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Precast Block Houses Built in the 1950s and Urban Mining Potential

Ucer Erduran, D.[1*]

[1] RUDN University, Moscow, Russian Federation
* denizucer.arch@gmail.com

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Abstract:

The transformation of the urban environment in Moscow continues at a high pace with the new constructions, renovations, and demolitions. Identical mass housing blocks built in the 1950s and after, which are also prevalent over Europe, are of distinct importance in this transformation since they generate a precious resource of industrialized precast concrete components. A nine-story precast dwelling type of the specified period is the research material in this current study for the determination of present material stock and its usability. Original design booklets and guidelines published by the planning committees in the 1960s and 70s provided architectural design-related data i.e., materials, dimensions, and assembly details. Moreover, the visual investigation of facade components on ten randomly selected buildings revealed their current state. Design data invariably showed that constructors typically gathered these precast components using steel anchors and cement, which naturally evokes the critical question for their possible separation and reuse. Additionally, the visual survey sufficiently illustrated that the surface quality of these components was high, which is a valuable hint for their further utilization. According to our simple calculations, the selected building type comprises 915 precast facade components, which results in 778 thousand for the entire series in Moscow. In brief, the possible recovery of this tremendous amount from the landfill or downcycling is crucial in terms of environmental welfare, as the components of other identical buildings in the city and the country. Owing to the presence of similar structures all over Europe, this verdict is also valid and useful for different contexts. Consequently, the precast components used during the 1950s over many countries are still re-usable and their separation from the demolition waste creates a significant environmental impact reduction.

1 Introduction

Constant urbanization resulted in excessive material accumulation in the built environment. Obtaining ready-made components from this active stock is wieldier and more environment-friendly compared to conventional manufacturing. Hence, the valorization of existing buildings as the resource - i.e., urban mining proposes a sustainable transformation for the cities [1 and 2]. Precast structures hold great potential in this respect with demount-ability. A significant share of European mass housing following World War II contained prefabricated components [3]. In many countries, this stock was either demolished or under the urban renewal program. Therefore, the fate of these buildings is an up to date question for all European countries, where Russia is not an exception.

Similarly, Moscow-Russia has been experiencing continuous urbanization for decades. The importance of urban mining in the city is evident due to the intense pace of demolitions and construction. Therefore, the literature survey comprises the history, construction materials, and techniques of housing projects in Moscow.

Population growth, urbanization, social, and political changes have had significant impacts on the architecture in Russia, particularly in Moscow since the 1920s [4 - 6]. Industrialization and the revolution resulted in low cost and collective living during the 1920s. In consequence, communal houses and residential complexes with shared service spaces were prevalent. Another trend dominated the architecture between the 1930s until the 50s, which was associated with luxury. Buildings, particularly houses, exhibited decorative features, high ceilings, and elaborate ornamentations. This luxury ended during the 50s, after the Second World War, and architectural motto evolved into the elimination of excesses in design and construction. State experts developed design typologies for low cost, simple, modern, and wholesome functions in residential and all other public facilities. Five-story mass housing block remained the featured type, of which components were produced in a factory and only installed in situ. Wall components, slab panels, and staircases emerged as large-scale precast items. These houses were minimal and brutal with small rooms, moderate ceiling heights, thin walls, and bare facades. A similar trend continued with considerable improvements during the 1960s until the late 80s. Typological diversity enriched, and the number of floors increased, e.g., eight, twelve, and seventeen. Following the end of the Soviet Union in 1991, the state allowed the privatization in the planning, construction, and ownership of residential buildings, which still shapes the urban space in Russia [5 and 6]. Unique projects, alternative plan layouts, material variations, and elaborate decorations are significant features.

1.1 Industrialized Housing in Russia

Prefabrication of building components, especially reinforced concrete ones, emerged to serve the needs of simple, fast, and identical constructions in the 1950s. The scale of prefabrication rapidly grew over time from regular brick to the larger unit, block, panel, and room-size volumetric box [7]. Such dwellings, erected operating a crane, were classified into three groups in the 1960s: traditional walls (in situ concrete/brick/stone) with prefabricated slabs/stairs; prefabricated wall components (concrete block/pre-built masonry block) with precast slabs/stairs; and thoroughly prefabricated elements (precast walls/partitions/slabs/stairs) [7 and 8]. Blocks (Large-block, *Krupnyy blok*) made up the wall of a room when they unite vertically and horizontally. Panels (Large-panel, *Krupnaya panel'*) were as large as the size of a room-wall without further division.

