Erich Mendelsohn's Red Banner Factory in Leningrad 1926–1928: Laboratory for Early Concrete Works in the Soviet Union

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ABSTRACT: In view of the growing interest in contemporary architectural practice in the preservation and further utilization of the structures of the modern movement architecture (1920–1960s), there is a need to define clear criteria for analyzing and evaluating them. The current treatment of twentieth-century architecture as a subject of historical research in the humanities frequently fails to shed light on a basic aspect of its design method – the programme approach to planning and construction innovations, including constant experimentation with new construction materials. This summary, in line with current work to restore and develop the former Red Banner Textile Factory in Leningrad/Saint Petersburg, illustrates the practical and methodological potential of the engineering appraisal of historical structures from 1920 through the 1930s.

THE SPECIFICS OF DESIGNING AN INDUSTRIAL COMPLEX: BETWEEN BERLIN AND LENINGRAD

The design for the Red Banner Textile Factory was drawn up by the architect Erich Mendelsohn in his Berlin office on direct order of the Leningrad Textile Trust and was sent to Leningrad in March 1926 for implementation. Owing to the high architectural quality of the design and numerous publications of photographs of its model (Welt-Spiegel 1926, Mendelsohn 1930; fig. 1), this project soon became one of the recognized symbols of modern European architecture. The fate of the factory buildings themselves in Leningrad proved to be much more complicated. Mendelsohn's original design – which has as yet not been found in the Russian archives – was transmitted to the specially created Office for the Construction of New Buildings at the Leningrad Textile Trust for adaptation to local conditions and implementation. The Office entrusted its practical implementation to the Promstroy industrial construction corporation, the city's largest and most experienced construction organization at that time.

On account of the constant (often justified) changes made to the design, Mendelsohn halted his supervision of the project as design author and in 1927 ended all contact with the client. Further work in detailed design and construction was carried out by the architects S. O. Ovsyannikov and I. A. Pretro (who had worked in Petersburg before the Revolution), the engineer B. D. Vasilev and others. Drawings of the two approved design variations, relating to June and December 1927 have been preserved in Petersburg archives (the Central State Archive of Scientific and Technical Documentation and the Central State Archive of Saint Petersburg). They indicate that, while having considerably simplified Mendelsohn's original master plan, the Leningrad architects and engineers preserved and to a large extent developed their underlying structural principles. As a result, all of the Red Banner Factory buildings erected from 1926 to 1937 – the power station, the four-storey main production building connected by a walkway to the three-storey sales section, and the two dyeing workshops within the production yard – were erected with the use of various types of cast-in-situ reinforced-concrete structures, which were largely based on German experience in industrial construction in the 1920s.

A comparison of the archive materials preserved in Petersburg archives with the existing buildings shows that only the electrical power station (1926–1928) was constructed in accordance with Mendelsohn's original design (fig. 2, 4). As the most interesting part of the entire architectural composition of the new industrial complex, the station was recognized for many years as a model of contemporary European architecture in Leningrad architectural practice in the period of constructivism (Makagonova 1995, Magistris 1998 et al.). Despite

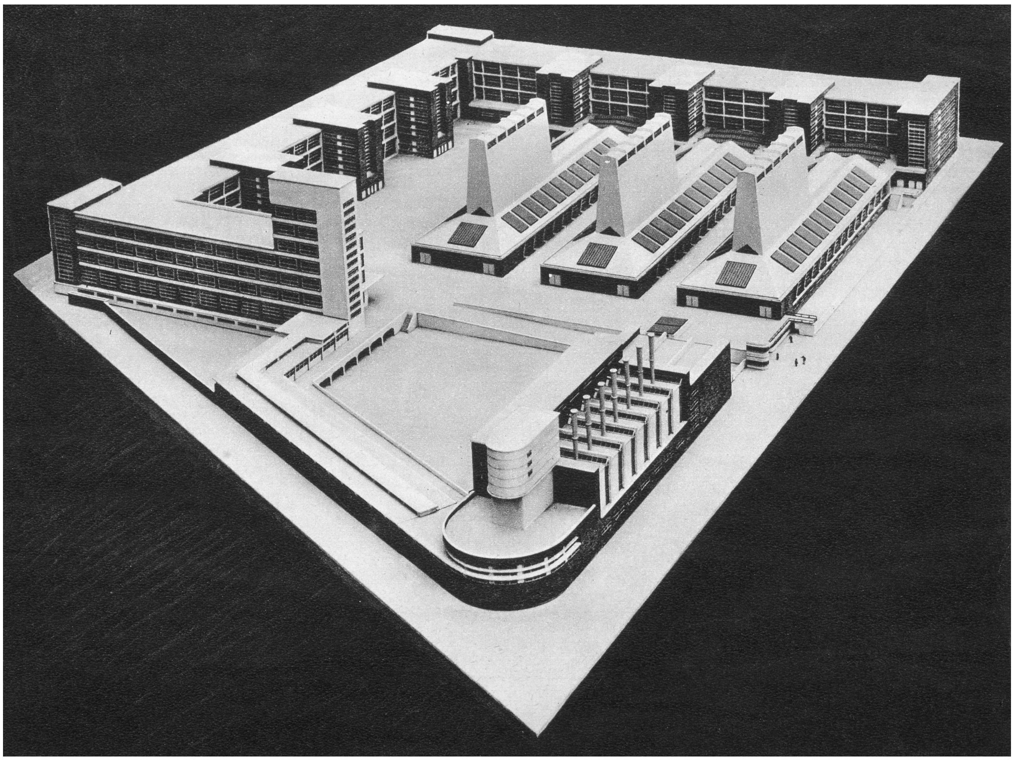

Figure 1: Erich Mendelsohn. Model for the final design version of the *Red Banner* textile factory in Leningrad, 1925/1926; (Photo: Kunstbibliothek Berlin, E. M. II/H/6)

the building's architectural fame, the fact that the construction of the power station constituted a kind of experimental laboratory for utilizing the potential of reinforced-concrete in the early period of Soviet construction practice is still little known.
In 1929 the building had already been proposed for the first competition of the city's best constructed buildings and received a very high evaluation. In the materials accompanying that proposal we encounter a comment which serves as a sort clue explaining now the building's structural specificity (Note 1929, p. 8):

> In evaluating the results achieved on site it is necessary to take into account the fact that both the design and the cost estimate were drawn up prior to the issuance of the special guidelines by government bodies on measures for reducing construction costs. Thus, at that time, it was impossible to employ the rational methods that we now have at our disposal, and the role of personal initiative was all the more significant in the construction.

