment conforming to standards is also available. This goes to show the ingenuity of manufacturers.

Exhibition of building materials

The team visited an extremely interesting and instructive exhibition of building materials in Japan, organised by the Japan Constructional Materials Association, in which all materials used in building industry are displayed. The exhibition, it was said, served a very useful purpose inasmuch as architects and others engaged in the building industry visited the exhibition frequently to study the latest developments in building materials with particular reference to their varying needs. The team also visited the Building Centre in Los Angeles which was run by a private individual with the support of the manufacturers of materials and a bigger one of this type in New York. An exhibition of building materials not only helps builders and architects to select materials of their own choice but also infuses a spirit of competition among the various manufacturers of building materials. The rapid advancement

in the building material industry witnessed in the USA as well as Japan can, to a great extent, be attributed to the organisation of material centres of this type. The team would strongly recommend the setting up of such centres in India, at least in the bigger cities like Calcutta, Bombay, Madras and Delhi where there is a great concentration of building activity.

Research on building materials

All big factories engaged in the manufacture of building materials have well equipped building research laboratories of their own and generally 1-1.5% of the sales amount is spent on research. Production of large variety of materials conforming to high standards has been due to the continued research in the industrial techniques of manufacturing such materials. As a result of scientific research work, new products of superior design, better performance and utility are pouring into the market. The team would, therefore, emphasise the necessity of directing both fundamental and applied research to this vital problem of development and manufacture of different types of building materials. As materials account for 60 to 65% of the cost of building works, any scheme for cost reduction gets immediately linked up with the systematic development and processing of new materials and the improvement in the manufacturing techniques of other existing materials. The team would recommend that at least 2% of the expenditure of buildings should be set apart for financing research work on these lines and for putting up pilot plants where necessary.

Equipment for the manufacture of materials

Development of materials is directly linked with the type and quality of equipment for their

manufacture. Some of the equipment like pigmills extrusion machines, rotary kilns, extrusion plants, centring stands, block making machines, etc are quite simple and can be manufactured in the country. Plants for the treatment of timber and those for the manufacture of asphaltic corrugated sheets need special mention here as the setting up of these plants will lead to saving of foreign exchange now spent on asbestos and other materials. The team would recommend that the provision for the manufacture of these equipments, and for setting up of precast factories and factories for the production of light weight aggregates be made in the Five Year Plan itself. If considerable thought is given to these aspects in the very early stages of the plan, it will be possible to improve the outturn of the existing type of materials and bring

in new materials for the efficient and economical implementation of the projects in the Third Plan.

Role of standardisation

Due to limited time available a visit to the American Standards Association could not be arranged. But it was reported that this Body has played a prominent role in rationalising the design and construction methods and in coordinating the dimensions of building materials and equipment. Along with standardisation, considerable attention has also been paid to simplification to bring down cost. Of particular interest to the team was the introduction of new techniques on the basis of performance standards. This is of prime importance at this juncture as no new methods or techniques can be introduced if standards on the basis of performance are not accepted.

CHAPTER V

Organisation for construction

General Trends

The construction methods adopted in a country are to be viewed in the light of economic factors prevalent there. The cost of labour in the USA is very high. The wage level for skilled workers is 13 to 15 times higher than in India and that for unskilled workers 20-25 times. In view of this high wage level, considerable thought has to be given to adopt methods of construction which will economise labour. Mechanisation, therefore, plays an important role, and machinery and equipment have been evolved to increase the productivity, thus reducing labour costs.

The wage for workers in the building industry compares favourably with that for workers in any other industry in the USA. In fact, it is higher than the wage level in majority of other industries. The worker in building industry, therefore, maintains a high standard of living and is conscious of his responsibility to raise output by adopting any new method of construction calculated to increase productivity.

Due to mechanisation, the overheads in building industry are high. It has accordingly become necessary

for all concerned in the building industry to preplan building projects and effect proper coordination among various trades engaged on building work so that the work is completed expeditiously. Special significance is attached to research directed to the evolution of new equipment and methods to increase productivity.