The production of large-blocks reached 5 million cubic meters countrywide in the first five years (in 1955). It later reached 18 million in 1958, 30 million in 1960, and 70 million cubic meters in 1967 [7 and 9]. Production of large-panels started in 1959, and their effective use covered more than 30% of all urban residential constructions in 1969 and 50% in 1977 [7, 10 and 11]. On the contrary, the utilization of room-size boxes never rose to the construction of blocks/panels and merely stayed as a minor shareholder. These boxes formed only about 130 residential buildings by 1971 [7 and 12]. The entire prefabrication process significantly accelerated the pace of construction, and as a direct result, more than 60% of the existing buildings today in Moscow emerged between 1950 and 1990 [13].

The national codes for reinforced concrete structures necessitating potential concrete strength between 5 to 60 MPa (cube with 200 mm height, 28 days) shaped the basis for the design of **prefabricated components** [14]. Produced using rolled plain bars having 165 to 435 MPa yield strength, wire rod with a diameter of 5.5 mm turned into the reinforcement of these components. The level of seismic activity in regions and the number of building floors determined the reinforcement density. Accordingly, a non-seismic area, Moscow typically required 25 kg. of steel reinforcement for per m^2 net-living-space in five-story buildings [14]. Blocks and panels were affixed in-situ with welded or bolted steel anchors and then grouted using a cement mixture.

Solid and hollow **large-blocks** came into play in various structural configurations, where the combination of load-bearing interior walls with longitudinal exterior ones was common [15]. One other was the integration of transverse load-bearing walls with longitudinal outer ones that were only self-supporting. The blocks were either as high as the building floor or horizontally divided up into four sections. The elements ranged in length from 140 to 180 cm, from 230 to 275 cm in height, and from 40 to 50 cm in width. Among the prominent materials of these blocks were factory-built masonry units, artificial stones, and various concrete mixtures, e.g., silicate and cinder, or ones with slag and expanded clay.

Frameless load-bearing system utilized **large-panels**, where the integration of walls and slab components created the entire rigidity [16]. Moreover, various combinations of the interior, exterior, longitudinal, and transverse load-carrying panels; pre-stressed slabs; and columns were present. Outer wall panels had either single, two, or three layers of cement blends and insulation materials. Single-layer elements contained light concrete mixtures with gravel, expanded clay, perlite, natural pumice, and slag, while non-load bearing ones comprised autoclaved aerated concrete and silicate. Two and three-layer panels were reinforced using heavy concrete in the form of shells or ribs and filled with mineral wool and porous concrete [16].

1.2 Current Urban Renewal Program

In 2017, the mayor of Moscow scheduled an extensive urban renewal program covering 40 municipal districts and 15 rural towns for completion over a decade [17]. The initial phase involved the controlled demolition of about 4,500 five-story industrialized housing blocks -i.e., the ones built with prefabricated components. Considerable loss of thermal insulation properties, water leakage, and lack of noise protection were significant parameters during the selection of these buildings. Machine demolition has already started regardless of heavy precast elements hosting the potential of deconstruction and readaptation.

While the current renewal program includes only five-story residential blocks, the steps ahead will likely be the possible replacement of other prefabricated buildings built over the same period. Therefore, it will be beneficial to create a material inventory for these buildings in advance for adequately identifying their potential for urban mining.

The main objective of this current study is to generate a material catalog for these precast buildings; including material types, dimensions, and connection details, as well as their current statuses with cracks, damages, and corrosion. Such an inventory serves as a guideline during the deconstruction of these buildings. Consequently, these components can be separated from construction waste, which is a significant environmental impact reduction.

2 Materials and Methods

This current research focused on one of the widespread mass housing types to analyze its material stock for up-to-date status and availability to recover. A nine-story residential building -i.e., Type II-18 was suitable for visual inspection of facades with bare components, exposed materials, and joints. To this end, research material narrowed down to the facade elements -i.e., wall blocks, bond-beams, lintels, balcony slabs, and parapets, except for foundation and other interior components. Information on design and material was available in historical documents prepared and published by the state during the planning stage of these buildings [15, 18-21]. These documents contained design and construction drawings at various scales, descriptions of possible material alternatives with required thicknesses, and installation methods. While the data collected from these documents constituted the first half of this study, the observations of the buildings still in use formed the second. The second part revealed the current situation using photographs and verbal descriptions of ten randomly selected buildings from within the city. In short, research combined field observations with theoretical data.

