# Development of large-panel building construction in the USSR in relation to progress in the production of building materials

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## DEVELOPMENT OF INDUSTRIALIZATION IN BUILDING

In the Soviet Union the tempo of house-building is rapidly increasing. The number of dwellings built in 1955 was approximately 1.5 million; in 1960 it rose to nearly 3 million and during the next 10 years (1961–1970) not less than 36 million dwellings will be built. Along with the growth of new housing the numbers of new schools, hospitals, kindergartens, nurseries, shops and cafeterias are also increasing.

In order to carry out such a programme of building construction in the short time stipulated by the plan, the USSR adopted the policy of turning the building industry into a mechanized process of assembling buildings by means of large prefabricated units. The material and production standards which are being created in our country serve as a foundation for the accepted policy of industrialized building construction.

Special attention is being given to the development of prefabricated, precast reinforced concrete elements. In 1955 the annual output of precast reinforced concrete equalled 5.3 million $m^3$, in 1958 it rose to 19.5 million $m^3$, in 1960 to 32.3 million $m^3$ and in 1961 it is envisaged to produce about 40 million $m^3$.

In the USSR there are more than 2500 plants producing precast reinforced concrete elements; of these plants more than 900 are of high capacity.

The great attention paid to the development of precast reinforced concrete production created favourable conditions for the improvement of various technological methods involved in this production. The production of reinforced concrete elements on beds as well as the flow line-aggregate and conveyor production of these elements is widely used in the USSR. Methods of precast reinforced concrete production are improved primarily by the reduction of manual processes made possible by the mechanization of production operations.

Attention paid to the development of the cement industry greatly favours the growth of the precast reinforced concrete production. During the last few years the output of cement has sharply increased – from 22.5 million tons in 1955 to 45.5 million in 1961; production has increased not only in quantity but also in quality. Cement acquired greater strength while the period of its hardening has been considerably reduced.

Reinforcing steel of different grades fully provides for the manufacturing of precast products, and the output of high-strength steel is being greatly increased.

In connection with the development of the industrialization of building in the USSR a considerable growth of the mechanical equipment available has taken place, as witnessed by the figures below:

| | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|
| Excavators | 24,600 | 28,500 | 32,800 | 36,800 |
| Scrapers | 10,100 | 10,500 | 11,500 | 12,200 |
| Bulldozers | 24,500 | 29,162 | 34,600 | 40,500 |
| Mobile cranes | 35,800 | 41,743 | 48,700 | 55,000 |

In 1960 the degree of mechanization of earth work averaged 95.7 per cent, of loading and unloading work for the transportation of heavy materials 89.5 per cent, of plastering 57.6 per cent, and of painting 61.5 per cent.

Large-scale production and application of precast reinforced concrete in all fields of mass building construction is organized on the basis of the unification and standardization of precast products and on the obligatory use of standard designs worked out in accordance with the approved catalogue of unified precast reinforced concrete products. The application of standard (or type) designs in house-building increased from 70 per cent in 1957 to 88 per cent in 1960. Type designs are characterized by a high degree of unification. In mass house-building accomplished in brick, a single floor span (of 6 metres), a single room-height and single overall dimensions of staircases are chiefly used, giving the possibility of specialization in the plants or their technological production lines. A number of factories, situated in large towns, demonstrated that two or three type-dimensions of products constitute from 50 to 100 per cent of the whole output of the plant or of the technological production line and this makes this type of production the most profitable one.

The accepted programme for the development of precast reinforced concrete production called for the typification of the plants. This enabled the possibility of organizing, in a centralized fashion, the manufacture of equipment at special factories, which considerably accelerated the construction and operation of plants.

The industrialization of mass building construction contributed to the reduction of building costs and to the increase of labour productivity. Thus, for instance, through the introduction of industrialized methods, the cost of house-building in 1960 decreased in comparison with 1958 by 7.5 per cent for brick buildings, by 12.8 per cent for large-block buildings and by 21.5 per cent for large-panel ones.

In Moscow the capital investment in house-building in comparison with 1958 increased by 20 per cent while the amount of new housing developed increased by more than 54 per cent. Maintaining the same number of workers, Glavmosstroy increased the amount of new housing by 50 per cent. Taken as a whole the productivity of labour in the country in 1961 exceeded the level of 1955 by 60 per cent.