In Japan, even though the wage level is comparatively low, mechanisation has come to stay. Firms engaged exclusively in mechanised civil engineering work are developing rapidly. Firms specialising in leasing equipment alongwith skilled operators have also come up. Side by side with this, the manufacture of equipment also has been stepped up considerably. There are about 100 factories engaged in the manufacture of construction equipment.

In Italy also the building industry has been mechanised but the extent of mechanisation is much lower as compared to the USA.

Organisation at site

The first thing which impressed the team in Japan and the USA was the amount of care and attention given to organisation at site. The building site presents a tidy appear-

ance with the logical and careful arrangement of materials and equipment. The site office, which is more appropriately called the *control booth*, is located on an elevated level which facilitates better control of operations. Even in congested areas, building sites present the same tidy appearance. In such cases a control booth is placed over the side walks on suitable props. In urban areas, the building site is cordoned off to avoid any hindrance to public. Attention is also paid to the screening of buildings under construction. In such a way as to afford protection to the public from building operations.

Construction methods

Foundations : The system of bored-in-place piles widely adopted in the USA and the *Caisson system* used for multistoreyed buildings in Japan may be adopted in India in certain situations. In big cities where land costs are high basements are normally provided. Pile foundations are common for multistoreyed buildings though certain other systems such as Kida or Shimizu type foundation have also been adopted. In certain type of pile foundations adopted for heavy structures, steel pipes of $1\frac{1}{2}$ cm thickness, 75 cm in diameter and 36 to 60 meters in length are driven plugged with concrete. Bars are welded on to the top of the casing for embedment into the pile cap.

Superstructure : Special techniques such as *tilt up construction*, and *lift slab construction*, have been tried on high jobs in the USA though their application has not been on a vast scale as yet. The team visited certain buildings where these methods had been adopted and had discussions with the officials there on their practical and economic aspects. The tilt-up construction adopted for the walls of warehouses and light workshops have the advantage of saving time and

enables the structure to be removed and refitted in case the building is to be expanded. The lift slab construction envisages the casting of all floor and roof slabs at one level, casting of columns and lifting of slabs by jacks and fixing them at the appropriate levels. This type of construction is claimed to have speeded up the pace of work.

Mechanisation of construction

As mentioned earlier the construction industry has been mechanised to a great extent in all the countries visited though there may be variations in degree between one country and the other. It may not be practical at this stage, for us to follow the USA but in this respect it is all the same necessary to start a phased programme of mechanisation. With the increasing tempo of construction activity in the Third and subsequent Plans and the *permeation of democratic ideas*, mechanisation has a greater significance. Some of the appliances such as scissors lift for raising and lowering of centring, portable belt conveyors for removing excavated earth or similar material, suspended scaffolding manoeuvred by winches for finishing work on tall buildings, floating machines for finishing of floors, weigh-batching equipment for concrete work, may be brought into wider use. It is also necessary to encourage the greater adoption of fork-lift trucks, hoists and derricks for the efficient and quick handling of materials on construction jobs. Some of the equipments are already being manufactured in the country. Steps may be taken to accelerate the production of these and to start the manufacture of others.

In the development of cranes for building construction special mention may be made of the climbing crane. This has a short fixed mast, but in all other respects is similar to a mobile crane. The crane is first erected to a height of 50 ft

inside the building. As the building grows and floors are installed, holes are left for the passage of the mast, and collars embracing the mast are mounted on adjacent floors. The whole crane is then lifted by manual or powered winches and fixed at higher levels. For tall buildings the climbing cranes are economical than cranes mounted on ground. It has a further advantage that the jibs of same length can cover a greater working area. It has also got considerable advantages on congested sites where a mobile crane would need more space. The use of the crane, however, is to be decided upon at the design stage, as the structural components of the building will have to be designed to take up the loads transmitted by the crane.