2.1 Design Documents

The Central Institute of Standard Design *[Tsentral'nyy Institut Tipovogo Proyektirovaniya GOSSTROYA, SSSR]* developed the typology and implemented it after the 1950s [18]. The current map showed that the number of this type was 850 at city boundaries [22].

In addition to the nine floors with private apartments, a shared basement and an attic were present in the buildings. Eight symmetrically placed flats on each floor contained one or two rooms equipped with a tiny kitchen and bathroom, as shown in Figure 1. The buildings had a single circulation core, including the staircase, elevator, and trash chute. Each component of the buildings was a precast element -i.e., foundation unit, wall block, bond-beam, lintel, slab panel, and staircase [15 and 18].

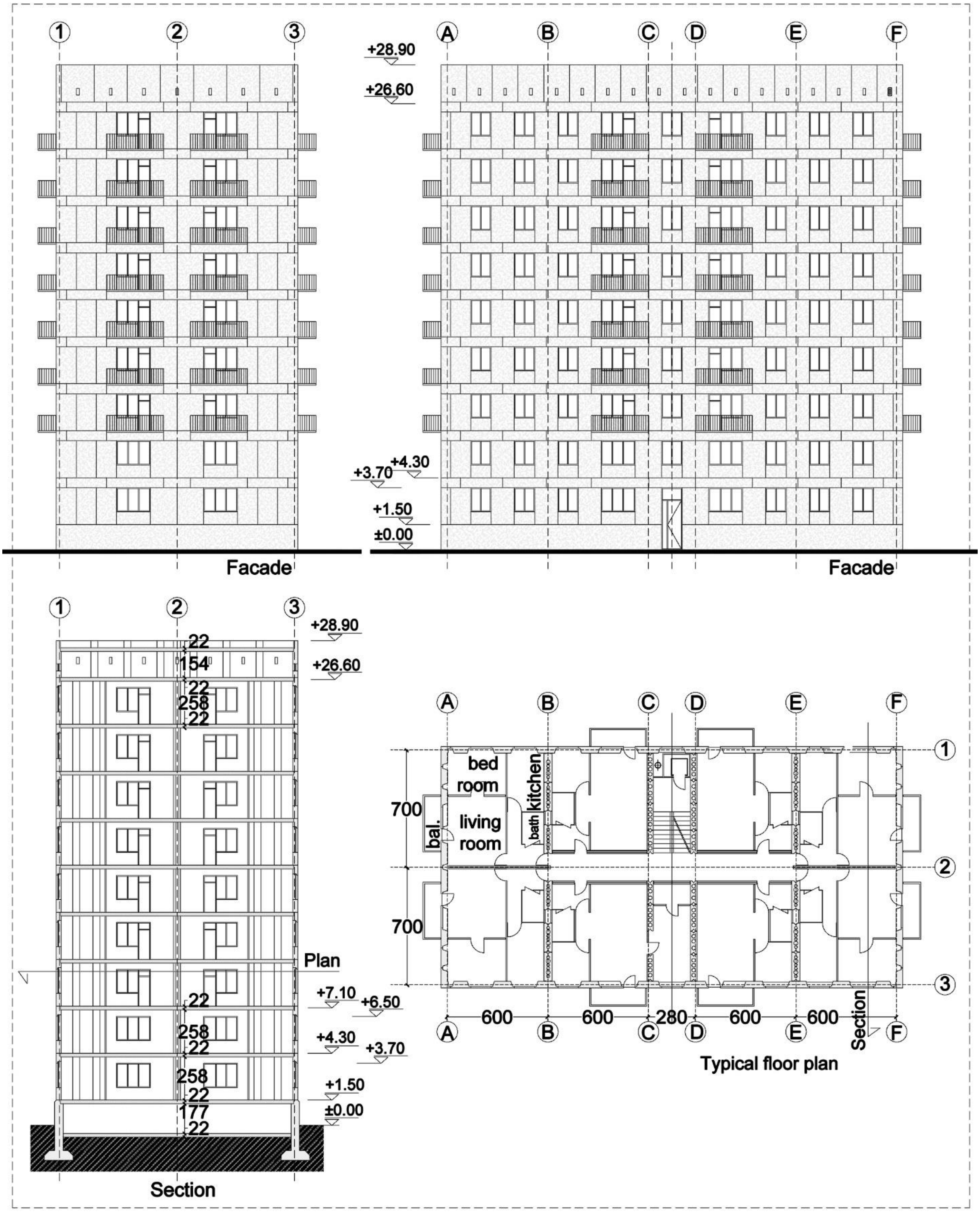

Figure 1 Design drawings (Adapted from Reference 15)

