Registered in Germany Europa Revue Journal
ISSN: 1862-6564 Vol. 6 No. 7 (2026) Published July 31, 2026

A STUDY ON CONSTRUCTION DEFECTS AND ASSOCIATED RISK FACTORS IN THE ERECTION OF PREFABRICATED RESIDENTIAL STRUCTURES

Narimova Kamila Bakhromovna

Architecture and Design, 1st Group AD1-24 Turin Polytechnic University in Tashkent (TTPU)

e-mail: narimova.kamila@ttpu.uz

Abstract

Prefabricated construction methods are increasingly used to meet growing residential demand because they shorten construction schedules, lower on-site labour requirements and improve dimensional precision compared with cast-in-place construction. Despite these advantages, prefabricated residential buildings remain vulnerable to a distinct set of construction defects that originate at the design, manufacturing, transportation, erection and operational stages of the project life cycle. This article examines the principal categories of construction defects encountered in the erection of prefabricated residential structures - joint and connection failures, geometric and dimensional deviations, envelope and moisture-related deterioration, and structural deformation - and analyses the risk factors that generate them, including inadequate design detailing, manufacturing tolerance errors, poor transport and storage practices, insufficient supervision of assembly crews and unfavourable climatic conditions. Particular attention is given to the implications of these findings for seismically active regions such as Uzbekistan, where large-panel and modular housing stock forms a substantial share of the urban fabric. Based on a review of international engineering literature and normative documents applied in the Republic of Uzbekistan, the article proposes a set of practical quality-assurance measures for defect prevention, including tighter tolerance control, systematic joint inspection protocols, qualification requirements for assembly personnel and the integration of digital monitoring tools into the erection process.

Keywords

prefabricated construction; residential buildings; construction defects; risk factors; joint and connection quality; precast concrete panels; seismic safety; quality assurance.

Introduction

Housing construction based on prefabrication - the off-site manufacture of structural panels, wall units, floor slabs and, increasingly, volumetric modules that are subsequently transported and assembled on site - has become one of the principal strategies for accelerating residential delivery in both developed and developing economies. Off-site production allows greater control over concreting, curing and finishing conditions, shortens site occupation time and reduces the workforce required for in-situ operations. These advantages have made prefabricated and large-panel systems a recurring choice for mass housing programmes since the mid-twentieth century and remain central to contemporary modular construction, which is now promoted as a route toward faster and more sustainable delivery of residential stock.

At the same time, decades of observation of large-panel and precast housing stock across Europe and Asia show that prefabrication does not eliminate construction defects; it relocates and, in some respects, concentrates them. Because the load-bearing capacity, weathertightness and durability of a prefabricated building depend heavily on the quality of the connections between discrete elements, defects that would be distributed throughout a monolithic structure instead cluster at a comparatively small number of critical interfaces - vertical and horizontal joints, sleeve-grouted connections, welded steel inserts and sealant-filled façade gaps. Recent reviews of precast and modular practice confirm that joint and connection integrity, together with geometric and dimensional deviations, remain the most frequently reported defect categories across the building life cycle, with assembly identified as the dominant stage at which defects materialise.

For the Republic of Uzbekistan, this topic carries particular relevance. A significant proportion of the existing urban housing stock consists of Soviet-era large-panel buildings, and the country's current housing programmes continue to rely on prefabricated and fast-erection technologies to meet demand in both urban and rural areas. Uzbekistan is also located in a zone of elevated seismic activity, so the structural

performance of joints between prefabricated elements is not only a durability issue but a life-safety issue governed by national seismic-design normative documents. Understanding which defects recur, at which stage of the construction process they originate, and which risk factors amplify them is therefore a precondition for effective quality assurance in the sector.

This article aims to (1) classify the construction defects most commonly documented in prefabricated residential structures, (2) analyse the risk factors associated with each stage of the design-to-erection process, and (3) formulate practical recommendations for defect prevention that are applicable to conditions typical of Uzbekistan's residential construction sector.