There are other small equipments which may add to better control of work on building sites. A few of them which need special mention are the different types of clamps used for centering and form work which enable quicker erection and dismantling, straight edges with built-in levels which can be used in the erection of form work and construction of walls and power rammers which can be profitably employed for consolidating the earth-fill in and around buildings.

Organisation of contractors

In all the countries visited, work is done mostly through contractors, and seldom it is taken up departmentally. It is common also to entrust designs of projects to private firms of consultants. This has set up a healthy competition among different consultants and has helped in fostering new techniques of design and construction.

In the USA there is a very powerful organisation of construction contractors, called the Associated General Contractors' Association. The part played by this organisation in setting up high standards of

workmanship and in resolving disputes between clients and contractors is praiseworthy. The close collaboration of the Association with technical institutions and labour unions has led to harmony in the construction work as a whole. The commendable part played by the Association in organising disaster relief and in standardising measures for accident prevention on construction jobs deserve emulation.

The incidence and cost of accidents in building construction are much higher than is often realised. Prevention of accidents, therefore, deserves much greater consideration. The problems of accident prevention is primarily an educational and a psychological one. The only effective way of keeping down the accident rate is continued publicity, education and constant vigilance. The work undertaken and the publications brought out by the Associated General Contractors in this line should serve as a good guide for taking similar precautions in building industry in this country, and for planning accident prevention in each project and into each of the many separate activities that make up the job. An extract from the *Manual of Accident Prevention* regarding concrete construction and another extract from the same publication outlining the inspection check list for some items of construction works are given in Appendix II.

Most of the contracts in the USA are given to the general contractors who in turn engage specialist contractors for executing several items of specialised work. This method has been found to be quite successful as there is unitary control over the operations at site. The representatives of the Contractors Association emphatically declared that this method had ultimately resulted in lower costs of construction. In India the system is quite

different. Though the work as a whole is awarded to a general contractor by MES and certain other organisations, in most places various items of work are given to different contractors. This gives rise to a multiplicity of agencies working on a building site. A proper coordination of their efforts is attended by numerous difficulties and the system also has an adverse effect on the quality of the completed work. The team is of the opinion that this method should be tried more often.

The system of bonding by Insurance Companies is prevalent in the USA and Japan. This system eliminates the locking-up of contractors' money with Government departments. It is well-known that the system of security deposits prevalent in India and the delays in the settlement of accounts of contractors lead to higher tender rates. The team, therefore, recommends the introduction of bonding system on similar lines in India also.

Throughout the tour of the USA the system seems to be that final payment to contractors are made within 90 days of the physical completion of work and that no changes are made in plans or specifications during the course of work. The Productivity Team on Buildings sponsored by the Anglo-American Productivity Council also had rightly emphasised the necessity of ensuring prompt payment to contractors and the strict avoidance of changes during the execution of work. This makes it essential to finalise all the detailed architectural, structural and service plans and specifications at the tenders stage. It is the practice in USA to prepare what is called the *Green Book* which incorporates all the documents and other relevant information for the guidance of the tenderers. Convinced, as the team is, of the economy that will accrue from such complete and comprehensive planning, it would recommend the

adoption of this procedure for all major works.

It was reported in Japan that financial assistance in the form of advance was also given to contractors for purchasing materials, tools and machinery, etc.

Organisation of labour

The building labour in the USA is well organised, each class of labour having its own association. The emphasis laid on the training of skilled workmen by various labour associations and the steps they take to implement the same deserve emulation. The training courses are arranged under the joint auspices of the Associated General Contractors of America and the Unions of respective crafts. Certain national standards have been formulated for apprenticeship in each craft. These cover the basic requirements of an effective apprenticeship system and are offered for the guidance of local organisations of contractors and craftsmen. The term of apprenticeship varies from 3 to 5 years. Apprentices are paid wages during that period ranging from 50 to 95 per cent of the wage earned by workmen of that particular craft.