The essential structural members were 40 or 50-cm-thick, transverse interior walls with perforations for ventilation. They contained concrete having about 20 MPa strength and 1,600 kg/m^3 density or higher. 40-cm-thick outer wall blocks were self-supporting and made of lightweight concrete with 8 MPa strength. This concrete contained slag and expanded clay, and its density was 1,200 kg/m^3. A two-cm-thick protective layer made of 2,000 kg/cm^3 of heavy concrete covered the outer surfaces of the exterior walls.

Wall blocks were 218 cm high with three alternative lengths -i.e., 118, 138, and 158 cm, as shown in Figure 2. Reinforcement bars in these blocks were near the head joints for their integration during the construction. Four holes on the edges allowed constructors to unite the bars of side-by-side blocks.

Moreover, extended bars on top of the blocks formed steel hangers to elevate these heavy components using a crane. Specific blocks with L-shape-plan formed the corners of the buildings. 32-cm-thick and 76-cm-high sill blocks had the mortises on their inner surfaces, unlike walls. Bond-beams and lintels were identical L-section-components, while the former connected the walls of consecutive floors with the slab panels; the latter was on the fenestration openings, as shown in Detail 5, Figure 3. The critical difference between these 58-cm-high and 40-cm-thick elements was the density of reinforcement. Lintels comparatively contained more steel bars placed at three levels, upper, middle, lower, and secured by densely located stirrups. Bond-beams, including specific corner ones, and lintels surrounded the perimeter of the building on each floor for stiffness.