Materials and Methods

The article is based on a structured review of peer-reviewed engineering literature on defects in precast, large-panel and modular residential construction, supplemented by an analysis of normative documents (ShNQ - Shahar-sozlik norma va qoidalari) applied in the Republic of Uzbekistan for seismic design and the organisation of construction works. Sources were selected to cover the full project life cycle - design, manufacturing, transportation, on-site erection and operation - and were grouped into defect categories using a classification framework consistent with recent systematic reviews of modular and precast construction. Risk factors were then extracted from the same body of literature and organised by the construction stage at which they most commonly originate, allowing the defect categories and risk factors to be cross-referenced in Sections 3 and 4.

Classification of construction defects in prefabricated residential structures

Joint and connection defects

Joints between prefabricated elements are consistently identified as the most defect-prone locations in precast residential buildings. In large-panel systems, assembly defects - including insufficiently filled vertical joints, incomplete welding of steel connectors, and misalignment of connecting plates - are described as a major cause of subsequent joint degradation, with many of these errors traceable to the original erection phase rather than to later material ageing. In modern precast shear-wall construction, sleeve-

grouting connections used to splice reinforcement between panels are particularly sensitive to workmanship: insufficient anchorage length, reinforcement misalignment and incomplete grout filling within the sleeve are reported as recurring defects that directly reduce the seismic performance and integrity of the connection. Investigations of prestressed precast elements further document cases of corrosion-prone cable connections caused by careless joint filling and of shallow girder-support seating that produced local concrete crushing under load.

Geometric and dimensional defects

Systematic reviews of modular and precast construction consistently rank geometric and dimensional non-conformities as the most prevalent defect category, reflecting persistent difficulties in tolerance control and element alignment during manufacturing and assembly. Typical manifestations in residential prefabricated structures include out-of-plumb wall panels, non-verticality of load-bearing elements, misfit between the as-manufactured geometry of an element and its intended supporting structure, and roof- or floor-slab buckling arising from insufficient dimensional tolerance during production or from field rectification carried out without adequate supervision.

Envelope, Thermal and moisture-related defects

Water intrusion at façade joints, window surrounds and balcony connections is a long-documented problem in prefabricated concrete sandwich-panel construction. Field inspections of precast façades have found vertical joints that were significantly narrower than specified and adhesion loosening of the sealing mastic used to close them, both of which compromise driving-rain resistance. Reviews of modular building defects likewise identify envelope and degradation issues - dominated by water leakage at panel and module joints, insulation deficiencies and thermal bridging - as a recurring, though somewhat less frequent, defect category relative to geometric and connection defects.

Structural Deformation and long-term degradation

Beyond immediate assembly defects, prefabricated residential structures can develop progressive deformation over their service life. Documented cases include excessive long-term deflection of prefabricated floor slabs that were originally rigidly

supported along panel edges but progressively lose that continuity, producing secondary damage to non-load-bearing partition walls. Destructive testing of decommissioned large-panel buildings has additionally revealed concrete carbonation, insufficient concrete cover and dimensional tolerance violations that were present from construction but became structurally significant only after several decades of service, underlining that many long-term degradation problems in prefabricated housing originate as construction-stage defects rather than purely as material ageing.

Risk Factors contributing to construction defects

Design-stage risk factors

A substantial share of defects observed during erection originates in the design stage: connection details that are difficult to execute with the tolerances achievable on a real construction site, insufficient specification of joint-filling materials and procedures, and the continued use of older structural catalogues and standardised connection details without adequate verification of current loading and durability requirements. Where design documentation lacks explicit guidance on joint sequencing, sealant application or grouting procedures, site crews are left to interpret critical details without engineering oversight.

Manufacturing-stage risk factors

At the factory stage, the principal risk factors are inadequate formwork and mould maintenance leading to dimensional drift between production batches, insufficient quality control of concrete cover and reinforcement placement, and variability in curing conditions that affects the strength and durability of the finished element. Because prefabricated elements are produced in advance of the specific building in which they will be installed, small manufacturing deviations can accumulate into fit-up problems that are discovered only during assembly, when correction is far more costly.

