

Evaluation of New Building Systems for Modular Construction of High-Rise Residential Buildings Using Prefabricate Prefinished Volumetric Units

1. Essence of the evaluation of new building systems

The main feature of a new building system (of any kind) is that the existing set of regulations and standards, which is based on accepted and familiar building materials and construction methods, does not cover all essential performance requirements and criteria, as well as verification methods, needed in the design and execution of buildings that are constructed using the said system. Due to the innovativeness that is inherent in new methods, there may also be cases in which some system details are incompatible with the instructions of the existing standard, despite the fact that the system is both sound and safe. The process of evaluating and approving new building systems is intended to avoid rejection of the use of the system as long as standardization has yet to be completed or amended, and to enable introduction of the system into the construction industry in a safe and correct manner from an engineering perspective. The Building Systems Evaluation and Approval Unit at the Technion's National Building Research Institute evaluates the ability of the details of the new method to provide a proper performance level in buildings that are constructed using the method, in terms of the following aspects: structural stability and strength under gravitational, wind, earthquake and other loads; protection against cracking and excess fluctuations; protection against the spread of fire; structural fire resistance; water and damp proofing; thermal insulation and prevention of excess thermal bridging; protection against air leakage through the building envelope; acoustic insulation with respect to both airborne and structure-borne sound; protection against health hazards (relevant for new materials with no existing standard), and durability (including resistance to accelerated weathering). The constructability of the execution technology is also evaluated to ensure that the new details can be executed and quality-controlled according to the design documents.

2. Inherent innovativeness of new building systems for modular Prefabricate Prefinished Volumetric Construction

When engaging in modular construction using **Prefabricate Prefinished Volumetric Construction** (hereinafter referred to simply as "modular construction"), the 3-D units themselves are fabricated and finished in the factory and the on-site works include various kinds of assembly activities, coordinating and connecting of systems, installation of fire barriers, closing of various exposures, completion of flooring, closing around openings between units, sealing seams, sealing roofs, and sometimes also finishing facades.

Since the 1980s, Israel has accumulated experience in the construction of low permanent buildings using this technology, which is addressed in the Israeli standard SI 2262 and is usually not considered innovative. The differences between various modular building systems, which are intended for the construction of high-rise permanent buildings, can be found both in the building details of the modular units (in the structural materials of the modular unit; in the unit's static scheme; and in the materials used in all layers of the unit's walls, floor, and ceiling) and in the building details of the on-site works (in the overall static scheme of the entire structure; in the various details of the connections between the units and between the units and other elements built on site (such as the foundation floor, the central core, residential safety spaces); in the materials and methods of the various sealing details; in the

materials and methods of the various fire barrier details; in completing the thermal and acoustic insulation; and in the facades' execution and finishing methods).

The nature and details of the interfaces between the units and of the on-site works differ from the building details and on-site works in regular construction (in which works that are specific to this technology do not even exist), and they are not addressed by existing standardization (in Israel and elsewhere in the world). Thus, most of the on-site activities include innovative building details (and sometimes new materials as well) that are characteristic to the specific new building system.

On the other hand, in most cases, the details of the units themselves are not innovative. When the unit's structure is made of reinforced concrete or steel according to specifications of Israeli standards IS 466 for concrete structures and IS 1225 for steel structures, it is not considered new. Similarly, all of the materials and components intended for various elements of the unit, which have standards that address the said designations, are not considered new (e.g. gypsum/drywall panels, wooden panels, thermal and acoustic mineral wool insulation, ceramic tiles, cladding stone, etc.).

Only when the unit itself contains materials or components for which no standard exists, or whose execution details cannot be tested according to the existing standardization, will the building system of the unit itself be considered new.

Lists of engineering aspects, including possible shortcomings of building systems for modular construction, are presented in Sections 2.8, 3.8 and 4.8 of the 2019 research report, prepared by the National Building Research Institute at the request of the Israeli Ministry of Construction and Housing, entitled "Industrialization of residential construction using 3D modular units – Architectural, engineering, and executional aspects".

3. Content of the Evaluation and Approval of New Building Systems for Modular Construction

Modular building systems for high-rise construction are evaluated in accordance with above Sections 1 and 2, as follows:

The first step in the preliminary evaluation determines whether the units' construction method includes any innovativeness.

- If there is any innovativeness, we will check whether all of the required information has been submitted in order to enable an in-depth evaluation of the innovative detail, and we will determine whether or not to reject it out of hand.
When the initial decision is positive, a more in-depth evaluation of the units' new building system can be conducted.
The evaluation of a new building system with a detail that has been rejected out of hand cannot be continued, and the detail must be rectified before evaluation of the system is continued.
- If the units' building system includes no innovativeness, it is not considered new and neither an in-depth evaluation nor approval of it is required.

The rest of the preliminary evaluation will address the building details that pertain to interfaces between the units, to details around the passage openings between units and between units and the central core, and to on-site works and preparations for such, including preparations required in the units themselves. This evaluation may include the overall static scheme; connections between the units and

between the units and elements that are constructed in-situ (such as the foundation floor, central core, and apartment security spaces); coordinating and connecting of systems; fire barriers around openings at interfaces between units and ceiling levels; details at passage openings designed to ensure fire resistance of the structural parts and connections; flooring coordination; moisture protection during transport and assembly; water proofing of joints and roof; elements designed to ensure air tightness of unit envelopes and around passage openings; completion of thermal insulation according to need; facade finishing, etc. If all of the information is submitted properly, and none of these details is rejected out of hand, the process may proceed to an in-depth evaluation.

The in-depth evaluation will only address the innovative elements, as specified above, and will ensure that they enable proper functioning in all that pertains to the engineering aspects, as specified in Section 1 and to constructability. The sampling-based follow-up stage will be carried out on the first buildings to be built using the system, and will check to see whether any difficulties arise in the execution or quality control of the innovative details according to their design, and whether any performance problems arise during or after construction.

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