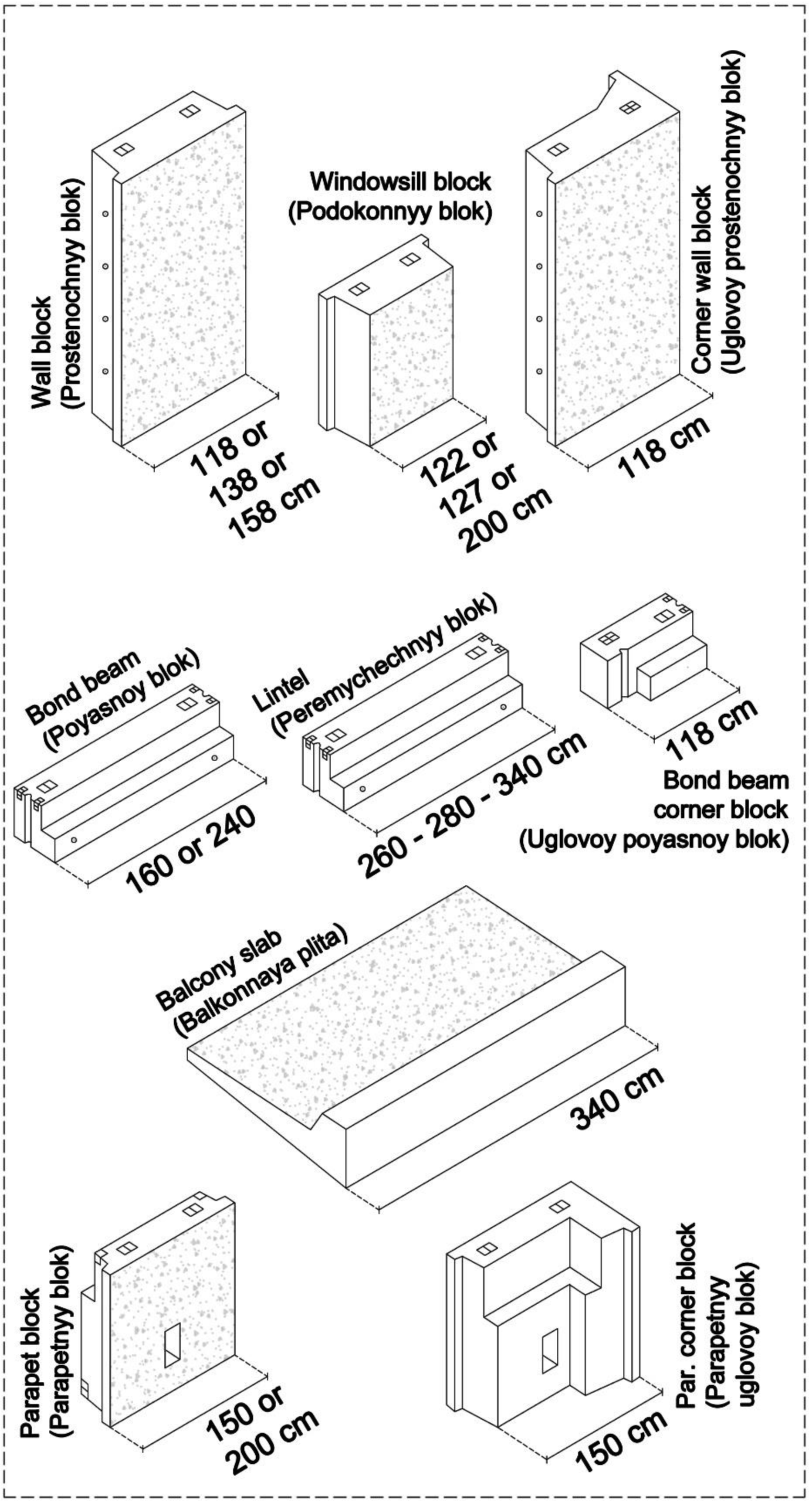

Figure 2 Facade components (Adapted from Reference 15, 19 and 21)

Balcony slabs were tapered solid cantilevers with dimensions of 340 to 100 cm, and lintels beneath were 10 cm thicker than the others. Parapet blocks having ventilation holes covered with steel cages envelop the attic floor. There were two lengths-namely 150 and 200 cm, as well as the corner type.

The initial installation took place between the reinforcements of adjacent wall blocks using anchors through the mounting holes [15, 18, and 20]. Afterward, cement grout filled the joint and integrated all together, as shown in Detail 1 and 2 (Figure 3). Following the installation of walls, their topsides were mortared with lightweight concrete to integrate bond-beams and lintels. The mixture was plain except the corners of the building and where outer and inner load-bearing walls were adjacent. Meshes embedded in mortar confined these intersections, as shown in Detail 3 and 4. Unlike wall blocks, bond-beams and lintels contained embedded grooves for the placement of anchors and grout, as seen in Detail 6 (Fig. 3). Anchors and mortar connected the adjacent slab panels and the beams, as shown in Detail 5 and 6.

