Engineering Structures 79 (2014) 22–31

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Assessing local-scale damage in reinforced concrete frame structures using dynamic measurements

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ARTICLE INFO

Article history:
Received 13 February 2014
Revised 25 July 2014
Accepted 28 July 2014
Available online 20 August 2014

Keywords:
Dynamic measurement
Reinforced concrete
Frame
Nondestructive testing

ABSTRACT

The applications of dynamic measurements on existing buildings are numerous: assessment of their seismic vulnerability, assessment of the structure's capacities in post-earthquake situations or after changes in the vicinity, etc. At present, this type of measurement enables structural diagnosis on a global scale (the whole structure), while the identification and the assessment of local damage (each element of the structure) remains to be explored. Herein, diagnosis at the local scale was studied in the laboratory on an instrumented reinforced concrete structure consisting of two columns and one beam. It was loaded in the central part of the beam in several stages corresponding to different damage states. Displacements were measured simultaneously using displacement sensors and image correlation. After each load/unload cycle, dynamic measurements were taken using accelerometers.

In the first part of this paper, the observations from the experiment were presented, with the appearance of damage and the decrease in natural frequencies that occurred simultaneously with stiffness reduction. Thereafter, the technique characterizing damage that was developed taking into account the semi-rigid connections of the frame was presented. The stiffness of the connections was identified by calibrating the dynamic responses of the structure with respect to a model. The fixity factors were used to assess the loss of stiffness in the semi-rigid connections. The validity of the identified fixity factors was evaluated using the static experimental results. This study shows that dynamic measurement coupled with finite element analysis can provide a fast and effective method to assess the quality of connections of reinforced concrete structures.

1. Introduction

Dynamic in-situ measurements are tests, most often nondestructive, achieved directly on real structures [4,11,32,33]. Dynamic measurements on existing building structures can be applied in numerous situations: verification of the seismic vulnerability of structures that were built before the development of seismic regulations [3]; assessment of the structures in post-earthquake situations or after changes in the vicinity (e.g., digging of a tunnel, demolition of neighboring buildings); and the study of the behavior of unusual structure [5,6,32]. At present, this kind of measurement makes it possible to diagnose a structure on a global scale (the whole structure), while the identification and the assessment of local damage (each element of the structure) remains to be explored. Herein, the diagnosis in the laboratory and at the local scale of an instrumented reinforced concrete (RC) structure consisting of two columns and one beam is studied, as part of the French national program for the re-assessment of existing structures.

2. Experiment on a reinforced concrete frame

2.1. Test set-up

The instrumented RC structure (Fig. 1) was composed of two 2-m-high columns (section, $20 \times 25\ cm^2$) and one beam spanning 2.27 m (section, $20 \times 20\ cm^2$), Fig. 2. It corresponds to a geometric scale of 0.4 comparing to current RC structures. The structure was manufactured by a RC company. Column ends were restrained by jaws. The structure was loaded in the central part of the beam in several stages to study different damage states (Fig. 3). Blue and white color was sprayed on the structure which enables to use an image correlation technique.

Cylindrical concrete specimens (16 cm diameter and 32 cm height) were made and tested to characterize the concrete used. The mean values of the compressive strength and the Young modulus were, respectively, 22 MPa and 20 GPa. These results