The apprentices are required to work 8 hours a day on works and to attend classes in subjects related to their field for about 144 hours in a year. They have to appear in an examination every year, and after passing the final examination at the end of the term they are awarded a certificate on the basis of which they can get a job in the industry. The programme is administered by a joint apprenticeship committee comprising of representatives of contractors and the labour unions.

With the increasing tempo of construction activity in India, there is a great need for the systematic training of building craftsmen. The Builders' Association and Construction agencies will have to devote

greater attention to this. It will also be advisable to draw up National Standards for apprenticeship training in various trades.

A noteworthy point with regard to labour unions in the USA is the fact that only the workers employed on the particular trade are entitled to hold any executive post in the union. No outsider is allowed to hold any post in a union. The unions are not affiliated to any political party. Their relations with the employers are cordial and almost all disputes are settled by mutual negotiations.

Mostly, the labour is engaged only for the duration of work though certain companies have a few permanent hands on their pay rolls. The payment to labour is on hourly basis and is made weekly in the USA and fortnightly in Japan. In the USA, however, there is a Fair Wage Act and the minimum wage is stipulated as \$1 per hour. Women labourers are normally not employed in building industry.

There is no labour participation in the management of industry as such, but there is ample opportunity for the labour to become employers themselves.

The organisations for contractors and labour in Japan are also modelled after those in the USA. No proper assessment of the situation in Italy could be made as the programme did not include any meetings with the associations of contractors and labour.

Productivity the key to plenty

In all the countries visited, it was clear that one of the factors contributing to higher production is the helpful attitude of trade unions and workers towards productivity. They realise that increase in productivity does not result in reduction in employment. Post-war experience has shown that advanced techniques and modern machinery would result in lower cost of products which invariably results in greater demand and increased scope of employment.

Summary of Important Recommendations

1 Location and zoning of industries

(i) Adequate attention is required to be paid to the question of exploring the possibility of locating industries in rural areas,

(ii) In order to prevent deterioration of living environments caused by mixed existence of factories and residences and to prevent factory nuisance; it is necessary for the city planning and building administrations to have more detailed zoning and measures for its strict enforcement. Study of zoning should immediately be undertaken with a view to formulating the basis for an adequate workable Zoning Code.

2 Layout of buildings

(i) *General* : A layout providing for separate groups of buildings with a plenty of inter-shop space for air ventilation would be more desirable. Such grouping of separate buildings has, in addition, inherent flexibility for future expansion. If the layout demands more than one open gantry, the logical decision would be to use the same span for all the open gantries to facilitate interchange of gantry cranes.

Single-storeyed construction is a logical solution for factories to facilitate modern material handling and for efficient arrangement of production lines.

As cost of paved roads is a substantial proportion of the development cost of site, the length and width of such roads should be kept to the minimum consistent with functional requirements.

(ii) *Factory-buildings* : To obtain cost reduction, the following salient features of industrial structures are highlighted :

- (a) the building should be as open as possible in the plan
- (b) in view of the economy offered, flat type roof may be adopted in arid regions
- (c) foremen's offices and other shop offices and employees' facilities such as locker space, etc may be situated on a mezanine floor so that the valuable shop floor below is not wasted

- (d) roof gutters and rain water down pipes in asbestos products can be used in preference to pressed steel gutters and CI rain water down pipes
- (e) roof purlins and gantry girders should be designed as continuous.

With the increase in steel production, it should be possible to set up factories for fabricating open web girders for different spans and loading conditions together with deckings of different sizes and patterns. This will facilitate single storeyed shed construction for industrial undertakings.

(iii) *Office buildings* : For office buildings, the best layout seems to be of the central corridor type with a corridor width of about 6' to 8' with rooms of 16' to 18' on one side and deeper halls on the other side. The usable space or carpet area should be of the order of 65 to 75% of the total built-up area.