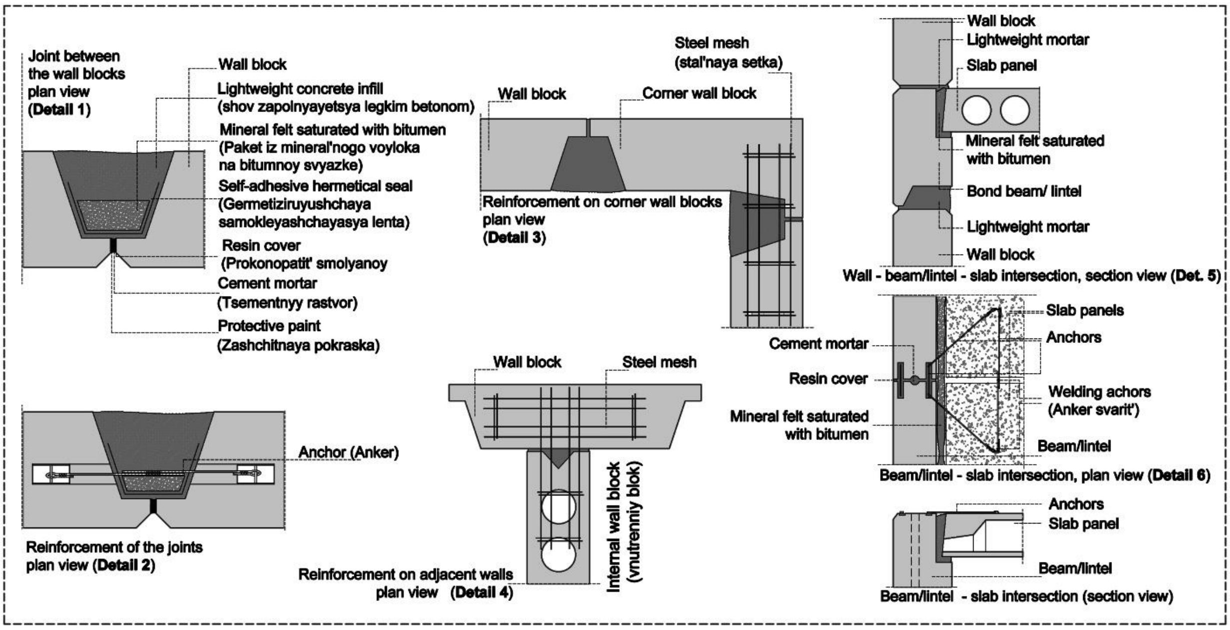

Figure 3 Connection details (Adapted from Reference 15, 19-21)

Lastly, bitumen-saturated mineral felt and self-adhesive hermetical seal isolated the joints against water leaks. Additionally, dense mortar layer and resin constituted the outer surface of these intersections.

2.2 Current Condition

Ten randomly selected buildings generated the set of precast facade elements to survey. Building #1, located in *Krasnogvardeisky passage 18k2*, exhibited decay, improper repairs, and water leaks at the joints. Moreover, wall components had fine surface cracks and deterioration on paint, as shown in Figure 4. Sill blocks had a significant color change due to humidity, while balcony slabs had exposed and corroded steel bars. In an overall assessment, this building gained the average condition label. Consequently, all buildings fell into four categories according to their current condition; poor, average, good, and very good. One building was poor, five were average, two were good, and two were very good, as seen in Figure 5.

Figure 4 Sample building #1

The primary issue of all structures was the deterioration of joints to some extent. Separation of adjacent blocks and the fillers remained a recurring problem not only between wall blocks but also between bond-beams and lintels, as seen in Building #1,5,7, and 9. This separation appeared in the form of 2-3-mm-thick cracks and surrounded by discoloration due to fungal activity triggered by the presence of humidity. The problem grew up in distinct points: upper floors, including parapets (Building #1 and 2) and sides of windowsills (Building #1,4, and 9). Freeze and thaw of rain and snow water, as well as inadequate water discharge, increased the rate of decay at these particular points. Although the principle design of connections had measures against water penetration, as shown in Detail 1-6 Figure 3, the implementation of solutions was either not adequate during construction or had to be repeated more frequently throughout the service life. Similarly, window and parapet-sills had slopes in the planning stage but were incapable of conveying the water away from the blocks in practice.

Decayed concrete balcony slabs represented the second common problem in the buildings, as was evident in Building #3. Steel bars reached out through the crumbled concrete and corroded below the cantilever edges of these slabs. According to the original design, there was not a water discharge system for these slabs, except for a slight slope; and it resulted in severe damage during the operation phase. This problem was not present for the enclosed balconies.

The surface quality of wall components was satisfactory even for the buildings in an unfavorable condition, as shown in Building #2. Scarce thin cracks seemed to stay only on the protective paint layer and did not grow in the components. This pleasing condition was likely due to the operational effectiveness of the 2-cm-thick dense protective coating. The only significant crack was on the corner of a bond-beam, as shown in the last photo of Building #10.

The integration of natural-gas pipes took place years after the construction of these buildings. For this purpose, facade components of the ground and first floors exhibited random holes.

Figure 5 Sample buildings (See the appendix for larger images)

3 Results and Discussion

The investigation illustrated that the precast facade components were serviceable even for the buildings in poor condition. Moreover, their joints had disassembly features, referring to the design documents. These two pieces of data showed that this building type has a high potential for material recovery at the end-of-life. This finding supported the verdict of research about the post-World War II building stock in Berlin, Germany [23]. It showed that historical, reinforced concrete components were not waste but valuable secondary materials. A similar outcome was available in a study on precast houses built in the 1970s in Finland. The researchers found out that material compositions, reinforcement, and bonding techniques were almost the same as this current research and they emphasized the high recovery potential of components and reasonable reusing strategies [3]. Moreover, significant studies attracted attention to that the reintegration of used masonry and concrete units were traditional and prevalent around the world throughout history [24 and 25].

The vast amount of precast facade components in the examined house -i.e., 915 in each building and 778 thousand in the city demonstrated the importance of this remarkable recovery, as detailed in Table 1.