## LARGE-PANEL CONSTRUCTION AS THE MAIN POLICY IN INDUSTRIALIZATION OF MASS HOUSING

The programme of new housing construction approved in the USSR can be carried out in the scheduled time only by means of the most modern methods of industrialization. Completely precast large-panel house-building represents the highest form of house-building industrialization because it transforms this sort of building into a mechanized process of assembling prefabricated units.

Achievements, quantitative as well as qualitative, in the USSR in the field of precast concrete and reinforced concrete elements created favourable conditions for the transition to the completely precast (large-panel) construction of buildings for different purposes and, first of all, for residential buildings in view of the very large numbers required. The target set envisages raising the output of large-panel house-building in 1965 to 34 million $m^2$ of space annually.

To achieve this programme, intensive construction of highly mechanized plants for large-panel house-building has been developed.

At present some 300 house-building plants are under different stages of construction and not less than 25 per cent of these have already passed into production and are successfully turning out complete sets of products for the construction of large-panel residential buildings.

In the near future the construction of house-building plants will be intensified, because in the approved programme of housing the average annual volume of industrial house-building during the period 1966–1970 is to be 130 million $m^2$. It is estimated that this volume of house-building requires that over the next 20 years the annual volume of industrial house-building increases approximately 75 times compared with the volume of 1961.

Along with the large-panel construction accomplished by house-building plants in large towns, which have available a large number of precast element plants, there is a development of large-panel building based on products turned out by highly specialized plants producing units of a quite limited range.

The practice of erecting large-panel buildings has demonstrated that the labour consumption needed for their assembly represents less than 10 per cent of the total labour consumption necessary for the whole erection process, and this is attributable to the high labour-consumption rate of all post-assemblage jobs. This fact raised the problem of increasing in every possible way the degree of prefabrication of products by improving the structural forms of large-panel buildings and the methods of producing precast units.

One of the lines to be followed is the creation of smooth wall and floor surfaces in factory conditions. In the USSR great attention has been paid to the manufacture of products in special vertical forms (the so-called plate-holders or 'cassettes'). Such vertical forms are now used to manufacture not only solid internal wall panels and floors but also ribbed thin-walled structures, stairs, etc. Work directed to the improvement of the technology of vertical forms is now in progress.

Great attention is also being paid to the prefabrication of prestressed hollow-core floor panels. At the present moment such panels, with a span of 6–6.4 m, are being produced in large quantities by hundreds of plants for brick buildings. These panels are being increasingly used for panel buildings.

For brick buildings a large-scale production has been developed for large-size gypsum concrete partitions manufactured by the rolling method. Such partitions are also more and more widely used in large-panel building construction.

Extensive work is being carried out with a view to improving the production of multi-ribbed thin-walled panels (of the shell type) by means of continuous vibro-rolling. These panels are most suitable for floors of the non-continuous type.

Due attention is being paid to the investigation of several other methods for the production of thin-walled structures. Vibro-rolling and vibro-pressing appear to be quite promising.

Wide application in housing construction is being gained by completely prefabricated and equipped sanitary units. These so-called 'three-dimensional' units are cast as one complete unit of heavy or lightweight concrete. They are also produced from frames sheathed with asbestos-cement sheets or wood-chip boards.

Transition to completely precast mass construction releases a large quantity of brick. Extensive experimental building using vibro-brick panels carried out in the USSR has demonstrated the effectiveness of using brick for wall panels manufactured in horizontal forms and subjected to vibration.

Further improvement of vibro-brick panel production methods will afford the possibility of using brick for completely prefabricated building.

Large-panel building in the USSR is not yet very prevalent but the value and effectiveness of this type of building are already evident. From 1959 to 1960 the volume of large-panel buildings increased 6 times and it is to be noted that in 1960 most of the flats were produced by means of serial equipment to standard designs.

In Moscow, Leningrad, Minsk, Kiev, Sverdlovsk, Pervouralsk, Nizhni Tagil, Cherepovetz, Angarsk and many other towns, large-panel building construction acquired the utmost importance and took the form of mass building. These towns contain whole neighbourhoods and residential districts built with large-panel buildings.

As mentioned above, the average cost of large-panel buildings in 1960 decreased, compared with that in 1958, by 21.5 per cent. Taken as a whole the cost of large-panel buildings is 14 per cent less than that of brick structures.

