DISMANTLEABLE JOINTS WITH CONTROLLED PROPERTIES OF A PREFABRICATED REINFORCED CONCRETE BUILDING SYSTEM

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Summary

The currently used cast-in-situ reinforced concrete structures set high demands for energy and material. It is, above all, the highly energy intensive production of cement and steel that has negative impacts on the environment. The "recycling" option for a reinforced concrete structure at the level of prefabricated units, therefore, represents significant energy and material savings and also reduces the negative impacts on the environment. The outstanding properties of the system also include its resistance to dynamic effects and vibrations and thus the elimination of negative effects on the quality of the interior environment in buildings exposed to such effects.

Keywords: prefabrication, dismantleability, vibrations, joint rigidity

1 Introduction

One of the prominent features of contemporary society is a significant dynamism of changes, manifested both in the economic and administrative area, but also in the social area. The development of the economy requires not only frequent requalifications, but also the mobility of the work force, flexible building systems that allow the relocation of buildings as required and their further utilisation at a new location. This dynamism is not in correspondence with the potential of present-day building systems which are usually characterised by a limited adaptability and high demands in the case of a change in their use. Any relocation of a building erected with the currently used building systems, induced by manufacturing, transportation or demographic needs, as a rule, results in a total or partial demolition. The experience with numerous buildings of so-called servicing facilities (buildings for pre-school or primary education, etc.) in residential neighbourhoods has also pointed out the need for the generational mobility – relocability – of buildings.

Repetitive use of prefabricated reinforced concrete units with a long life cycle within a new design solution in construction allows reaching considerable material and energy savings (Fig. 1). Instead of complicated demolitions and successive recycling of concrete components (steel reinforcement and crushed artificial aggregates), individual units are reused in agreement with their physical life cycle and the functional life cycle of the

building (e.g. relocation of a building for preschool and primary education, accommodation and hotel complexes, structures for temporary use, etc.). The dismantleability and a possibility of a new spatial arrangement – extension or reduction in size, a change in the functional use of a building in keeping with its current contractor's or user's requirements, gradual additional construction, design solution of generation cycles, etc. (Fig. 2).