Indeed, by the time the competition was held, during the implementation of the first five-year plan for the country's development (1928–1932), the programme approach to the widespread use of reinforced-concrete pursued other objectives – the all-round industrialization of construction processes within the framework of the strict economy of building materials. Accordingly, the Mendelsohn's power station building constructed in the years 1926–1928 remains one of the most interesting examples of the potential of early Soviet structural engineering that was still free of the rigid regulation to be imposed under the coming industrialization (Fedorov 2005).

STRUCTURAL BASIS OF THE POWER STATION BUILDING: A REINFORCED-CONCRETE FRAMEWORK

The basic means for carrying out Mendelsohn's innovative architectural design which relates to one of the most successful implementations of his architectural conception of "Dynamic and Function" (Zevi 1999) was reinforced-concrete. The report drawn up on the results of the building's construction identified as follows the structure's characteristics and the complications that arose in working with moulded reinforced-concrete during the building process (Note 1929, pp. 7 and 8):

(1) the absence of standard repeated structures;
(2) the complicated structural layout of the three-part semi-circular building (the filtration unit): the circular covering panels on radial beams, a Vierendeel girder et al.;
(3) the complex frame and semi-frame roof structures of the large halls;
(4) the complexity (irregularity) of the distribution system (in the turbine section unit);
(5) the massive size of individual reinforced-concrete components: the turbine foundations, the cross-beams of the semi-frames in the boiler section et al.;

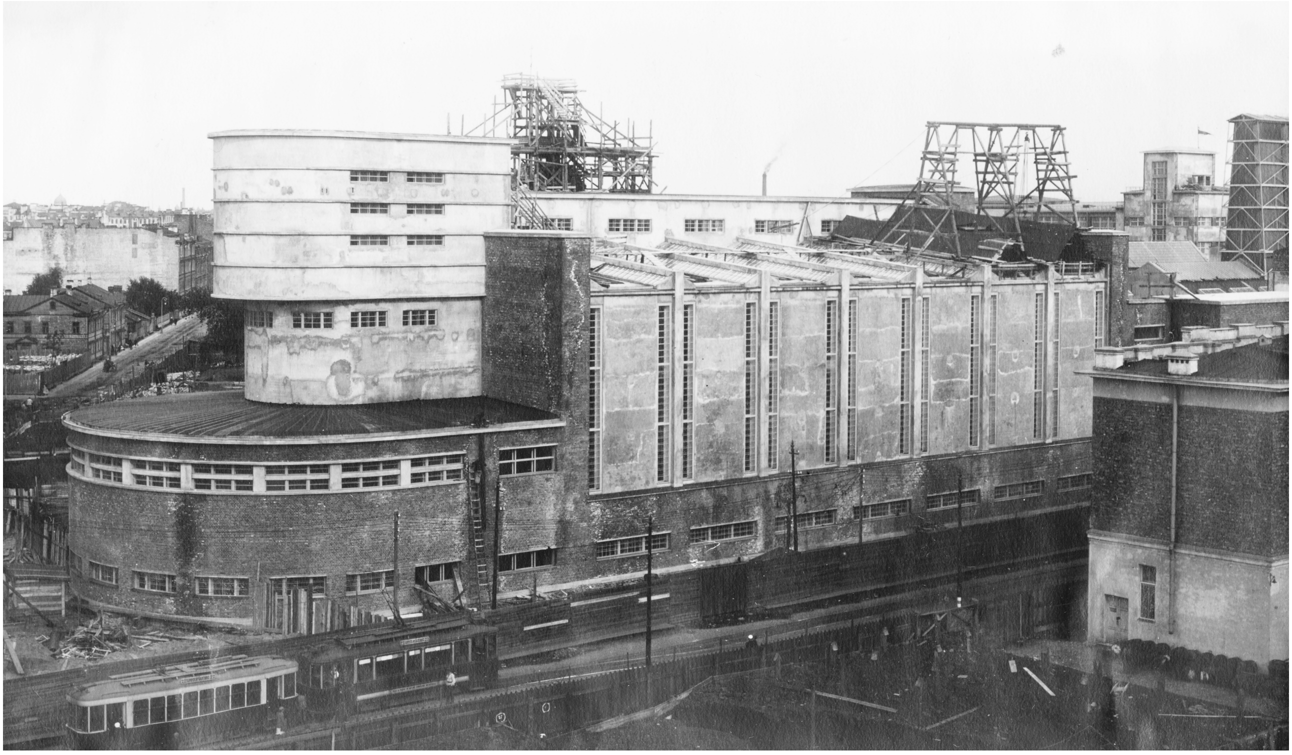

Figure 2: The *Red Banner* Factory power station. General view from Grebetskoy (now Pioneer) Street after completion. Photo 1928/1929; (CGANTD SPb 192-3-1-9797)

(6) the presence in the building's structure of various reinforced-concrete objects, often resting on independent foundations: tanks, water-storage tanks, sedimentation basins et al.

