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RESTRICTED

INFORMATION REPORT

COUNTRY USSR

DATE DISTR. 6 February 1945

SUBJECT Building Construction

NO. OF PAGES 7

PLACE ACQUIRED

NO. OF ENCLS. (LISTED BELOW)

STAT

DATE ACQUIRED

SUPPLEMENT TO REPORT NO.

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PROFILES OF MODERN FERROCONCRETE FACTORY INSTALLATIONS IN THE USSR

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(Diagrams referred to herein are not reproduced.)

The profile and construction of multi-storied ferroconcrete industrial buildings was extensively rationalized and perfected during the past ten years in the USSR. General progress was made in technique and in the employment of modern building materials. In addition, new specifications for lighting and airing workrooms and the effort to standardize building parts played an important role. A building with lighting from two sides is permitted by industrial building standards to have a maximum width of 8 H in some cases (particularly for textile factories), where H equals the height from the floor surface to the upper edge of the window. At the same time, the building width must not exceed 40 meters and the relation of the lighting surface to the floor surface remains within the limits of 0.1 and 0.2, according to the type of the work (coarse or fine). When the factory building width is 40 meters, the minimum for the height H according to these standards is 40 : 8 = 5 meters. (In America a height of 4.8 meters is assumed with this width.) If it is one meter up to the window and the window is 4 meters high, then the maximum relation of 0.2 with lighting from two sides can only be attained by continuous windows since $\frac{4+4}{40} = 0.2$. Consequently, many factories more than 35 meters in width have continuous windows since the darkening of parts of the window frame, possibly as much as 10 percent, must be taken into account.

Demands for ventilating and cooling workrooms during summer have been increased. Thus, for example, in a textile plant the maximum temperature permitted when the humidity is 70 percent, is 25 degrees C (when the humidity is 75 percent, the temperature must not exceed 24 degrees C). These standards make it necessary to install air inlets and outlets with cross sections of 5 square meters and more.

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It is most convenient to locate the ventilation ducts in one-storied buildings (sheds) in the ground under the floor. In two-storied buildings it is best to install those for the second story in the loft and those for the first story in the ground. In multi-storied buildings, particularly those with flat roofs (without lofts), the location of the ventilation ducts poses a very difficult problem. The solution to the ventilation question and a number of structural questions is indicated in the cross sections which we are about to describe.

Diagrams 1 and 2 depict simple types of industrial buildings with flat roofs (pitch up to 10 percent) of doubled roofing paper or rubberoid on a wooden framework and rafters and provided with an exterior rain drain. In Diagram 1 the building is lighted by ordinary factory windows with window sills as much as 1 meter in width. Diagram 2 represents a continuous window. There are double windows and the outer window frame passes in front of the ferroconcrete post and protects it from the effect of the low outdoor temperature.

Various types of construction f the external skeleton walls are presented in Diagrams 1, 2, 3, and 4.

Types of construction for lower wall sections near the ground surface are particularly varied.

Diagram 1 shows a usual filling in of the skeleton by wall A. 2.5 meters high (1.5 meters in the ground and 1 meter from the ground to the window). The wall rests directly on the ground. Even if it is made of the cheapest materials with a fracture resistance up to 40 kilograms per square centimeter, it may be regarded as a construction element with little economic and no static value.

Diagram 2 shows another type of construction in which a beam B transmits wall pressure to the base of the main external pillars. This type of construction is only permissible when wall C has a low height and a slight weight in view of the additional load on the pillar base and the high cost of beam B.

Diagrams 3 and 4 show the most economical and suitable types of construction.

The hollow ferroconcrete breast wall L (Diagram 4) is particularly economical. It may be regarded as a ferroconcrete beam with a Π-shaped cross section and equally strong walls or as a beam with a Γ-shaped cross section, strengthened inner wall, and a horizontal slab forming the window sill. The second thin outer wall then serves for insulation purposes only and may be attached and connected with the inner working wall by diaphragms. In special cases the hollow space between the walls is packed with insulating materials or simply filled with suitable earth.

Breast wall L then is shown to be a self-supporting, light structure which does not throw too much load on the main columns and at the same time forms a good rigid binder for the skeleton.