3 Landscaping

Landscaping is an essential item in factory buildings layout. Sufficient attention must be given to this.

4 Working conditions in factory

The following factors should be kept in view to ensure better working conditions in a factory :

- (a) ease of access to the various shops of the plant
- (b) adequate parking facilities for the employees' conveyances, such as cycles, etc ; and
- (c) short walking distance from parking space to the place of work or the time clock.

5 Space planning

In workshops provided with extensive cranes, the economical spacing of internal columns along working bays can be about 40'. The width of bays can also be 40'.

For palletized storage, the distance between the column spacing across the building should be a multiple of 3' and along building a multiple of 7'.

6 Lighting and ventilation

Advantage should be taken of the abundant daylight available in the country to avoid recurring cost of artificial lighting. In view of the higher cost involved, northlight roofing should be restricted only to those particular buildings in the layout which need it. An effective glazing area of 20 to 30% of floor area gives a reasonable standard of lighting for our climate consistent with economy. In hot humid regions of India, windows and permanent openings should be placed sufficiently low to ensure thorough ventilation. In arid regions, louvres in the side sheeting and precast concrete louvres in the masonry walls below should be eliminated.

7 Services

(i) The use of compact floor trenches, covered with steel chequered plates for accommodating services is recommended,

(ii) Overhead busbar distribution system should be considered only if otherwise unavoidable,

(iii) Indian industries located along the sea coasts should investigate the economies of the ocean conduit system, wherever large quantities of cooling water are required,

(iv) In large halls, provision should be made for wide fire aisles, well marked and always kept clear to sectionalise the plant and prevent the spreading of fire.

8 Construction in seismic zones

(i) The development of Steel Skeleton Reinforced Concrete Construction as in Japan, will be of advantage in the seismic zones in India. The ISI should look into the problem of preparing a Code for such construction.

(ii) Further research on aseismic design and construction is essential. Necessary facilities for this should be provided.

9 Composite construction

The ISI should take up the preparation of a Code of Practice for composite construction urgently.

10 Shell construction

(i) The construction organisations should see that shell designs are promoted wherever they are economical in order to save use of structural steel, which, even though may be available in greater quantities now, should not be wasted on structures, for which other alternatives are possible,

(ii) The extensive use of model analysis in structural design which has been adopted in Italy is worthy of emulation. It is desirable that suitable facilities for this are made available in this country.

11 Concrete construction

(i) Considering the economy in cost and better control over quality, central batching plants for concrete mixing may be set up, at least at places where there is concentration of building activity,

(ii) Metallic forms may be standardised for increased use as it would lead to conservation of timber which at present is in short supply.

12 Steel materials

(i) Steps may be taken by Government to step up factories for production of light gauge steel and other structural units. The plans for the factory proposed to be set up for manufacturing high tensile wire should be finalised quickly,

(ii) The manufacture of deformed bars may be undertaken in the country so that they may be used in RCC work, thereby affecting economy in cost as well as in the consumption of steel reinforcement,

(iii) The possibility of introducing high strength bolts in the country needs examination.

13 Light weight aggregate

The possibility of manufacturing light-weight aggregates in India requires investigation.

14 Building materials centres and research

(i) Building materials centres may be set up in this country in the bigger cities like Calcutta, Bombay, Madras and Delhi where there is great concentration of building activities,

(ii) One-fourth per cent of the expenditure on buildings should be set apart for financing research work on building materials and for putting up pilot plants where necessary.

15 Manufacture of equipments

Provision must be made in the plan itself for the manufacture of equipments like rotary kilns, block-making machines, extrusion plants, etc and for the setting up of pre-cast factories and factories for the production of light-weight aggregates.

16 Standardisation

Encouragement must be given to the adoption of new techniques of design and construction on the basis of performance standards.

17 Mechanisation of construction

A phased programme for mechanisation of the building industry is essential. Greater adoption of fork lift trucks, hoists and derricks in construction jobs should be encouraged. Steps should be taken to manufacture some of these construction equipments in the country.