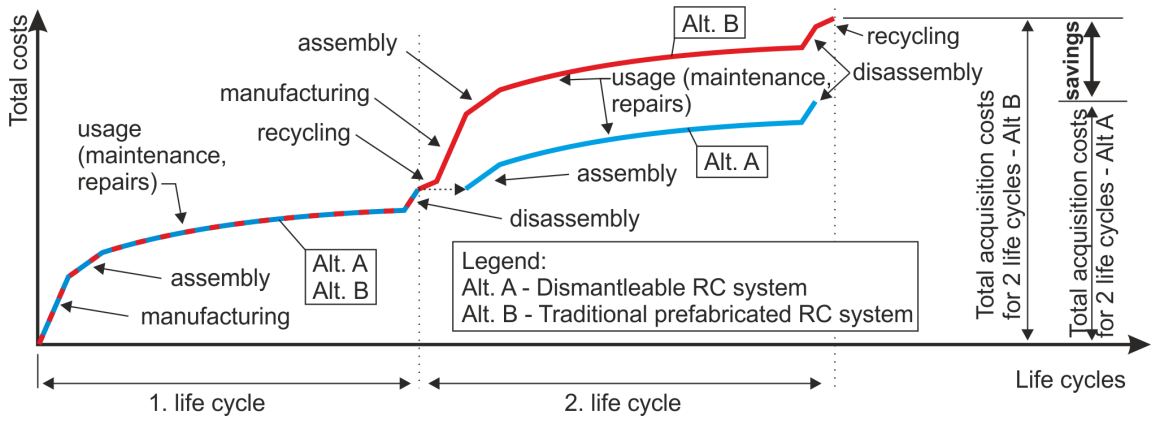

Fig. 1 *Illustration of "Total costs x Life cycle of structure"*

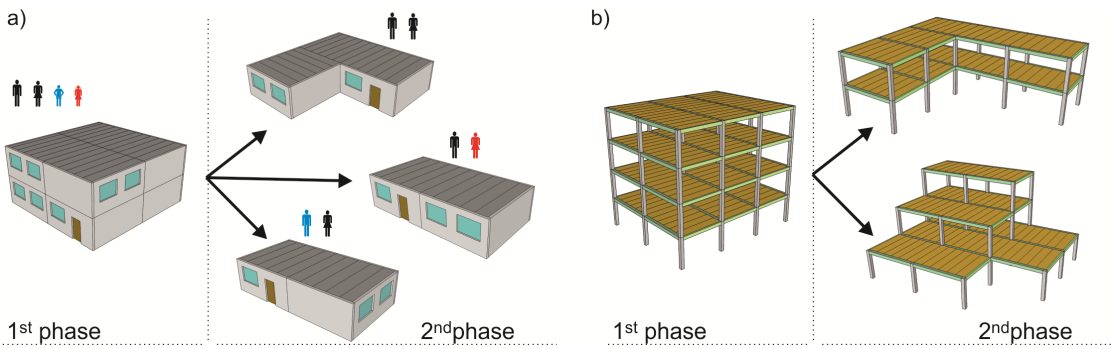

Fig. 2 *Generation cycles of dismantleable prefabricated wall (a) and frame (b) structure*

2 Multi-storey buildings with controlled elastic joints properties

Systems with controlled joint properties allowing damping of vibrations may also find their applications in buildings with strict conditions and requirements such as special production plants, health care, research and development facilities, etc.

Static and dynamic characteristics of prefabricated systems with controlled properties (rigidity) allow a relatively diverse application of these systems in zones with increased and natural seismicity. Prefabricated systems are characterised by such a deformation and failure mechanism in which the limit state of the structure as a whole is preceded by the joint failure, or in which the structure passes from linearly elastic behaviour to non-linear elastic to plastic state usually by exceeding the proportionality limit in its joints [1].

Standard prefabricated reinforced concrete systems do not allow modifications of joint properties to the extent enabling active damping of vibrations due to dynamic loading effects. Changes in the operation or purpose of such designed reinforced concrete building systems are usually connected with laborious interventions in the building systems involving demolitions and deterioration of structures even before their life cycle period has

elapsed. Reconstructions or demolitions of reinforced concrete systems are usually connected with undesirable environmental impacts, both in terms of environmental degradation (noise and dust pollution, higher traffic volumes) and in terms of induced costs for the deposition of construction rubble, costs for recycling materials, etc. There are also significant additional material and energy demands connected with demolition works and the transport, deposition or recycling of materials; it often happens that the materials, or products made of these materials, still have not reached their service life limit. The "recycling" option for a reinforced concrete structure at the level of prefabricated units, therefore, represents significant energy and material savings and the mitigation of negative impacts of the building industry on the environment. Repeated use of reinforced components requires the use of high-strength concrete with low permeability and compliance with requirements for the protection of reinforcement in accordance with exposure of reinforced components during their planned lifetime. Major characteristics of prefabricated systems with controlled properties of joints also include the system's resistance to dynamic effects and vibrations implying the limitation of negative effects on the quality of the internal environment of buildings exposed to such effects (Fig. 3, [2]).