All parts of the building's framework (figs. 3, 6, 7), including the roof, fuel tanks, water-storage tank and sedimentation basins, were constructed of reinforced-concrete. Frame and semi-frame structures with flat and semi-circular covering on the beams served as the building's structural base. The building has no standardized elements, and all the dimensions were determined by Mendelsohn's architectural design. Parts of the framework supplement the load-bearing outer walls, which were made of clinker bricks.

In accordance with the original design, the power station building (approximately 102 m in overall length, 45 m in width, and 24 m in height) consists of three functionally different units with independent structural designs. All three units are situated on the same axis along present-day Pioneer Street (figs. 4, 5). The main rectangular structure of the boiler and fuel tank section with lateral and overhead lighting adjoins the semi-circular filtration section by staircase No. 1. Behind it is the rectangular abutting structure, which includes the turbine section, the distribution chamber, staircases Nos. 2 and 3, and utility rooms (fig. 5 right part).

The frame structures of all parts of the building rest on a 1 m thick monolithic slab reinforced by ribs of that height and placed at a depth of 2.3 m. The load-bearing structure for the three-part cylindrical structure of the building's corner section (26.4 m in height and 12.4 m in diameter at the base) is an incomplete framework. It consists of three frames: one under the wall at the edge of the boiler section, a central frame and an end frame (figs. 5–7). The frames are multi-tiered with rigid cross-beams at the level of the overlapping ceiling panels (3.8 m, 10.25 m and 18.75 m). The cross-sections of the frame posts are rectangular and narrowing towards the top along the tiers in accordance with the reduced weight load. The radial beams of the ceiling panels for the lower semi-circular part of the corner structure converge at the level of 10.25 m on the cross-beam, which is in the form of a Vierendeel girder. On the opposite side, they rest on load-bearing brick walls (fig. 7). The self-sustaining reinforced-concrete walls of the upper tier of the cylindrical structure are 180 mm thick and the internal insulation consists of boards, felt stripping and plaster on lathing.

The basic structure of the building housing the boiler and fuel-tank sections, which, according to the design, consists of seven 7.2 m wide blocks (= 7 boilers), adjoins the filtration section (figs. 8–10). L-shaped semi-frames with support hinges and sliding supports at the height of 18.2 m serve as the load-bearing structures for the boiler section. The reinforced-concrete support bolsters of the boiler section frames rest on widening rubble stone foundations. The height of the frames is 18.38 m, and their span length is 18 m; the height of the cross-beam (it has the same thickness as the overlapping ceiling panels) is 1.9 m; the cross-beam has a slight T-shape, the gradient of the cross-beam and the covering is 1:10. Concrete binders run between the frame posts at the height of 0.0 m, 5.25 m and 17.18 m. Imposts, which together with columns form narrow vertical windows that become skylights, were placed between the binders at the height of 5.25 m and 16.38 m. They were intended to provide light for the open space between the boilers (fig. 9).

The boiler section's ceiling consists of concrete beams which join the cross-beams of the frames and narrow flanking frames. The openings formed by them (3.10 x 3.86 m) were left for the possible repair of the boilers from above or in case of an explosion and initially were covered with specially designed light wooden panels. For architectural reasons, a ceiling panel was placed at the lower part of the cross-beam in order to improve the visual perception of the structure.
The fuel-tank section occupies a narrow part of the power station's hall on the courtyard side (figs. 8, 10). High frames at a distance of 6 m between the column axes and the two cross-beams at a height of 3.8 m (with a cantilever arm at the courtyard side) and 17 m form the load-bearing structure for this part of the building. The upper 1 m high cross-beam is also the foundation for the binders of the silo tanks. The general height of the tank walkway is 23.16 m. The largest cross-section of the walkway columns is 1.35 m x 0.7 m. There is a continuous two-layer frame glass cover in the tank section between thin reinforced-concrete imposts, which provides good light for the boiler furnaces, the automatic weighing machine and other mechanical equipment.
The turbine section unit, built perpendicular to present-day Pioneer Street, is situated at the back end of the boiler section unit, behind the narrow rectangular room housing the pumping station (fig. 5 right part). In Mendelsohn's original design, this unit was assigned an important architectural role – it flanked the area of the main pedestrian and vehicle entrances to the factory, which remained unrealised (fig. 1). The boiler and the fuel tank sections are divided along the length by two expansion joints into three parts, 2 + 3 + 2 respectively. In addition, all three parts of the station's buildings are separated by contraction joints. The insulation of the reinforced-concrete ceiling panels and walls – at the height of 10.25 m in the filtration section and 17 m in the fuel tank section, was provided through light slag-based concrete that is 20 cm thick an the ceiling panels and 10 cm thick an the walls.

GENERAL CONSTRUCTION AND CONCRETE WORK: WITHOUT SCAFFOLDINGS AND WITHOUT A WINTER BREAK

The work of erecting the power station began at the end of 1926 with the demolition of the six-storey house situated on part of the building site and the preparation of the foundation pit and was conducted continuously during the years 1927–1928. At the same time, work also started on constructing the reinforced-concrete foundations. All the work was carried out without seasonal interruption, during the winter work proceeded in a temporary closed heated premises ("tepljak"). The basic work of building the exterior reinforced-concrete structures was conducted in 1927. After they were completed, the construction of the interior structures began and was completed at the end of 1928 (according to other information, at the beginning of 1929 – s. fig. 2) in the already glazed and heated building. The engineer S. M. Fish was chief construction supervisor for the power station until the middle of 1928. Subsequently, the building of the power station was carried out as a separate, independent project (No. 126 b), which was supervised by the engineers S. Y. Vygodsky and A. P. Berezkin (Note 1929, pp. 12 and 13).
The high quality of the reinforced-concrete work, which was highlighted in all the appraisals of the completed construction work, was, according to the specialists who drew them up, in equal measure linked to the painstaking organizational work and the well thought out proportions of the concrete components. All the structures comprising the power station were built with concrete 2. A reinforced-concrete production plant with two Storrer-system concrete mixers supplied with cold and hot water was built at the work site. During the winter, all components of the concrete (sand, gravel and water) as well as the bricks for the wall enclosure were warmed up.
In determining the concrete mixtures, basic attention was focused on the optimal correlation of the various proportions of the sand and gravel components as well as water content. Since the gravel was brought to the construction site in small quantities and was of different types (the sand content varied from 5 % to 60 % in sub-