18 Planning for safety

Planning for accident prevention in building industry is of great importance. Greater attention to this is called for.

19 System of contract

(i) The method of giving contracts for complete works to the general contractor who, in turn, should engage specialists contractors for executing several items of specialised work should be tried,

(ii) Bonding system, as is prevalent in the USA, should be introduced in India.

20 Comprehensive planning

Complete and comprehensive planning of all major works is essential in order to avoid changes during execution of work and to ensure overall economy.

21 Apprenticeship training

It is advisable to draw up National Standards for apprenticeship training for various building trades.

List of establishments, institutions and organisations visited

Industrial establishments

- 1 Asano State Company Ltd, Tokyo, Japan.
- 2 Sanki Sash Company, Tokyo, Japan.
- 3 Tokyo Rayon Factory, Shiga Japan.
- 4 Matsushita Electrical Company, Ibalaki, Japan.
- 5 Japan Nippon Steel Tube Company, Kawasaki, Japan.
- 6 Kawasaki Power House, Japan.
- 7 General Petroleum, Los Angeles, USA.
- 8 Ware House of the Pacific Railway, Los Angeles, USA.
- 9 Lytton Industries, Los Angeles, USA.
- 10 Wales Pre-cast Concrete Factory, Los Angeles, USA.
- 11 Thermal Power Station, Huntington Beach, California, USA.
- 12 Tax-Crete Ltd, Dallas, USA.
- 13 Great South West Corporation, Dallas, USA.
- 14 Brook-Hallow Industrial Estate, Dallas, USA.
- 15 Brick and tile factory, Milan, Italy.
- 16 FIAT Automobile Manufacturing Factory, Turin, Italy.
- 17 FIAT Spare Parts Manufacturing Plant, Turin, Italy.
- 18 Olivetti Factory, Ivrea, Italy.
- 19 Una Officina Neccanica a S Bernardo d'Ivrea, Italy.

Technical and industrial institutions

- 1 Building Research Institute, Tokyo, Japan.
- 2 Testing Materials Laboratory of Tokyo University, Japan.
- 3 Kyoto University, Kyoto, Japan.

- 4 California Institute of Technology, Pasadena, California, USA.
- 5 Portland Cement Concrete Association, Chicago, USA.
- 6 Research and Development Laboratory, PCA, Skokie, USA.
- 7 Instituto Sperimentale Modlli, E Strutture, Bergamo, Italy.

Other organisations

- 1 Japan Construction Materials Association, Tokyo, Japan.
- 2 Obayashi Gumi Construction Co, Osaka, Japan.
- 3 Japan Federation of Architects and Building Engineers Associations, Tokyo, Japan.
- 4 Architectural Institute of Japan, Tokyo, Japan.
- 5 Shimizu Construction Company, Tokyo, Japan.
- 6 International Trade Centre, Tokyo, Japan.
- 7 Building Material Centre, Los Angeles, USA.
- 8 M/s Amman & Whitney, Consulting Engineers, New York, USA.
- 9 Trades Council of Greater New York & Vicinity, New York, USA.
- 10 Associated General Contractors of America, Washington, USA.
- 11 American Institute of Architects, Washington, USA.
- 12 US Department of Labour, Washington, USA.
- 13 International Centre, Washington, USA.
- 14 Ministry of Public Works, Rome, Italy.
- 15 Prof Nervi & Bartoli, Consulting Engineers, Rome, Italy.
- 16 Dr Ricardo Morandi, Consulting Engineer, Rome, Italy.

Extracts from the Manual of Accident Prevention in construction

Concrete construction materials

Men handling sacked cement should wear goggles, durable close-fitting clothing with snug wrist, ankle and neck bands. The use of protective cream on exposed skin surfaces should be encouraged. Men handling bulk cement should, in addition to the above, be equipped with goggles and respirators. Men working in the sun should be required to wear shirts and head covering, as protection from the sun's rays and irritants.