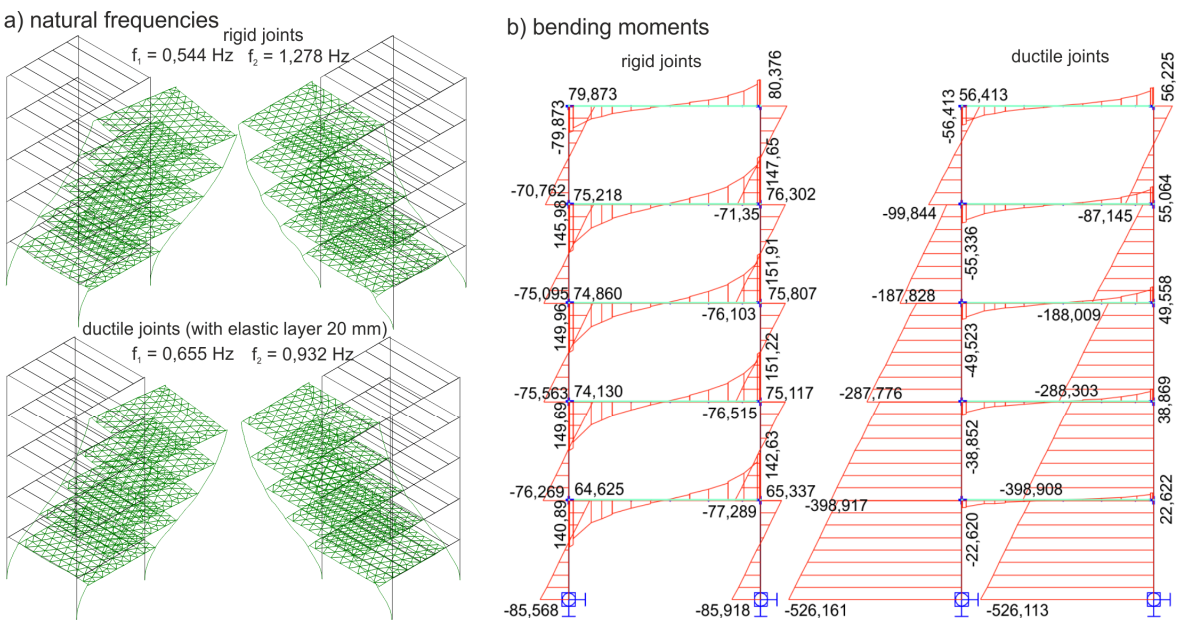

Fig. 3 *Comparison of the response of a reinforced concrete storey structure (frame) with rigid and ductile joints (rigidity 0.01) loaded by shearing force at the upper free end (natural frequencies (a) and bending moments (b))*

Controlled properties of joints (modification of joint rigidity) create preconditions for the system's utilisation in extreme conditions and situations – natural disasters, extraordinary effects, etc. Controlled properties of joints of prefabricated units allow eliminating, to a certain extent, the dynamic and seismic effects caused by human activity, traffic, building and production activity, or natural effects. Besides the limitation of the intensity of dynamic effects to a level that will not cause the failure of a building and its parts, due to compensation (elastic) elements inserted into the joints, capable of absorbing energy with specified dynamic characteristics, another significant property of these joints is the elimination of outside noise (traffic, building activity, industrial activity) below the absolute threshold of hearing and thus the enhancement of the quality of the internal environment, allowing potential development in areas with increased noise levels. The

system may analogically be applied in places with poorer foundation conditions, with underground traffic, in undermined zones (vertical rectification of vertical members which had been subjected to settlement) and in areas with a high probability of the occurrence of natural seismicity.

Great emphasis is currently placed on the solution of issues of seismic loading and the response of structures to the effects of natural, technical and induced seismicity worldwide, these efforts are focused not only on buildings situated in zones of increased natural seismic activity, but also on buildings affected by growing volumes of overground as well as underground traffic and construction activity, and buildings exposed to the effects of technical and induced seismicity [3]. High sensitivity of reinforced concrete prefabricated pillar or wall systems of particularly multi-storey buildings with "rigid" joints to the effects of induced deformations, strain and vibrations increases potential risks of the failure of the structural function of the load-bearing system exposed to long-term intensive vibrations and shocks, or seismic effects, and of a related loss of its static (dynamic) resistance.

3 Conclusions

The dry assembly and dismantling option create conditions for reaching a harmony between the service life and the serviceability of a building (e.g. relocation of facilities for pre-school and primary education, temporary buildings, etc.), reducing material and energy needs (highly energy intensive manufacturing of cement and steel, reduced purchasing costs through the reuse of precast units) and reducing the negative effects of building operations on the environment. Specific characteristics of the designed system create preconditions for the system's utilisation in extreme conditions and situations, e.g. at sites of natural disasters – floods, land slides, seismic effects, etc. These characteristics create preconditions for a potential export of the system in a direct or indirect way.

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References

[1] Witzany, J., Working Diagrams of Joints under Repetitive Loading, In: *Pozemní stavby*, Vol. 25, No. 8, Prague, Czech republic, 1982

[2] Makovička, D., Makovička, D., Analysis of vibro-based isolated building, 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 2012, Vienna, 9 pp.

[3] Witzany, J. et al, Prefabricated Planar Structure of a Multi-Storey Building Exposed to Cyclic Load and Engineering Seismicity. In *Proceedings of the Fifth International Structural Engineering and Construction Conference*, *Las Vegas, 21-27 September 2009*. Leiden: CRC Press/Balkema, 2009, p. 339-344