The type of construction represented in Diagram 3 stems from a directly opposed structural conception. The massive breast wall (base) H shown here, with a height H, is used as a working element which distributes the pressure of the fluxes P of the individual columns resting on wall H over the entire surface of the wall base.

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In this way a transition from foundations in the form of concentrated loads to strip foundations comes about. This type of construction can only be used when there is a complete absence of horizontal thrust, when there is vertical column pressure only.

In this case, the horizontal rigidity of the skeleton must be assured by additional interior columns or by the rigidity of the entire floor. Beam D can be turned down (Diagram 1) or up (Diagram 3) in the (upper) story breast walls. The latter arrangement has two advantages. In the first place, the height of the story can be decreased by the height of the beam without lessening the lighting surface of the window; in the second place, construction of ducts 5 (Diagram 2) for cooling the electric motors by outdoor air is made considerably easier. The unturned beam can be extended the entire length of the breast wall since it is box-shaped as shown in Diagram 3. The box shape makes it very convenient for filling with loose insulating material. A wall half-a-brick thick is erected on the outside. The high breast wall gives great rigidity to the entire ferroconcrete skeleton.

The effort to free the building of superfluous load leads to the construction of a breast wall consisting of an angular ferroconcrete beam only (Diagram 4). In this case, the front window frame goes up to the beam pressure plate and serves as insulation for it. This construction eliminates the need of additional insulating material in addition to saving considerable weight. Unfortunately this light, rational type of construction has two disadvantages: in the first place "a" the upper part of the window frame can not be used for lighting purposes, and secondly, the outside window frame is larger than the inner one which means that standards are not maintained.

A number of successful constructional types of a wall with external support for the skeleton are indicated above but they are not all erected accurately and logically. The types in Diagrams 2 and 3 which omit the window pier and have a support concealed under glass, and the type in Diagram 4 with a breast wall protected from the cold by glass are to be regarded as compromise types in spite of their structural advantages. In addition to the deficiencies indicated above, which are evident in the cross section, they have other disadvantages occasioned by the construction of the windows in the ground plan (Diagram 5). When factory buildings have normal artificial ventilation, the windows do not require casement parts for ventilation by outdoor air. Only openings for cleaning window frames are required, and these in a restricted number so as not to impair standard specifications for immovable windows. The practical solution to the problem adopted by many USSR factories consists in increasing the space between the window frames to 40 centimeters (Diagram 5) so as to allow for cleaning windows and repairing of the frames.

The ferroconcrete front columns I and II obstruct this passage or reduce it to 20 - 15 centimeters (Diagram 6, Figure 1). In addition, columns I and II in the inner window frame do not conform to standard specifications for window frames. The Central sections "a" are equal but the outside sections "b" are larger.

The other arrangement of window supports shown in Figure 2 increases the passage to 25 - 30 centimeters. As a result, narrow sections of the window frame (C) have to be built in. The only radical solution presents a structural type in which a continuous unified floor system without columns in the glazing surface corresponds to the con-

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tinuous window frame. Only continuous cantilever floor with columns set up at a distance of 2 - 3 meters from the outer wall will satisfy this condition (Diagram 8, Figures 3, 4, 5, and 6).

The cantilever system with main cross beams does not present a satisfactory solution since the large cantilever K impairs the continuity of the inner window frame just as columns I and II do. Two good solutions can be attained in the main longitudinal beams. In Figures 2 and 3 a number of small crossbeams merge into a smooth, continuous cantilever slab which conforms very well to the continuous standard windows.

A ribbed cantilever floor with the pressure plate inclined downward constitutes an equally successful solution (Figure 6). The last-mentioned systems represent radical standard solutions. The large workroom wall problem is brilliantly solved by the use of these systems. It is extremely difficult to find a suitable type of construction for the window frames of continuous glass walls (Diagram 4). Of course, standardization of the window elements is possible here. The ferroconcrete window frames for the first two stories (Diagram 4) consist of three parts, 1, 2, and 3, but the top story which has light from above as well as from the sides, has window frames consisting of only two parts, 1 and 2. In spite of this, however, the cost of construction is high because of the vertical window supports (I and II), which absorb the wind pressure, and the difficulties in mounting the window frames. The continuous window is the least expensive solution. In Diagram 2 an ordinary window done in wood is presented.