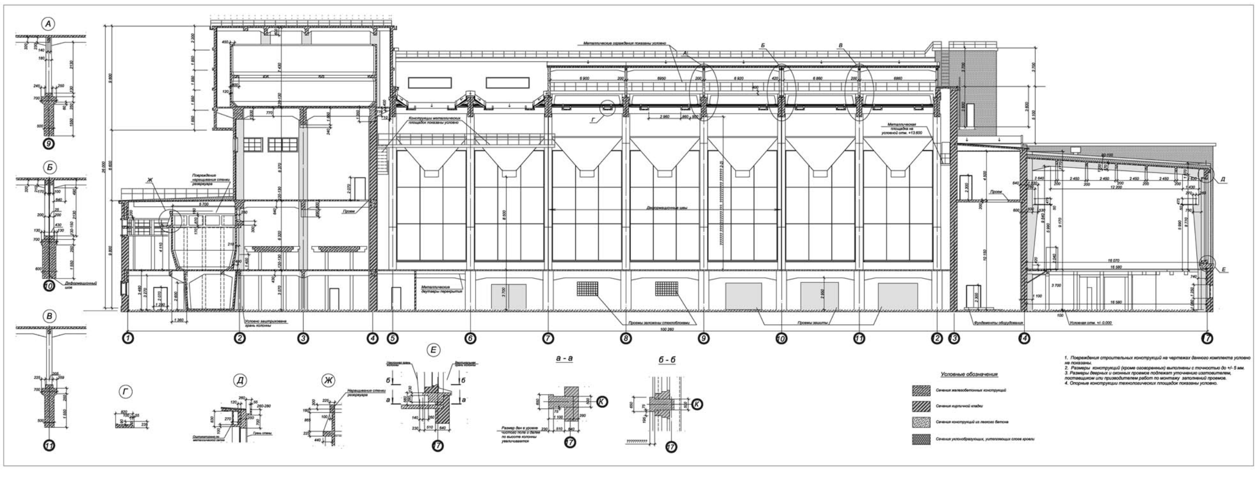

Figure 3: Longitudinal cross-section of the power station. 2008 Measurements; (Stroynauka, Minsk)

Figure 4: The *Red Banner* Factory power station. General view from Pioneer Street, November 2007; (Photographed by Rüdiger Kramm)

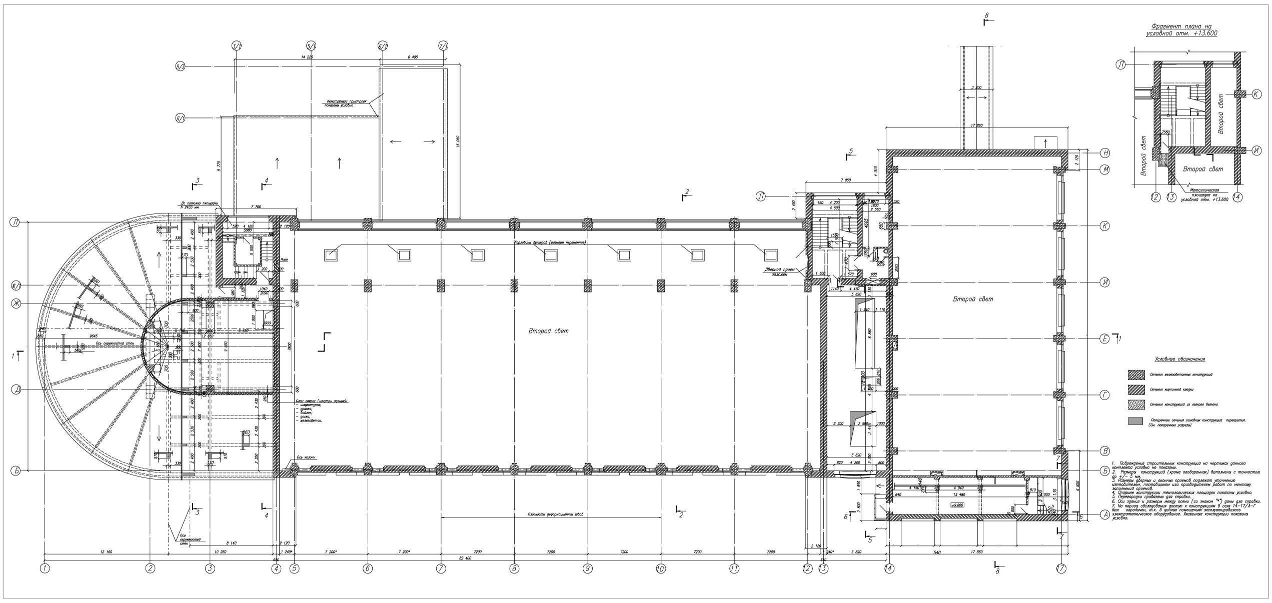

Figure 5: Plan of the power station, upper level. 2008 Measurements; (Stroynauka, Minsk)

soils from Lakhta), the composition of the filler materials used constantly varied in order to ensure complete utilization. In actual fact, experiments were conducted on the work site in the granulometric analysis and selection of the concrete mix. They were carried out in a small laboratory outfitted with the necessary equipment. The purpose of the experiments was to produce the strongest concrete using the least amount of filler materials.