Practice has already shown that labour consumption indices for sites developed with large-panel buildings are a factor of two less than those for sites built up with brick buildings having precast reinforced concrete details of floors, stairs, balconies and other elements.

The weight of large-panel buildings is half that of brick structures.

The speed of assembling large-panel buildings is rapidly increasing. Thus, for instance, Sverdlovsk demonstrated the erection of a five-storey large-panel house in 10 days, which was made possible by the thorough mastering of erection devices. At the house-building plant No. 1 in Leningrad, a team of 36 workers assembles 2.5 residential buildings with 80 flats each in one month.

## STRUCTURAL SOLUTIONS USED IN LARGE-PANEL BUILDINGS

Large-panel building is represented mainly by four and five-storey buildings, which prove to be the most expedient from the economical point of view. They are built to the following principal structural schemes.

(a) Frameless buildings with loadbearing cross-walls having a spacing of about 3 m, with floors supported along the edge. External walls, usually bearing the dead load, are either three-layered or solid; in the first case they are of heavy concrete with insulating wool slabs, and in the second they are manufactured of lightweight concrete. Some other types of external wall have also been developed. Internal loadbearing wall panels of heavy concrete manufactured in vertical forms are 12 cm thick. Floor panels of heavy concrete manufactured in the same way are 10 cm thick (Fig. 1).

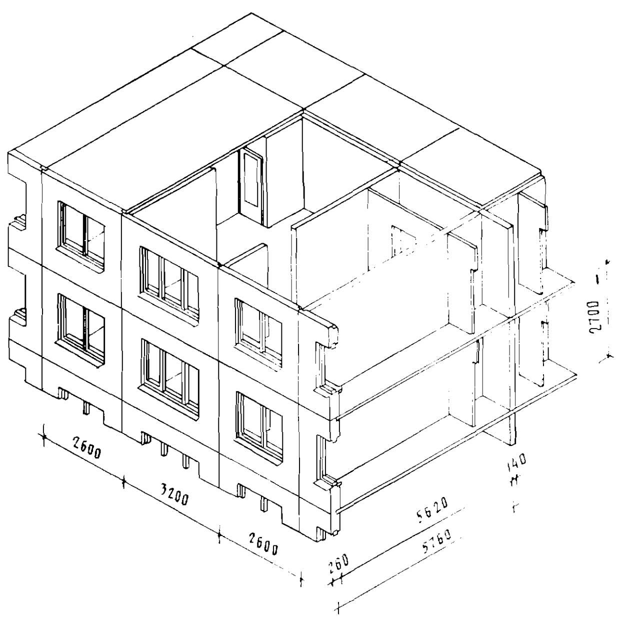


Fig. 1. Frameless building with load-bearing cross walls, spaced at about 3 m, floors supported along edge.

(b) Frameless buildings with a broad spacing of bearing cross walls placed at 6-m intervals. External self-bearing walls are of room-size panels manufactured of autoclaved cellular concrete. Lightweight concrete external walls as well as some other solutions are now being considered. Internal loadbearing cross-walls of heavy concrete produced in vertical forms are 15 cm thick. Floors are of cored prestressed panels resting along two sides. Partitions of gypsum concrete; partitions in the form of built-in cabinets made of sheet materials are also being provided (Fig. 2).

Flats with load-bearing cross-walls spaced at 6.40 m and 3.20 m intervals are similarly being built.

This system differs considerably from all other systems of large-panel building in that it applies for external and internal walls two panels per storey height, with the possibility of utilizing the production turned out by factories with special or narrow conveyors and cranes of 3-ton instead of 5-ton hoisting capacity.

(c) Frameless buildings with three load-bearing longitudinal walls of room-size panels produced of lightweight concrete. Floors are generally made of prestressed cored panels. Floors of hipped and ribbed panels are also used. Partitions are of gypsum concrete (Fig. 3).

(d) Frame-panel buildings with incomplete (or partial) frame and transverse placing of collar beams at approximately 3-m intervals. External load-bearing walls are mainly of ribbed reinforced concrete panels insulated with non-autoclaved aerated concrete. According to local conditions walls of lightweight concrete may be used. Floors are assembled of flat panels 10 and 8 cm thick laid on transverse collar-beams. Columns are placed along the internal longitudinal axis of the building. Partitions are of gypsum concrete (Fig. 4).