Transportation and storage risk factors

Off-site manufacturing inherently requires the transport of large, often heavy and dimensionally sensitive elements by land or, in some markets, by sea, using cranes, trucks and trailers; this stage introduces its own risk of impact damage, cracking and connector distortion, particularly when elements are inadequately braced or are stacked

without proper dunnage during storage. Prolonged uncontrolled storage on an open site prior to erection also exposes elements to moisture ingress and surface contamination that can compromise later joint sealing and coating adhesion.

Erection and assembly-stage risk factors

The assembly stage is repeatedly identified as the dominant point at which defects materialise in prefabricated construction. Key risk factors include insufficient supervision and quality checking of crews, low qualification levels of assembly workers, disregard for unfavourable weather conditions during joint sealing or grouting operations, and schedule pressure that encourages shortcuts in joint preparation, cleaning and filling. Because access to completed joints is often technically difficult once adjacent elements are installed, assembly-stage errors frequently remain undetected until much later inspection or, in the worst cases, until partial structural distress becomes visible.

Operational and environmental risk factors

After handover, ongoing risk factors include moisture penetrating from bathrooms and kitchens into internal joints, freeze-thaw cycling and driving-rain exposure acting on façade sealants, and - in seismically active regions - repeated low-level ground motion that progressively loosens connections not originally detailed for cyclic loading. In Uzbekistan's climatic and seismic context, these operational risk factors interact directly with construction-stage defects: a joint that was under-filled or a connector that was misaligned during erection is disproportionately more likely to fail prematurely under subsequent thermal cycling or seismic action.

Implications for Uzbekistan's residential construction sector

Uzbekistan's housing stock includes a substantial number of Soviet-era large-panel residential buildings, alongside a growing share of new construction using fast-erection and modular technologies within state housing programmes. National seismic-design requirements, set out in the construction norms and rules (ShNQ) governing building in seismic regions, place particular emphasis on the ductility and continuity of connections between prefabricated elements, since the seismic performance of a panel building is governed as much by its joints as by the strength of the panels themselves. The defect patterns identified in this review - under-filled or poorly welded joints, dimensional non-

conformities and inadequately supervised assembly - are therefore not only durability concerns but factors that can directly reduce a building's seismic safety margin if left uncorrected.

The organisational requirements set out in national norms for the organisation of construction works call for staged quality control at manufacturing, transport and erection; however, the international evidence reviewed above suggests that consistent enforcement of joint inspection and documented sign-off at each stage - rather than reliance on final visual inspection alone - is the factor most strongly associated with lower defect rates in comparable large-panel and modular housing programmes elsewhere.

Recommendations for Defect Prevention and Quality Assurance

Based on the defect categories and risk factors analysed above, the following measures are recommended for reducing construction defects in the erection of prefabricated residential structures:

First, design documentation should specify joint-filling materials, sequencing and tolerances explicitly, rather than leaving these details to be resolved on site, and connection details inherited from older structural catalogues should be re-verified against current seismic and durability requirements before reuse.

Second, factory quality control should include systematic dimensional checking of every production batch against design tolerances, with non-conforming elements withheld from dispatch rather than corrected informally during assembly.

Third, transportation and storage procedures should specify bracing, lifting-point locations and maximum storage duration for weather-exposed elements, to prevent the accumulation of handling damage before elements ever reach the erection stage.

Fourth, erection crews should be required to hold documented qualification in joint sealing, grouting and welding procedures specific to the connection systems used, and joint completion should be subject to a mandatory hold-point inspection before the next element is installed and access is lost.

Fifth, periodic post-occupancy inspection of joints - particularly in wet-area zones and at building perimeters exposed to driving rain - should be incorporated into building

maintenance programmes so that construction-stage defects are identified and remediated before they progress into structurally significant degradation.