Diagram 7 presents an original window-frame system, details of which are shown in Figures 8 and 7, Diagram 5. Ready-made ferroconcrete supports weighing 100 to 120 kilograms, with a cross section of about 12 x 16 centimeters, and with rabbets for the window panes (Figure 7, Diagram 5), are set up at a distance of 1.0 to 1.2 meters from one another in special recesses. The horizontal division of the glass is made by iron window bars with a special profile built into holes in the ferroconcrete supports and cemented in by elastic putty. Diagram 5 gives a general view of a window for which this system was employed.

The window of such a structure requires no mechanical work. It represents a system made from finished parts and in comparison with wooden window frames it proves to be more practical.

Large ventilation ducts have great influence on the profile of the building. When the roof is flat and there is loft space, this space can be utilized very well for the installing of ducts.

Diagram 2 shows a simple solution to the problem where the duct A is installed in the loft over the ordinary ribbed floor. A better solution is shown in Diagram 1. Duct K is attached in three sections to the ribbed floor. At the same time a Rabitz ceiling is installed. In the section nearest the window the ribbed floor is lowered to the top of the Rabitz ceiling. This ribbed floor has a plate on the under side. In this way a continuous, smooth ceiling which diffuses light well is secured.

In factories with horizontal wood cement roofs, only suspended ducts can be used with Rabitz ceilings. In Diagram 4 where the roof slopes outward and there is an external rain drain, the ceiling is horizontal in a-a, the two sections next to the window, while a-k, the

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central sections, have an elevation for the purpose of decreasing the height of k-1, the light shaft of the skylight, and for better diffusion of light. Diagram 3 shows the water drain through m, the central column. This makes it possible to elevate the roof towards the outer wall, to enlarge the window, and to slant the Rabitz ceiling also starting at column m. At the same time both halves of the ceiling, km and mn, are equally well lighted and the diffusion of light is also satisfactory.

It is particularly difficult to install ducts in intermediate ceilings. The simple solution with suspended ducts K_1 and K_3 (Diagram 2), gives little satisfaction. The ducts greatly reduce the height of the working room and the ribs of the ferroconcrete ceiling furnish great resistance to the ventilation air. In Diagram 1, the ducts K_1 and K_2 are inserted into the ribbed ceiling, cut through the main beam, hang from its cantilevers, and are only covered over by the slab mn. In this solution the entire cross section of the factory is divided into four frames I, II, etc., connected in the loft by a continuous bar. Wind pressure in the stories is transmitted from rigid frame I to frame II, etc., by means of the slab mn and is proportionately distributed to the rigidity of these frames. Allowing for wind pressure of 0.1 ton per square meter the measurements of the supports in the front frame I were as follows: outer wall with a rectangular cross section 70 x 40 centimeters and J = 900,000 centimeters 4 [sic], and an inner spiral-encircled round column with a diameter of 45 centimeters and J = [illegible] centimeters 4.

Such a case is to be regarded as an exception. Usually one can install a large duct N along the factory building axis in the central ceiling sections. This likewise involves cutting the beam and a slab on the cantilevers. (Diagram 3 and 4. The shaded places in Diagrams 3 and 4 indicate unutilized sections of the duct.) At the same time, cutting the beam in only one of the seven ceiling sections would not impair the general rigidity of the building as much as in the case of Diagram 1.

Diagram 4 shows a successful example of exhaust ducts under the floor in the ground. To relieve the load on the duct walls they are given the slope of the ground. In order to decrease the thickness of the duct top, the top is made in the shape of a beamless plate, at small intermediate supports.

The inlet ducts are best installed in the breast wall. Diagram 7 gives an interesting example of new factory profiles. The stories have different dimensions. The flat central and side roofs and the suspended ceilings form a number of hollow spaces which are very convenient for housing the ventilation ducts.

The ducts K_1 and K_2 transmit air to the second story. Ducts K_3 and K_4 transmit air to the first story. The outer shaded sections are not used. The sloping ceilings diffuse the light well, as is also the case in the example shown in Diagram 3. Ducts K_3 and K_4 insulate the second-story breast wall against cold.