(e) Large-panel buildings of thin-walled ribbed structures; sound insulation of internal enclosing structures is achieved by organizing separate floors and partitions. Floor panels rest on thin-walled crossed partitions edged with ribs along the whole perimeter. While resisting bending, the partitions transfer the load through vertical end ribs to the foundations (Fig. 5).

These buildings are of the lightest type; their weight is about 1000 kg per square metre of living space.

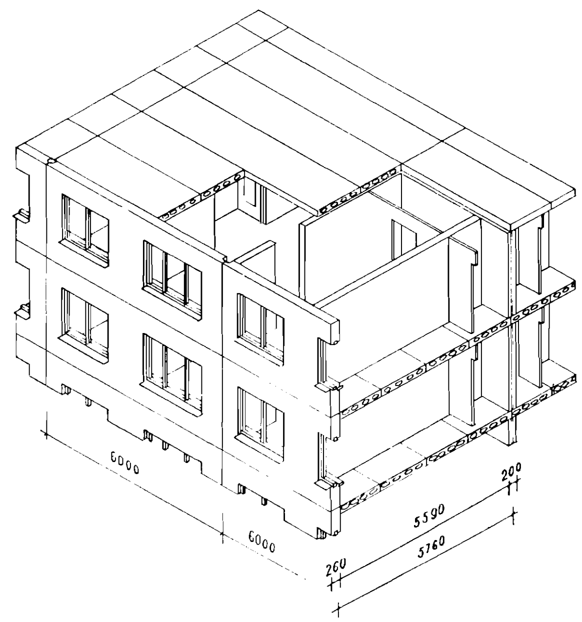


Fig. 2. Frameless building with bearing cross walls, spaced at 6 m, floors of panels resting along 2 sides.

Apart from the above-mentioned structural systems some others have also been used, from 1946 up to the present time. Thus, for instance, during the first years of panel construction great attention was paid to buildings with a complete precast frame. Several multistorey buildings in Moscow have been built according to such a system using the products turned out by specialized plants.

Differences in climatic, geological and production conditions of building in the USSR make it necessary to introduce structural changes into the above-mentioned schemes of large-panel buildings. Large-panel buildings of all systems use precast ribbon and column foundations. Foundations on short piles are now being introduced. By way of exception, in case of difficult soil conditions, *in situ* foundations are sometimes used.

Versatile development of the building materials used for the production of external wall panels affords the possibility of applying different methods for the external wall structural solutions. The growing production of mineral-wool slabs already makes it possible to use, on a large scale, three-layered panels of heavy concrete for external walls. As well as the quantitative growth of mineral-wool slab production, the technology of their production

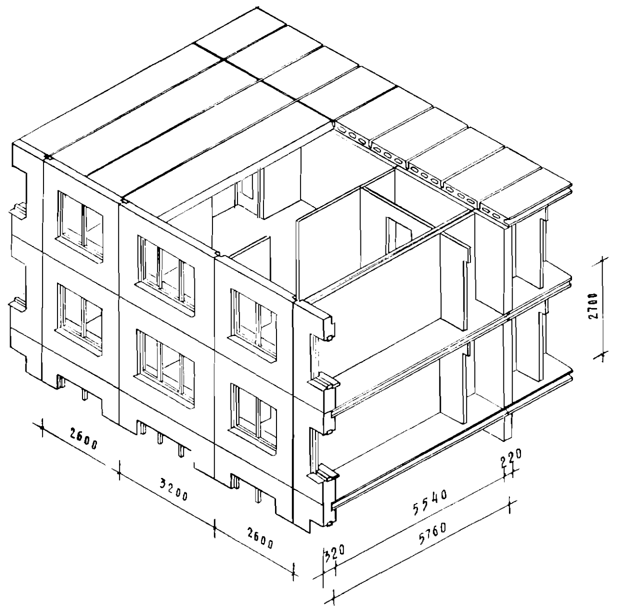


Fig. 3. Frameless building with longitudinal bearing walls.