One of the best means of avoiding skin irritation from cement dust is personal cleanliness. Frequent and thorough washing, combined with the use of protective cream is recommended.

Forms

Form lumber and supports should be selected after careful consideration of loading factors, including spans, setting temperature, rate of pour, and working loads that will be supported. Good housekeeping is important in preventing injuries caused by falling objects, nails, splinters, etc. Stripped form materials should be cleaned and neatly stacked after removing all nails.

Scaffolding should be erected before placing decking on joists, to enable men to work safely.

Men constructing forms or placing reinforcing steel where there is a falling hazard should wear safety belts, or other adequate protection should be provided.

Shoring

All loads must be carried to the ground through shoring. Proper allowance must be made for the weight of forms, concrete, men and equipment. Shoring should be erected and maintained in plumb, and adequate footing must be provided. Spacing of shores is governed by design economics, form material used, etc.

It is suggested that shores be spaced to provide a minimum safety factor of four. Adjustable shores should be securely locked when in position, in accordance with the instruction of the manufacturer.

Shoring should be properly braced horizontally and/or diagonally, in both directions along lines of shores. In any 50 foot line of shores, it is recommended that cross-bracing be used at least once.

If vertical shoring is spliced, the American Concrete Institute suggests a diagonally-braced line of struts at each splice level sufficient to carry 1% of the vertical load, in two directions at right angles to each other.

Tubular steel scaffold sections are widely utilized as form supports. Erection and loading instructions of the manufacturer or supplier should be carefully observed. Each scaffold unit is self supporting and most types are internally braced in both directions. All installations should be plumbed, and provided with adequate footing.

All shoring should be protected from damage, such as might be caused by moving vehicles or swinging loads.

During concreting, one or more carpenters, as required, should be assigned to tighten wedges and see that centering supports are in no danger of collapsing. No incidental duties should be assigned from watchers during periods of concrete pouring.

Removal of forms and shoring

Forms should not be removed prematurely. **CONCRETE SHOULD BE PROPERLY SET—NOT FROZEN.** Only test on job-cured specimens will insure that concrete has attained sufficient strength to carry loads. These tests should be supplemented by surface hardness impact (hammer) tests on the members in question. Job specifications and local building codes should be consulted before removing forms.

These precautions apply principally to flexural members, such as slabs and beams. Vertical form faces for walls can be stripped at any time.

Only personnel actually engaged in form stripping should be allowed in the area during the operations. Hard hats, gloves, and, heavy-soled shoes should be worn. Approved safety belts and lanyards should be used if adequate footing is not provided above the 6-foot level.

Before stripping forms, centering should be well supported by shoring. Ledgers should be fastened to shores to prevent the centering from falling.

In cutting the wires under tension, care should be taken to prevent back lash which might, hit the body, particularly the face, eyes or throat.

Excavation and shoring

- (a) Shoring of adjacent structures
- (b) Shoring and sheathing as needed for soil and depth
- (c) Public roads and sidewalks supported and protected
- (d) Materials not too close to edge of excavations

- (e) Lighting at night
- (f) Water controlled
- (g) Equipment at safe distance from edge
- (h) Ladders or stairs provided where needed
- (i) Equipment at ramps adequate, slope not too great
- (j) Frequent inspection

Explosives

- (a) qualified operators
- (b) Proper transport vehicles
- (c) Local laws and regulations observed
- (d) Storage magazines constructed per regulations or as recommended
- (e) Experienced personnel handling explosive at all times
- (f) Cases opened with wooden tools only
- (g) *No Smoking* posted and observed where appropriate
- (h) Detonaters tested before each shot
- (i) All personnel familiar with signals, and signal properly used at all times
- (j) Inspection after each shot
- (k) Proper protection and accounting for all explosives at all times
- (l) Proper disposition of wrappings, waste and scrap
- (m) Advise residents nearby of blasting cap danger
- (n) Check radio frequency hazards

Concrete Construction

- (a) Forms properly installed and braced
- (b) Adequate shoring, plumbed and cross braced
- (c) Shoring remains in place until strength is attained
- (d) Proper curing period and procedure
- (e) Check heating devices
- (f) Mixing and transport equipment supported and traffic planned and routed
- (g) Adequate runways
- (h) Protection from cement dust
- (i) Hardhats, safety shoes, shirts covering skin
- (j) Nails and stripped form material removed from area.