Conclusion

Prefabricated construction offers substantial advantages in speed and dimensional control for residential building delivery, but it also concentrates structural risk at a limited number of joints and connections whose quality is determined by decisions and workmanship spanning the design, manufacturing, transport, erection and operational stages. The literature reviewed in this article shows a consistent pattern: geometric and dimensional non-conformities and joint or connection defects are the most frequently reported problems in prefabricated residential and modular buildings, and the erection stage is the point at which most of these defects are introduced or become irreversible. For Uzbekistan, where large-panel housing forms a substantial part of the existing stock and prefabricated technologies remain central to current housing programmes, these findings underscore the importance of treating joint quality as a seismic-safety issue rather than a purely aesthetic or maintenance concern. Systematic tolerance control at manufacturing, disciplined handling during transport and storage, qualified and supervised assembly crews, and staged inspection with documented hold points together represent the most effective available means of reducing construction defects and improving the long-term safety and durability of prefabricated residential structures.

References:

1. Krzywoń, R.; Hulimka, J. Common Defects of Prefabricated Prestressed Elements for Industrial Construction. Buildings 2024, 14(3), 673. https://doi.org/10.3390/buildings14030673

2. Wang, Y.; Wang, H.; Wang, F. Simplified Modeling Method for Prefabricated Shear Walls Considering Sleeve Grouting Defects. Buildings 2024, 14(6), 1813. https://doi.org/10.3390/buildings14061813

3. Karunasena, G.; Gurmu, A.; Shooshtarian, S.; Udawatta, N.; Perera, C.S.R.; Maqsood, T. Effect of construction defects on construction and demolition waste management in building construction: a systematic literature review. Intelligent Buildings and Cities 2025. https://doi.org/10.1093/inteam/vjae026

4. Baltrocchi, A.P.D.; Shafique, M.; Torretta, V. A Systematic Review on Life Cycle Assessment of Prefabricated Buildings. Sustainable Horizons 2026, 17, 100168. https://doi.org/10.1016/j.horiz.2025.100168

5. Kamali, M.; Hewage, K. Life cycle performance of modular buildings: A critical review. Renewable and Sustainable Energy Reviews 2016, 62, 1171–1183.

6. Almaskati, D. Modular Construction: A Comprehensive Review. Buildings 2025, 15(12).

7. Parracho, D.F.R.; El-Din, M.N.; Esmaeili, I.; Freitas, S.S.; Rodrigues, L.; Martins, J.P.; Corvacho, H.; Delgado, J.M.P.Q.; Guimarães, A.S. Modular Construction in the Digital Age: A Systematic Review on Smart and Sustainable Innovations. Buildings 2025, 15(5), 765. https://doi.org/10.3390/buildings15050765

8. Defects in Modular Building Construction: A Systematic Lifecycle Review and Implications for Sustainable Delivery. Sustainability 2026, 18(8), 4000. https://doi.org/10.3390/su18084000

9. fib (International Federation for Structural Concrete). Planning and Design Handbook on Precast Building Structures, Bulletin 74; fib: Lausanne, Switzerland, 2014.

10. O‘zbekiston Respublikasi Qurilish vazirligi. ShNQ 2.01.03-2019. Qurilish seysmik hududlari (Construction in Seismic Regions). Toshkent, 2019.

11. O‘zbekiston Respublikasi Qurilish vazirligi. ShNQ 3.01.01-2018. Qurilish ishlarini tashkil etish qoidalari (Rules for the Organisation of Construction Works). Toshkent, 2018.

12. Shodmonqulov, T.A.; Otaqo‘ziyev, T.A. Temir-beton konstruksiyalar (Reinforced Concrete Structures). “Fan va texnologiya”, Toshkent. 2019.

13. Ashrapov, N.T. Qurilish konstruksiyalarini loyihalash va montaj sifatini nazorat qilish (Design and Assembly Quality Control of Building Structures). TDTU nashriyoti, Toshkent. 2021.

14. Rahimov, Sh.T.; Yusupova, M.A. Bydro qurilish texnologiyalari va ularning sifatini ta’minlash muammolari (Fast-Erection Construction Technologies and Their Quality-Assurance Problems). «Arxitektura, qurilish, dizayn» ilmiy-amaliy jurnali, 2022, №2, 45–52-betlar.