ADVANTAGES OF SUSTAINABLE STRUCTURES CONSISTING OF CONCRETE FRAMES WITH HYBRID AND NON-ADHERENT HYBRID JOINTS

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ABSTRACT

The strategic objectives of the European Construction Technology Platform aim to achieve a sustainable development of the sector till 2030. It is intended to satisfy also the free market innovation requirements. In order to ensure the sustainability of the RC monolithic structures the priority of the research is focused on materials (concrete and reinforcement) and of the RC precast structures, the target is the improvement of the connections between the members. A new concept of reinforced concrete moment frame structure, composed of discretely jointed precast and post-tensioned concrete members, with hybrid joints and non-adherent hybrid joints is presented. There are presented the main advantages of this kind of structures, considering the entire life cycle of the buildings, taking into account the technical, economical, social and environmental aspects.

Keywords: hybrid joint; non-adherent hybrid joint; sustainability; seismic loadings

REZUMAT

Obiectivele strategice de cercetare stabilite de Platforma Europeană pentru Tehnologia Construcţiilor, prevăd şi realizarea unei dezvoltări sustenabile a sectorului de construcţii până în anul 2030, care să satisfacă în acelaşi timp şi necesitatea de inovare specifică pieţei libere. Pentru structurile monolite de beton armat prioritatea în cercetarea de asigurare a sustenabilităţii vizează în principal materialele (beton, armături), la structurile prefabricate această prioritate vizează cu precădere îmbinările între elemente structurale. Se prezintă o nouă concepţie de realizare a structurilor din cadre prefabricate de beton armat, asamblate prin precomprimare, cu noduri hibride şi respectiv cu noduri hibride neaderente, rezistente la încărcări laterale inclusiv seismice. Avantajele principale ale acestor structuri se prezintă prin prisma aspectelor tehnico-economice, sociale şi protecţiei mediului, având în vedere toate etapele din viaţa unei construcţii

Cuvinte cheie: nod hibrid, nod hibrid neaderent; sustenabilitate; sarcini seismice

1. INTRODUCTION

A new concept of precast reinforced concrete frame joints assembled by prestressed non-adherent strands and provided in the column-beam connection with special reinforcement, compatible with seismic safety criteria enforced by European and Romanian codes, have been studied from the sustainability point of view as well as from the design, technology and experimental analysis ones.

2. RESEARCH PROGRAM

2.1. Research program goals

The research program aimed to assure the new design concept an experimental basis as well, in order to:

– establish the construction technologies of the hybrid joints and of the non-adherent hybrid joints;
– validate the removability features of damaged hybrid joints and of non-adherent hybrid joints;

– check out the structural response of prefabricated frame hybrid joints under the cyclic alternating seismic type loading, (in terms of strength, deformation, cracking, ductility, energy dissipation) ;
– find the principles of calculation and develop relationships for the non-adherent hybrid joints.

2.2. Sustainability of the new concept

The proposed new joint solutions for reinforced concrete frame structures are sustainable within the specific performance criteria regarding:
– European and national strategy and research directions, for achieving a sustainable construction sector;
– technical solution requirements (economical, social and environmental).

3. RESEARCH RESULTS

3.1. Experimental research results

The main results were the following:
– implementation and validation of hybrid joint and of non-adherent hybrid joint erection technology;
– determination of the behavior under lateral seismic-type loading of full-scale models, containing each type of analyzed joints;
– proving the removability of the locally damaged special reinforcement and of the restoring of the structural integrity for the non-adherent hybrid joints RC frames.