On the basis of the work carried out by the German specialists Otto Graf, Adolf Kleinlogel, Heller and others, the construction managers in Leningrad increased the size of the sand components to 5 cm in building the power station. In casting the concrete, an analysis was conducted of the porosity of the filler materials, which reached the standard level of 35–40 % for sand and 45 % for gravel. All the combinations of filler materials used in the experiments were recorded in a special journal and were tested for strength in comparison with control specimens. The documents that have been preserved indicate that these tests were part of the basic production cycles of the reinforced-concrete and were carried out from the beginning of June until the end of October 1927. The average strength range achieved was 159–202 kg/cm^2 (in 49 to 52 days). The documents refer to ranges of 307 kg/cm^2 as good results (for the columns in the fuel tank and filtration sections).

A second question considered by the laboratory related to the percentage ratio of water to cement in the concrete mix. The presence in the power station design of segments for large fixtures and also, as is referred to in the documents, "the experience gained in constructing the *Volkhovstroy* electrical power station" (the first station built in the electrification programme of the USSR national economy during the years 1919–1926 at a distance of 122 km to the east of Leningrad) made it necessary to use very plastic types of concrete, They included mixes with a 13 % water content (of the volume of dry mix according to the Zaliger classification). This standard was implemented with the help of a special 150 liter tank (the Storrer system). The batching principles described, according to the construction supervisors, led according to the later presentation date to a significant increase in strength in terms of existing technical standards and the efficient use of cement (figs. 11 a, b).
While focusing on the strength characteristics of the concrete, no less attention was given to its "geometric contours", that is, the architectural quality of the façade finish. This was achieved by completing the fixture installation and woodwork (production of the formwork and laying out of the flooring) and careful supervision of concrete placement. As the documents referred to indicate, the plaster finish on concrete surfaces and part of the facades (11,000 m^2 in all) that was provided for in both Mendelsohn's original design and the revised design drawn up by the Institute (the Promstroy design) for the purposes of "efficiency and economy" was eventually replaced by a finish of cement mortar 1:3 (Note, 1929, p. 20).
In less than three years of work, 4000 m^3 of concrete were laid, more than 659 tons of steel fittings were installed and approximately 1 million bricks were laid. Each day 200–300 persons worked on the construction site. The total cost of building the power station (materials, work, water-supply system and sewage system) amounted to 1,110,128 rubles. In terms of the power station's 59,657 m^3 space, 1 m^3 cost 18.58 rubles. With account taken of the preparatory and overhead expenses, 1 m^3 cost 23.03 rubles.
Upon the completion of the construction work two years after it began, no defects or cracks were detected in the building's concrete frame. As pointed out in the records of the meetings held to discuss the quality of the structure in 1929 after it was finished, in spite of all the innovations and advances in the field of reinforced-concrete, "its quality and actual strength can be judged no earlier than 10 years following completion of the work".

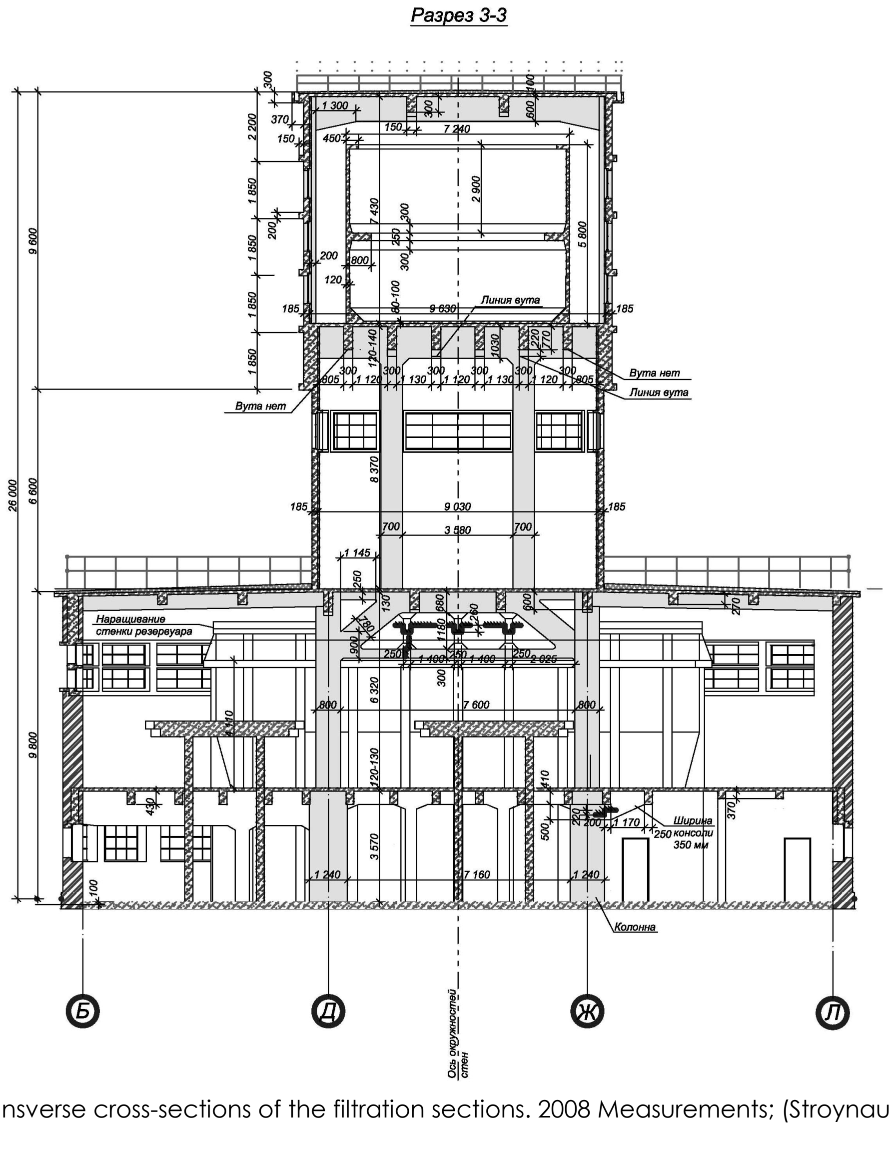

Figure 6: Transverse cross-sections of the filtration sections. 2008 Measurements; (Stroynauka Minsk)