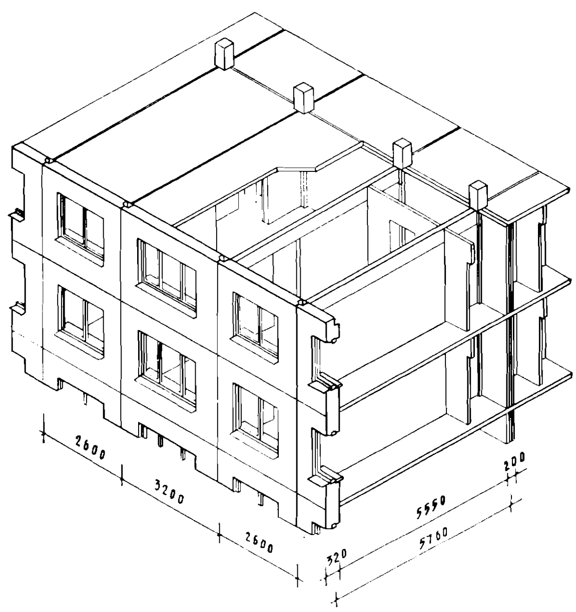


Fig. 4. Frame-panel building with partial frame and transverse collar beams, spaced at about 3 m.

and their performance are being improved. There is a considerable increase in the production of cement fibrolite, which will have a wide application as thermal insulation for laminated external wall panels.

The rapidly developing production of ceramite will allow the possibility of constructing a large volume of large-panel buildings with ceramite-concrete external wall panels. Such a possibility is, however, somewhat limited by the quality of local clays, which are not always suitable for the production of high-quality ceramite.

Expanded perlite is to be widely developed for use in the manufacture of external wall panels; one of its values is that it is economically profitable to transport it in the unexpanded condition. Large deposits of perlite have been found in some regions of the Soviet Union. In a number of districts the production of external wall panels is being organized on the basis of vermiculite and of natural pumice.

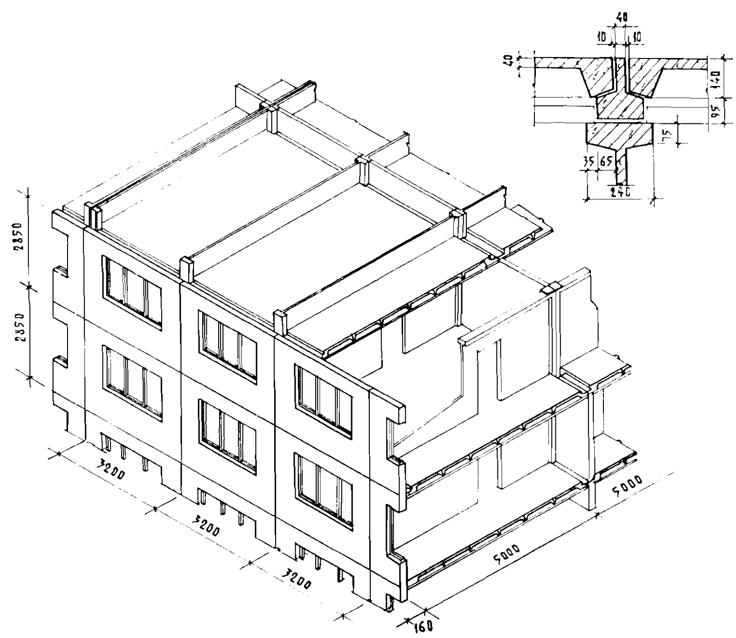


Fig. 5. Large-panel building of thin-walled ribbed structures.

An ever growing popularity for the production of external wall panels is being gained by cellular concretes, which are used for two main purposes: as heat insulation in heavy concrete panels and as the basic material for external wall panels.

When used for heat insulation, cellular concrete takes the form of precast slabs of foam concrete, gas concrete, foamed glass and foam ceralite. Another widely used system is the insulation of laminated panels by means of a foam-concrete mix poured over a freshly formed ribbed panel with a subsequent thermal treatment of the panels in steam-curing chambers.

When used as a principal material for walls, cellular concrete must have a sand basis. This type of cencrete serves for the production of room-size panels, manufactured in special autoclaves 3.6 m in diameter.

External room-size wall panels are also produced of non-autoclaved cellular concrete based on slag (or fly ash) from heating and power plants (aerated concrete).

Slabs of cellular concrete produced by a cutting technique are beginning to be used for external wall panels. Such slabs are assembled in factory conditions to produce room-size panels.

The correct evaluation of the durability of new building materials used for external wall panels presents a serious problem. It may be stated that the design of external wall panels using various building materials is being carried out in the following main directions:

(a) Laminated reinforced concrete panels, using effective heat insulation in the form of slabs or in some other form.