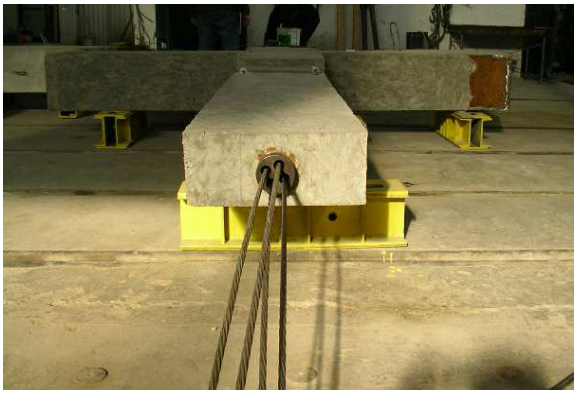

Fig. 1. Strands for beam post-tensioning

Fig. 2. Fixing of non-adherent special reinforcement

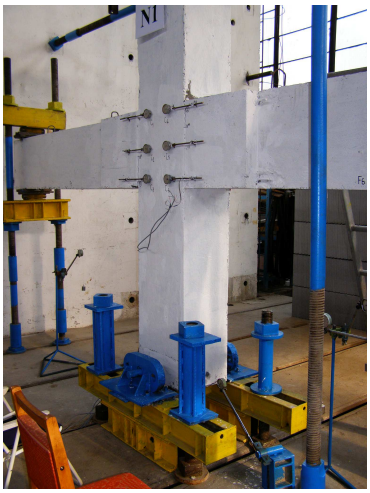

Fig. 3. Test set-up of hybrid and non-adherent hybrid joint specimens

3.2. Design proposals

Based on the experimental results, design requirements were proposed as follows:
– definition and principles of composition for non-adherent hybrid joints (2);
– detailing of the hybrid joints and of the non-adherent hybrid joints, specifying requirements regarding: materials, structure frame components, frame joints, and beam-column interface;
– appropriate method for computing the moment resistant frame structures with hybrid and non-adherent hybrid joints based on displacements, such as the Direct Displacement-Based Design "DDBD"(3)

– cross-sectional calculation methods; for the hybrid joints, the U.S. standard ACI T1.2-03 (1) provides the necessary assumptions and relationships, for the non-adherent hybrid nodes; a new calculus method was proposed, which was presented in a previous paper (2).

4. SUSTAINABILITY

The new concept for prefabricated structures, which uses either the hybrid joints or the non-adherent hybrid joints at the reinforced concrete frames, provides advantages regarding all main aspects of a sustainable approach.

4.1. Technical and economic aspects

The main advantages of the new solutions comparative to classical frames are:

– simplicity of execution, for example columns without brackets (Figs. 2 and 3), reflected in reduced costs for casing;
– reduced workmanship and materials costs on site;
– favorable structural behavior to accidental actions: degradations focused in pre-defined local areas, (column-beam interface) and at the unbonded pre-stressing of the beams re-establishment of the initial shape of the frame after lateral loading (as a strong earthquake);

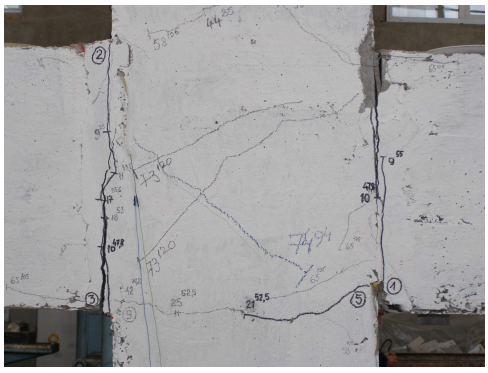

Fig. 4. Damage concentration at column-beam interface

– quick, easy and cost-effective interventions for post-earthquake repair (limited to areas of interface between column and beam or/and at the outside the building, at the strands anchorage devices) than the classical structures interventions that require extensive repair areas, several times being necessary to remove the finishing or non-structural elements, involving high costs and long time of construction;
– moreover, for the non-adherent hybrid joints, it is possible to replace the special reinforcement, and thus to restore the initial load bearing capacity and ductility of the structure after an important seismic action;

Additional costs due to pre-stressing comparing to classical frame structures should be taken into account.

4.2. Social aspects

The social aspects favorable to the new concept of construction of prefabricated structures consisting in reinforced concrete frames with hybrid nodes and of new hybrid nodes are:

– reduced social costs involved in repairs and reinforcements (no need of moving the occupants during repairs and only short-time inner activities gaps)
– beneficial visual impact to users after a moderate or strong earthquake, due to the fact that the structure returns to its original configuration;

Fig. 5. Return to original shape after seismic-type loading

– post-use of the buildings can be made, so that it is possible to recover most of the

structural elements, which contributes to reduce the social effort for replacing the built space;
- providing highly specialized and well-paid jobs; thus, it is necessary to use a skilled workforce to erect these types of structures due to the prefabrication and mainly to the pre-stressing procedure.

4.3. Environmental issues

Some of the most favorable aspects in terms of ensuring a cleaner environment of the new concepts of prefabricated structures with hybrid nodes, including non-adherent hybrid nodes and considering virtually all life stages of construction are the following:
- the on-site activities are reduced; so are the processes involving generation of particle emissions (dust);
- after strong earthquakes the repairs consist in few activities located in known zones, which have virtually no impact to the environment;
- demolition of structures would be made by disassembling, excluding procedures using explosives or mechanical shocks, which produce large amounts of dust and waste, emitting particles in the atmosphere, as well as the loading and unloading of debris resulting from demolition;
- disestablishment of such structures by removal allows the use of structural elements in other buildings, because these elements were not overloaded, due to the fact that almost all damage was concentrated at the column-beam interface. So, a large part of the concrete members are not to be recycled through energy intensive processes (with consequences in terms of resource depletion).

5. FINAL ASSESSMENT

In the paper there were revealed only some of the sustainability aspects of a more complex study. The other main contributions and innovative aspects of the study, such as the new compositions of frame structures with hybrid and non-adherent hybrid joints, such as the testing under seismic loadings, calculation methods and design details are presented in a recently published paper and in other publications which are now in preparation, as the research is still developing.

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