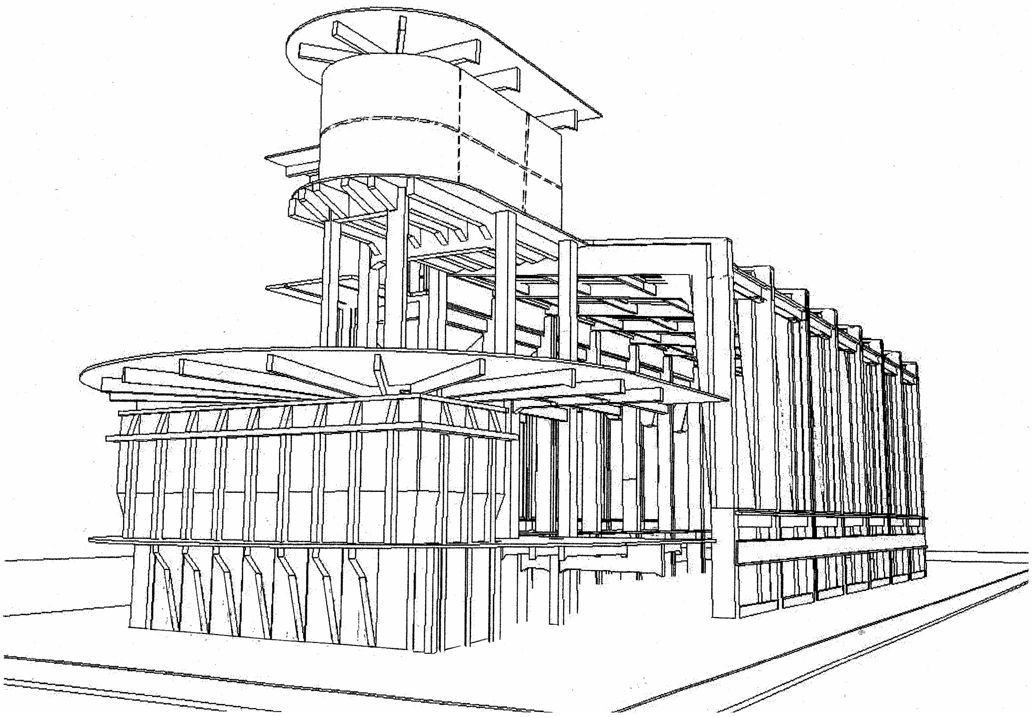

Figure 7: The reinforced-concrete framework of the power station building. The exterior brick walls intentionally omitted. 2008 CAD-simulation; (Stroynauka, Minsk)

CURRENT STATE OF THE BUILDING'S CONCRETE STRUCTURE: WITHOUT SERIOUS DEFECTS OR DEFORMATION

During the years from 1930 through the 1990s, the Leningrad *Red Banner* Hosiery and Knitting Factory (right up to the phasing out of production in the years 2000–2003) remained one of the country's largest industrial enterprises in its field, employing up to 8,500 persons. As part of the ongoing work to expand and develop textile production, the Factory's buildings were periodically subjected to careful engineering inspections (for example, by the GPI-3 institute in 1972–1973 and 1982–1984), which confirmed the structural reliability of the power station building.

In 2007–2008, within the framework of devising a plan for the further architectural development of the factory in connection with the transfer of most of the site to a new owner, the Stroynauka Engineering Office (Minsk, Belorus) conducted the most recent detailed inspection of the state of the electrical power station's reinforced-concrete structure (Lapshinsky 2008; figs. 3, 5–7, 9). In general, this inspection also found no serious defects or deformation of the reinforced-concrete elements indicating any fundamental errors in planning or design. All the elements of the concrete framework had retained their operating capability and maintainability.

In the building consisting of three units that was placed on a shallow concrete-slab foundation in rather complicated subsoil, no irregular sedimentary deformation of the foundation or the load-bearing structures has been detected, The first corner unit, whose structural design is the most complicated, has not shown any indications of overstress in the load-bearing frame and beam structures. The greatest movement in the L-shaped frames in the basic boiler unit is up to 50 mm. According the results of the strength tests conducted, the structural concrete used in the building corresponds to the class C15-B20 (principally C15) according to the strength classification system used in Russia.

Nevertheless, the building's structures and details do show significant defects and damage, the presence of which can be explained by the following reasons:

1. The novelty of the original design or the complex nature of the operation and maintenance of most of the programme monuments (and characteristic structures) of the modern movement architecture;
2. Insufficient experience (as well as experiments) in designing and constructing the reinforced-concrete structures and also the attempts to conserve construction materials with regard to the design;
3. Negligence in operating an architecturally and functionally complex building during the Soviet period.