(b) Single-layer panels of different lightweight concretes.

(c) Single-layer panels of cellular concretes.

(d) Light 'curtain' panels with effective slab insulating material and with a skin of sheet materials (asbestos-cement sheets, aluminium, plastics, sheets of dry plaster of various types).

Depending upon the floor-supporting method, external walls are designed as load-bearing (when floors are resting on them), or as self-bearing (when floors are not supported by walls). Now light (curtain) walls have been introduced that are supported by floors or some other structure.

Though the question of joints between panels has a large variety of solutions, the problem of securing airtight joints appears to be very complicated. At the conference of the CIB Commission dealing with large-size components (Paris, 1961), it was recognized that resilient gaskets and plastic mastics, though providing airtightness of joints, are of considerably shorter durability than the panels themselves. The use of cement mortar or cement mortar with some additional agents was thought to be unsatisfactory as the only measure for protecting joints from the penetration of water.

It was observed that in externally opened horizontal joints of reinforced concrete panels an anti-rain barrier of a height equal to the maximum velocity pressure head with oblique rain affords quite adequate protection from rain water under conditions of strong wind. In order to prevent the penetration of rain water through an open vertical joint it is necessary to provide a vertical groove or channel, causing a sharp broadening of the jet and making water run down. It was also recognized that at present the most effective solution is the combination of a rational section of the joint with gaskets or mastics.

The work of the above-mentioned Commission in the field of airtightness of joints has greatly facilitated the solution of problems connected with joints.

Joint connections between panels that are now accepted for our large-panel building construction are generally accomplished by welding. Such connections are easier to execute (particularly in winter, a fact of great importance for the climatic conditions in the USSR) than the monolithic joints accepted in Western European countries. But the application of welded joints still presents considerable difficulties, especially in securing protection against corrosion. Numbers of methods have been worked out in an attempt to protect welded joints against corrosion by covering steel connections with protective layers. At the same time attempts are being made to find ways of concreting joints in winter conditions by the use, in some cases, of chemical agents.

Considering the question of floors in large-panel buildings two principal trends may be clearly traced:

(a) The improvement of different types of floor in which sound insulation against airborne noise is provided by the weight of construction; labour-consumption can be considerably lowered by applying to such floors a surfacing of 'Tapiflex' with resilient gaskets eliminating the impact noise.

(b) The improvement of different types of floors in which sound insulation against airborne noise is achieved by providing in the structure air cavities and sound-absorbing gaskets. The application of new acoustic materials (sound-insulating and sound-absorbing) will strongly influence the development of such types of floors.

In most cases, panel buildings have flat composite (or combined) roofs. Considering heat and humidity conditions preference is given to ventilated roofs.

Roof structures are of heavy reinforced concrete with some kind of effective heat insulation. As a variant roof structures can be of light or cellular concrete (without effective heat insulation).

Materials applied for external walls are widely used for roof structures.

## IMMEDIATE PROSPECTS AND TASKS

The completely precast large-panel house-building in the USSR has already passed the first stage of its development and now large-panel residential houses are being built at higher rates and with lower construction costs than traditional brick houses. From the point of view of performance, large-panel houses hardly differ from those built of traditional materials and meet the necessary requirements of durability and maintenance.

Great possibilities for reducing the construction costs and for improving the performance of large-panel houses are being opened up by the development of new building materials and by the continuous improvement of precast units production methods. The realization of these possibilities represents the primary task in the development of completely precast building construction.

Up till now factory house-building has turned out only residential buildings of sectional type and of limited range. The transition to large-panel mass construction raises the problem of using the products manufactured at house-building factories for the comprehensive development of large-scale residential areas; this development makes it necessary to build up these areas with completely precast large-panel buildings serving different purposes (residential buildings, *viz.* sectional ones with flats as well as houses of hotel type, boarding schools, schools, kindergartens, nurseries, shopping facilities, public dining rooms, restaurants, etc., cultural facilities and so on). This problem can be solved by the creation of a complex series of designs for the construction of large-panel residential and public buildings accomplished of standard reinforced concrete prefabricated elements.

Wide popularity for public buildings will be gained by completely precast-frame construction with the spacing of frame elements $3 \times 6$ m and $6 \times 6$ m and with curtain-wall panels. A broad set of residential and public buildings showing various planning, volume and space solutions will create conditions necessary for the diversified development of large residential areas, built up with large-panel buildings and demonstrating high aesthetic value. Scientific research institutes and design organizations have already started to tackle this problem.