The entire deconstruction should remain the reverse of the construction process. The use of temporary confinements and a crane is essential due to the considerable weight and size of the components. The deconstruction should start from the top floor, and the primary load-bearing walls -i.e., transverse interior panels should wait until the last phase for integrity. Therefore, the initial step is the separation of wall blocks that formed the long facades. Sawing the lightweight infill together with steel bars or carving the concrete first and separating the reinforcement can disassemble the joints, as evident in Detail 1 and 2 in Fig. 3. The de-constructor can apply both methods since the seams are freely accessible. What remains when this phase is complete represents the load-bearing walls, beams, and slab panels. At that moment, after disconnecting the slabs and beams, the floor panels can be carried away. These joints are reachable by their upper surfaces, as shown in Detail 6. The essential load-bearing elements remain at this stage, and temporary confinements should assist. Only after affixation, the relation of beams and load-bearing walls terminates, and they can move separately. The top and bottom surfaces of the beams reveal the embedded seams, and their separation finalizes the removal of the top story. The same process should be repeated from top to bottom for each floor.

Table 1 Number of precast facade components in the building and the city (*minus one windowsill due to the entrance door)

Façade Components					All in Moscow
Type	Length, cm	In one floor	No of floors	Total	850 buildings
Wall block	118	12	9	108	91,800
	138	12	9	108	91,800
	158	8	9	72	61,200
Corner wall block	118	4	9	36	30,600
Windowsill block	122	14	9	126 -1	106,250
	127	8	7	56	47,600
Lintel	260	12	9	108	91,800
	280	2	9	18	15,300
	340	8	9	72	61,200
Bond beam	160	2	9	18	15,300
	240	4	9	36	30,600
Bond beam corner	118	4	9	36	30,600
Balcony slab	340	8	7	56	47,600
Addition, Ground & First floors					
Windowsill block	200	8	2	16	13,600
Attic					
Parapet block	150	32	1	32	27,200
	200	14	1	14	11,900
Parapet corner	150	4	1	4	3,400
	Grand total			915	777,750

Among recovered components, windowsills and walls blocks next to them and parapets need further investigation for reinforcement corrosion. These were the zones where the steel bars were close, and the humidity was constant. Moreover, balcony slabs require repair for the same damage in case of their reuse.

Recovered facade components can replace the interior walls of new housing projects. To this end, already started decay can slow down when the atmospheric effects are not present.

Buildings with prefabricated elements that shaped the cities of Russia, especially Moscow, are crucial in terms of urban mining. The components are large-sized, and the joints are distinct; hence deconstruction and readaptation are applicable. Moreover, these buildings are identical, and one deconstruction plan can ensure successful disassembly for all. Consequently, a vast amount of construction material stays useful instead of filling the disposal areas.

Similar buildings with unique features are present not only in Russia but all over Europe. Therefore, even if the size of components, compositions, and joints differ from region to region, the data presented in this current research are adaptable to different contexts. Material inventory carried out, which shows the material properties, element dimensions, and the available stock in the city can supply the regional data for the cross-country comparisons. Moreover, the data about the decay of these components under the climatic conditions of Russia can offer essential information for interpreting the expected damages for other regions.

4 Conclusions

Buildings with prefabricated elements that shaped the cities of Russia, especially Moscow, are crucial in terms of urban mining. The components are large-sized, and the joints are distinct; hence deconstruction and readaptation are applicable. Moreover, these buildings are identical, and one deconstruction plan can ensure successful disassembly for all. Consequently, a vast amount of construction material stays useful instead of filling the disposal areas.

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6 Appendix

Figure A1 Building #1 Joints: Partial separations, improper repair, water problem, and decay. Blocks: Paint decay and fine surface cracks. Sill blocks: Water problem. Balcony slabs: Separation of clear cover and corrosion of reinforcement. Condition: Average

Figure A2 Building #2 The same symptoms as Building #1
Addition: Repetitive joint repairs on upper floors and parapet. Condition: Poor

Figure A3 Building #3 The same symptoms as Building #1. Condition: Average

Figure A4 Building #4 Slighter symptoms than Building #1
Addition: Better joint repairs, Better wall surfaces. Condition: Good

Figure A5 Building #5 The same symptoms as Building #4. Condition: Good

Figure A6 Building #6 Very slight damages. Condition: Very good

Figure A7 Building #7 The same symptoms as Building #1
Addition: Broken parts on wall surfaces. Condition: Average

Figure A8 Building #8 Very slight damages. Condition: Very good

Figure A9 Building #9 The same symptoms as Building #1. Condition: Average

Figure A10 Building #10 The same symptoms as Building #1. Condition: Average

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