A type of planning which has had considerable influence on the profiles of factory buildings utilizes the ceiling rigidity for transmission of the horizontal force of the wind to individual immovable points, such as staircases, elevator shafts, and partitions.

Present industrial building standards for fireproof, ferroconcrete factory buildings provide for a distance between staircases whereby

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the distance from the farthest point C to the staircase A, represented by the straight line CA, does not exceed 80 meters, and the [illegible] represented by the line CBA do not exceed 80 meters (Diagram 4). Under these circumstances, when CB, the width of the building, equals 40 meters, BA also equals 40 meters and the distance between the staircases is 80 meters. If the width, CB = 20 meters and AC = 60 meters, BA will be about 55 meters and the distance between staircases will be as much as 110 meters.

Expansion joints are usually to be installed at intervals of 30-40 meters. Thus, an additional rigid point C, in the form of elevator shaft, and toilets must be set up opposite the joint BC. Since the immovable part of the ceiling is located between the joints on the axis CC and the slab edges AD and CB experience considerable shifting, amounting to 1.0 and 1.5 centimeters, the rigid points, staircases, etc., must be separated from the main building by a space "ab". This brings about a conflict between two requirements, connection of the main building with the staircases for the purpose of wind resistance and the separation of the stairs for considerations of temperature. This conflict can be satisfactorily leveled out by a flexible connection.

This is achieved by separating the stairs from the main building by a joint and a continuous vertical window a and b (Diagram 9). The only connection is in the form of pendulum plates with cross reinforcement fixed at the points of support. The pendulum plate can absorb pressure and tension from the wind and oscillatory motion to both sides in case temperature causes the building to expand or contract. In the present case the main joint AD goes through the zero points of moments of the small beams (1/6, 1/7 L) and both halves of the building are connected with the staircase. If the joint in the next span is installed outside of the staircase, (joint EF, see Diagram 8), then the two separated parts must be connected by a projection K in the joint EF and of the size of a ceiling section, or by projections at each column in the joint BC.

If the direction GKI [sic] is given to the joint Ge which goes around the staircase, or if the building together with the stairs is separated by the continuous joint LM, either one of these solutions would have to be termed faulty. In the latter case the staircases at H and N are to be regarded as rigid points while the opposite points of the joints L and G will be movable. This may result in severe cracks in the ceiling.

In addition to the continuous joints at intervals of 30 to 40 meters, to protect the structure from temperature and shrinkage strain, suitable local, special movement joints, are to be set up at intervals of 15 to 20 meters in the outer parts of the building which are directly exposed to the influence of the cold winds. These joints are represented in Diagram 9 for a cantilever-type construction with projecting lower story. The local joints a and b which go through the breast walls and the lintels have a scissors-like effect and may be prolonged to the first inner column. In practice such a division has shown positive results.

The thickness of the column is of the greatest importance for factory buildings in which the same type of machine is set up (for example, textile factories). In spans of 5-6 meters there is a 10-centimeter reduction in the column cross section, or a saving of up to 2 percent in the cubical content of the building. This can also be attained by the use of spiral binding, also quite a usual method. An

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additional reduction in the column cross section (20 percent), and a 4 - 5 percent decrease in the cubical content can be attained by the use of bound cast-iron pipe. Wherever a reduction in the column cross section is undertaken, the moment of wind load must be diverted from the columns. To this end the methods indicated above for utilizing ceiling rigidity and staircase stability are to be adopted. To attain the desired maximum reduction in the column cross section a transition must be made from loose reinforcement, usually not exceeding 3 percent, to rigid skeleton reinforcement (according to Professor Melan) from hardened corrugated steel with a strength of 3,000-3,500 kilograms per square centimeter. Such a type of construction is used in America in the form of composition columns.

The engineer Dr Bruno Bauer (Industrial Construction, 1929, No 5) proposed good solutions for rigid reinforcement in the form of special skeleton produced in workshops. The percentage rate of steel can be raised to 6 - 8 percent. Accordingly concrete from high grade cement, with a safe strain of up to 90 kilograms per square centimeter is required.

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