TECHNICAL BOOKLETS

The National Productivity Council has secured a number of publications for supply to the industries. These comprise various types of publications. They are follows :

1. **TECHNICAL TRAINING BULLETINS (TB)** : These bulletins provide excellent material in the field of training in business management and industrial administration.

2. **FACTORY PERFORMANCE REPORTS (FP)** : These reports present operational profiles of U. S. Plants against which industrialists can evaluate their operations and isolate areas of poor performance, as a guide to selective improvements in factory operations.

3. **PLANT REQUIREMENT REPORTS (PR)** : These reports present basic information for the use of potential plant operations in establishing and operating a small plant.

4. **PLANT OPERATIONS REPORTS (PO)** : Plant operations reports are designed to assist in establishing and operating small plants, or improving the operating of existing plants

✓ 5. **CAPITAL REQUIREMENTS AND OPERATING RATIO REPORTS (CR)** : These reports provide information on capital use, operational costs and profits of selected U. S. Industries in a form to facilitate comparison with their counterparts.

6. **OPERATIONAL DATA REPORTS (OD)** : These reports have been prepared as a result of inquiries received by the Technical Inquiry Service.

✓ 7. **TECHNICAL INQUIRY SERVICE REPORTS (TI)** : These reports provide information relating to the establishment of manufacturing plants.

8. **STANDARDIZATION, SIMPLIFICATION & SPECIALIZATION STUDIES (S)** : These reports relate to developments in this field resulting in increased efficiency.

9. **COTTAGE INDUSTRIES REPORTS (CI)** : Reports based on programmes dealing with cottage and small scale industries.

✓ 10. **INDUSTRIAL DEVELOPMENT GUIDES (ID)** : Studies presenting basic considerations in Industrial development planning.

11. **COST SYSTEM OUTLINE (CD)** : Guides for managers and accountants to understand cost accounting problems and general management techniques.

12. **BIBLIOGRAPHIES, REFERENCE LISTS AND GLOSSARIES (GP N)**

All these publications are available from :

NATIONAL PRODUCTIVITY COUNCIL

38 Golf Links, New Delhi (India)

at modest charges

NPC Publications

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|---|---------|
| 1. Productivity Journal—Annual Subscription | Rs 9.00 |
| 2. Speaking of Productivity : | |
| English edition : | Re 1.25 |
| Hindi „ : | Re 1.00 |
| Bengali „ : | Re 1.00 |
| Tamil „ : | Re 1.00 |
| 3. Productivity Team Reports : | |
| (1) Productivity in Industries of USA, West Germany & UK | Rs 2.50 |
| (2) Small Scale Industries in USA, West Germany, Sweden and Japan | Rs 1.00 |
| (3) Road Transport Industry in West Germany, UK and USA | Rs 2.00 |
| (4) Plastics Industry in USA, Italy & Japan | Rs 2.00 |
| (5) Cotton Textile Industry in USA, Japan, West Germany, France & Switzerland | Rs 3.00 |
| (6) Industrial Management Organi- sation and Training in West Germany, UK & USA | Rs 2.00 |
| (7) Factory Building, Layout and Construction in Japan, USA & Italy | Rs 2.00 |
| (8) Bituminous Coal Mining Indus- tries in USA, UK, France & West Germany | Rs 2.00 |
| 4. Productivity A Challenge | Re 1.00 |

Copies available from :—

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National Productivity Council
38 Golf Links, New Delhi.