Thus, the design's novelty led to decades-long complications in maintaining the flat roof provided for in all parts of the building. The maintenance of the roof in turn was complicated by a primitive drainage system consisting of external water tanks and pipes, which was used in Russian pre-revolutionary construction and carried over into Soviet practice. The unregulated collection of moisture and snow caused warping of the impervious layer in places, the accumulation of debris in the water tanks, and as a result, the penetration of moisture into wall structures. By the middle of the 1930s, the light wooden cladding and the glass covers on the roof

Figures 8, 9: General views of the power station’s boiler hall (fig. 8 – section with fuel tanks) after completion. Photograph 1928/1929; (CGANTD SPb 192-3-1-9797)

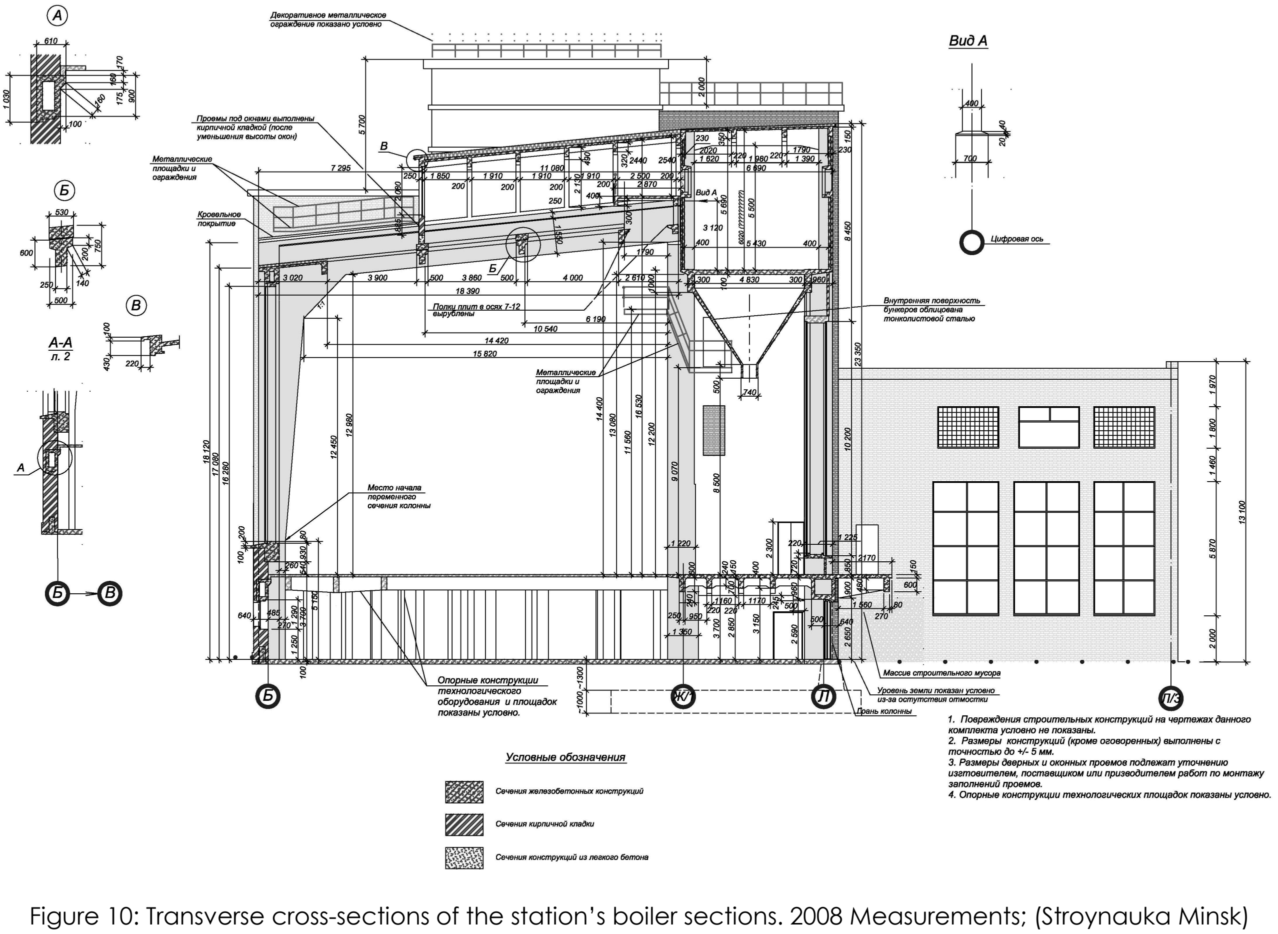

Figure 10: Transverse cross-sections of the station’s boiler sections. 2008 Measurements; (Stroynauka Minsk)