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http://dx.doi.org/10.1016/j.engstruct.2014.07.038
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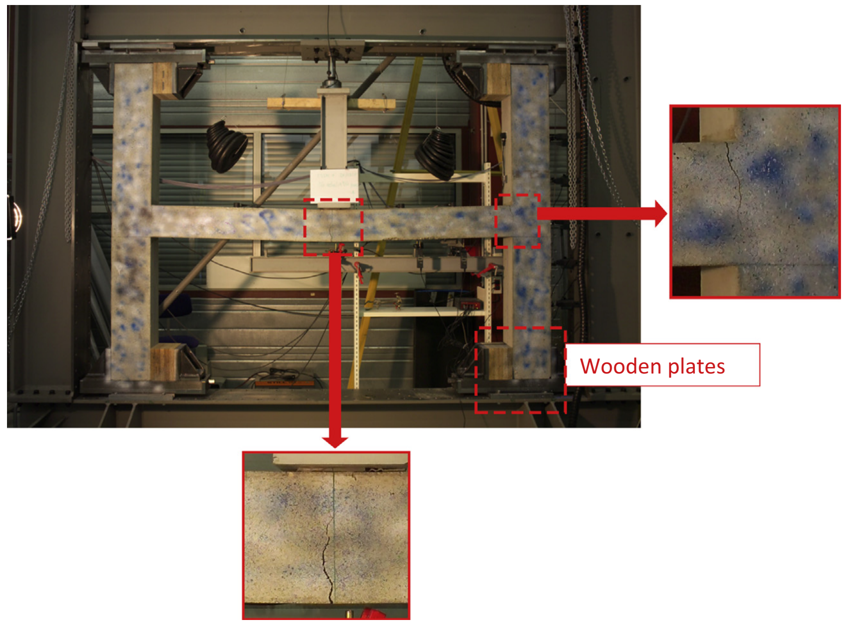

Fig. 1. The reinforced concrete frame studied, at the maximal load.

are relatively low compared to the values usually obtained in the laboratory but come from an industrial manufacturing. In addition, after form removal, two shrinkage cracks were observed in the connections between the beam and the two columns.

Steel used for reinforcement is S500B. Reinforcement in the columns was composed of four HA10 lengthwise bars and 17 HA6 stirrups spaced 12 cm apart. Reinforcement in the beams was composed of two upper lengthwise HA10 bars (with 40 cm of anchorage in each column), two HA12 lower lengthwise bars (with 12 cm of anchorage in each column), and 18 HA6 stirrups spaced 13 cm apart, Fig. 2.

Displacements were measured simultaneously by the press sensor, three displacement sensors positioned on the lower face of the beam, and image correlation. In image correlation technique, displacements field is generated by comparing two images which are taken at two different times (eg. before and after specimen is deformed) [31].

The dynamic characteristics of the structure were determined by means of four one-directional accelerometers: one was attached to a column to measure the horizontal accelerations and the others were put on the beam to measure vertical accelerations (see Fig. 5 for more details). The sensors were placed in the central axis of beam and column elements.

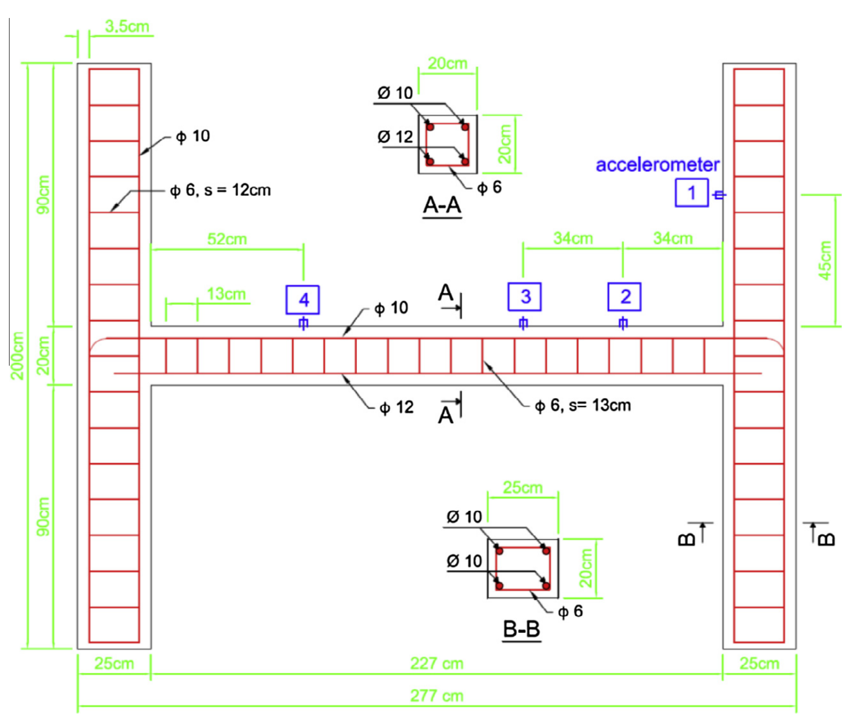

Fig. 2. Plan of reinforcement bars.