The development and continuous improvement of the large-panel method of building is aimed at enlarging the units (panels) and increasing the degree of their prefabrication. Wall, floor and partition panels, stairways and stair landings are approaching the stage of complete prefabrication; the application of prefabricated sanitary cabins fully equipped in factory conditions, of electrotechnical panels, of external panels of two- or three-room size, of wall-bearing panels including heating elements, etc. increases continuously.

Industrial methods of building are developed and improved in close connection with the improvement of physical and technical qualities of the materials used in the past. Prefabrication of building elements, in particular, gave an impetus to the perfecting of qualities of normal concretes with natural crushed stone and gravel aggregates and brought to life such new concretes as fine-grained concretes, light concretes, etc. These concretes have, in turn, opened up great possibilities for the perfection of structural systems and for the improvement of the performance of buildings in use.

Prefabrication of building units and details has recently involved such ancient and traditionally satisfactory materials as brick and ceramics and is continuously improving their qualities as well as the qualities of houses built of these materials.

Particularly large prospects are available for the application in building of synthetic materials (polymers) whose physical and technical qualities easily yield to a wide variety of modifications. Up till now synthetic materials have been used in building only as finishing and insulating materials and sometimes for sanitary equipment. In future polymers will play an important part in the enclosing structures, such as walls, partitions, transparent screens, etc. Such prospects are based on the possibility, due to polymers, of developing building materials possessing high heat insulation and other qualities unattainable by the already known building materials.

Future improvement of structural systems for precast buildings assembled of large-size factory-made units will necessarily involve an ever enlarging list of materials and the perfection of conventional materials as well as new ones not yet applied in building practice.

Quite promising for reducing site operations connected with the erection of completely precast buildings appears to be the prefabrication of whole rooms, kitchens, staircases and even dwellings, coming from factories as a single completely finished, furnished and equipped unit. In the USSR multi-storey buildings comprising such units were erected for the first time in 1958–1959. At present this method is being tested and mastered by practice.

Two trends in the development of large-panel building structural systems – framed and frameless buildings – are to be maintained; but structural details will be modified in compliance with the ever improving strength and insulation properties of the materials. In the near future the principal part in the enclosing structures will be played by lightweight and cellular concrete; prospective use of more effective materials based on polymers is also envisaged.

Multi-storey prefabricated flats in the immediate future will, on the one hand, be large-panel (framed and frameless) buildings with the load-bearing reinforced concrete core in the form of load-bearing partitions or stanchions of the frame supporting the floors and with an enclosing structure made of plastics in some form of combination; on the other hand, they will be buildings of large reinforced concrete (primarily lightweight concrete) three-dimensional units presenting a whole room or a whole dwelling where insulation, finishing and equipment are in different kinds of plastics.

Reinforced concrete provides for the safety, stability and durability of a multi-storey building, while polymers used for enclosing structures and finishes and taken in combination with light metal alloys impart lightness and grace to the building.

Along with the technical progress reflected in the structural systems of complete prefabrication, there will come the perfecting of factory production technology, the wider applicability of plant and equipment; all this taken together will give rise to the possibility of producing at house-building factories whole sets of various residential and public buildings, which will have to undergo subsequent modifications in accordance with changing standards of building and with the requirements of the population.

Thus it is evident that the industrial (factory) methods of house-building that replaced the traditional primitive methods provide unlimited opportunities of erecting a larger quantity of buildings, and of building faster, better and cheaper.

Rapid development of large-panel building in the USSR and its envisaged wider development in the near future calls for scientific, experimental and design work on an ever growing scale for its perfecting and further development. In the USSR scores of large scientific and design institutes are conducting work in this direction.

In connection with such a wide scope of scientific and research work conducted by a large number of institutes in the field of designing, constructing and maintaining large-panel buildings in the USSR, a scientific and experimental centre for large-panel house-building has been created in the Academy of Building and Architecture of the USSR. It is a special research institute conducting large-scale scientific and research work, experimental design and experimental building and continuously improving the existing standard designs.

The scientific centre of large-panel building created in the Academy of Building and Architecture of the USSR unites and coordinates the activities of the research institutes and design organizations carrying out work in the field of large-panel house-building.