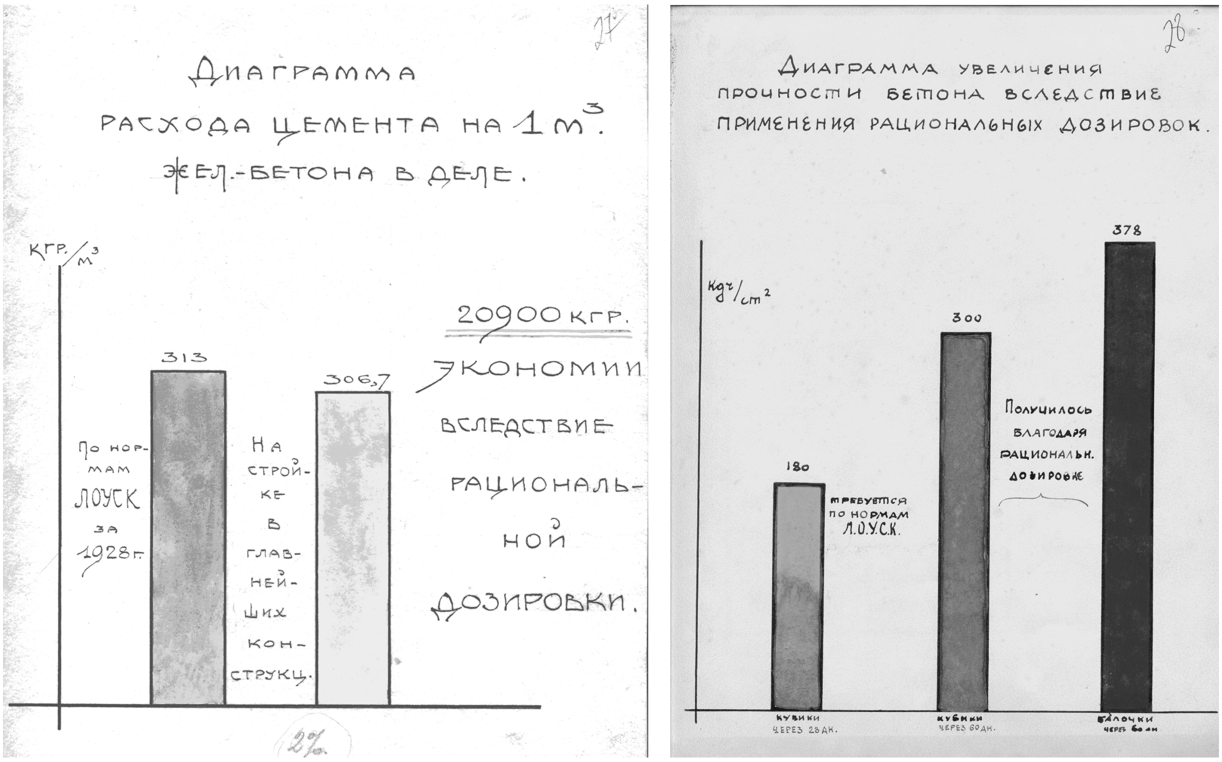

Figure 11 a, b: Diagrams illustrating the strength of the concrete and the amount of cement used in the concrete. 1928/1929 (CGANTD SPb 192-3-1-9797)

upper light in the large boiler hall were replaced by pre-cast reinforced-concrete plates on the metal beams. A new chamber was built (1934–1936) on the roof over the boiler hall, which altered the load on the frame cross-beams (s. fig. 10).

The heat insulation of the exterior wall surfaces and parts of the overall framework – the very heavy and ineffective heat-insulation materials, particularly the packed and dampened boiler ash and sand – proved to be short-lived. Over the years, extensive areas with low thermo-technical characteristics formed in exterior structures.

Common defects in components of the early concrete framework – the corrosion and collapse of metal fittings – in the power station building were aggravated by the minimal thickness of the protective concrete layer. As a result of the wedging action produced by corrosion, the thawing effect of the periodically moistened areas of concrete and local mechanical effects due to the adaptation of spaces for new purposes, cracks formed in the protective layer, leading even to the splitting off of separate sections of the concrete cover. This being the case, the extend of the carbonization of the exterior layer of the concrete structures in most cases does not exceed that of the protective concrete layers over the metal fittings.

Another factor in the intensive development of the corrosive processes affecting the metal fittings in the power station building turned out to he linked to the experiments relating to the composition of the concrete mix (focusing on large amounts of sand filler), which specifically caused the insufficiently solid structure of the concrete. The use of gravel as aggregate produced porosity in the concrete, which in turn lowered the resistance of the material to the penetration of aggressive chemical agents – water vapours, oxygen and gases.

Much of the damage was caused by the unqualified maintenance of the building in the Soviet time. In addition to the roof damage, this also led, for example, to the widening of the gaps in the glass cover and the deterioration of the concrete imposts during the delivery of bulky technological equipment, e. g. through the openings of the boiler hall.

CONCLUSION: A MODERN MOVEMENT MONUMENT AS A REFERENCE SOURCE OF INFORMATION ON EARLY REINFORCED-CONCRETE WORKS

1. The power station of the *Red Banner* Factory in Leningrad, current-day Saint Petersburg (architect Erich Mendelsohn, 1926–1928, Promstroy construction) was, until recently, one of the most famous monuments of the European expressionist architecture that was inaccessible or presumably lost for the purposes of research and needed restoration.

2. The transfer of the building at the end of 2006 to a new private owner, who expressed his interest in restoring and re-using it, opened up the possibility of carrying out a comprehensive evaluation of the condition of the monument and developing modern architectural conceptions for its further use.

3. The archival research and on-site inspection which were begun in 2007–2008 indicate that, in addition to its generally recognized architectural merits, the power station building ranks among the special monuments of the construction history of the second half of the 1920s: the fully preserved structure of its complex framed reinforced-concrete skeleton demonstrates the potential for adapting early reinforced-concrete to new form-creating concepts of the modern movement and expressionist architecture.

4. The materials already found and systematize in line with the current work are of considerable interest for analyzing the processes and practical way of transfer of construction experiences between West and East Europe. Here it can be termed an adaptation of European (Hassler, Schmidt 2004), primarily German, experience in reinforced-concrete construction in the conditions of Soviet Russia (the work of Otto Graf, Adolf Kleinlogel, Heller et al.). In particular, this approach sheds light on the questions regarding the sources amid theoretical bases for the programme to develop a new concrete industry in the Soviet Union – a task formulated during the period of the first five-year plan and the country's industrialization (1928–1932).

5. The work of evaluating the buildings comprising the *Red Banner* Factory as a kind of laboratory for testing and using early reinforced-concrete in Soviet Russia is of basic importance for formulating a rehabilitation project for the power station building. Both architectural as well as structural aspects of the building, which in many respects has remained a unique monument of the Russian-German architectural ties in the period of the Weimar Republic, are the object of preservation in the ongoing work.

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Unpublished and archive materials:

This primarily relates to materials of the two Petersburg archives: the Central State Archive of Scientific and Technical Documentation (CGANTD SPb) and the Central State Archive of Saint Petersburg (CGASPb). Searches are being conducted in other depositories at the current time.

The archive file of the State Archive of Scientific and Technical Documentation, fund 192-3-1-9797, "The Red Banner Factory Power Station. Construction Design. Architectural-structural part, 1927", consists of three folders with materials prepared for the competition for the best technical structure in the city of Leningrad. Materials from this file form the basis for the present publication.

Note, 1929: "Explanatory note on the construction of the Red Banner Factor power station", The Central State Archive of Scientific and Technical Documentation, 192-3-1-9797, pp. 1–27 + 1–3 (typewritten text in Russian, probable author of the note: the engineer S. Y. Vygodsky).

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