HORIZON 2020

ANALYSIS OF RC STRUCTURES EMPLOYING NEURAL NETWORKS

Sprawozdania

Informacje na temat projektu

ARCSENN

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Periodic Reporting for period 1 - ARCSENN (ANALYSIS OF RC STRUCTURES EMPLOYING NEURAL NETWORKS)

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Podsumowanie kontekstu i ogólnych celów projektu

Structural analysis software employed in practice for predicting the behavior of reinforced concrete (RC) structures is based on simplified assumptions concerning concrete material behavior and structural response. Such software is often developed on the basis that the code provisions effectively safeguard flexural types of failure. However, this is not always the case in practice. On the other hand, more advanced structural analysis tools, mainly used in research, employ complex constitutive laws and numerical procedures which are often dependent on case-sensitive parameters which detrimentally affect the generality and objectivity of the predictions obtained. Such packages require higher computational resources and longer analysis time. In view of the above there are concerns regarding the ability of the existing structural analysis packages to provide solutions capable of safeguarding structural integrity and resilience.

To address the above issues, present work employs Artificial Neural Networks (ANNs) [see Fig.1] for predicting the load-carrying capacity of individual RC structural components. These ANNs are trained directly through the use of published test data. They are then used for the development of a new structural analysis procedure capable of accurately predicting the behavior of RC structures by employing hybrid artificial neural network finite element analysis (ANN-FEA) models [see Fig.2] to represent the structure at hand. The proposed procedure requires significantly less computational resources compared to more traditional structural analysis methods based purely on the finite element method. The proposed analysis procedure provides a way of enhancing the ability of current structural analysis tools employed in practice to accurately predict the behavior of RC structures even when characterized by brittle modes of failure [see Fig.3] without requiring high computational resources or lengthy analysis time.

Research Objectives:
- Create databases containing valid test data on RC beams, columns and exterior beam-column joints. These databases are enriched with numerical data where necessary.
- Employ these databases to develop ANNs capable of realistically predicting the load-carrying capacity of the above elements.
- Use the trained ANNs to objectively assess the ability of the current design codes and alternative assessment methods to accurately predict the load-carrying capacity and failure mode of the RC elements considered.
- Develop a computationally efficient ANN-based structural analysis procedure capable of accurately predicting the nonlinear response of RC structures.
- Validate the proposed structural analysis procedure by comparing its predictions concerning the behavior of RC frames with its counterparts established experimentally and numerically [see Fig.2].

Prace wykonane od początku projektu do końca okresu sprawozdawczego oraz najważniejsze dotychczasowe rezultaty

The work carried out and the main results obtained are as follows:

•Literature review of the available physical models employed for describing RC structural behavior at the ultimate limit state.

•Review on the ability of the available nonlinear finite element analysis packages employed for predicting RC structural response.

•Development of databases from valid published test data on the behavior of RC beam, columns and joints. The databases include information concerning the behavior of 863 RC beams with rectangular cross-sections, 89 RC T-beams, 169 RC columns and 194 external beam-column joints.

•Comparison of the predictions concerning the load-carrying capacity of beam/column elements and the joint strength of exterior beam-column joints obtained from the current design codes with the test data included in the databases.
As regards flexural capacity, the comparative study concerning the RC beams revealed that, out of around 190 specimens designed to exhibit ductile behavior, over 20% failed prematurely in a brittle manner. As regards shear capacity, the comparative study revealed that the current codes of practice underestimate by about 15% on average the shear load-carrying capacity of the specimens investigated. For the case of the RC joints, the comparative study revealed that current codes cannot provide accurate predictions concerning the joint strength or the mode of failure exhibited.

•The development of ANNs capable of predicting the load-carrying capacity of beam/column elements and the failure mode and strength of beam-column joints.
The trained ANNs provide predictions concerning load carrying capacities which correlate closely with the test data. They are found capable of predicting the failure mode of beam-column joints in over 95% of the 153 cases investigated.

•Comparison of the ANNs predictions with their counterparts provided by current codes and alternative methods.
For the case of RC beams and columns the code predictions for load-carrying capacity exhibit a significant deviation from the ANN predictions, although the test data used for training the ANNs were also used for calibrating the code methods. The alternative assessment method is found to produce values of load carrying capacity and joint strength which correlate closely with the ANN values.

• Development and validation of a new structural analysis method for assessing the behavior of RC frame structures through the use of hybrid ANN-FEA models
The main feature of this method is that each structure is subdivided into portions extending between points of maximum bending moment and points of contra-flexure or consecutive points of contra-flexure (see Fig.2) equivalent to cantilevers or simply-supported beams, respectively. These portions are identical to specimens which have been extensively experimentally investigated to date. Through the proposed framework the available test data is objectively analysed and used to develop ANNs capable of predicting the behavior of individual RC members which are in turn used to develop the hybrid ANN-FEA models. Good agreement is observed between the predictions of the proposed analysis method and those obtained from nonlinear FEA and experiments for the case RC frames.

The work carried out to date has formed the subject of four articles published or under review in scientific journals and four articles presented or to be presented in Conferences. Additional articles are under preparation. A website presenting information relevant to this project (e.g. databases, a video describing the work conducted) has been setup.

Innowacyjność oraz oczekiwany potencjalny wpływ (w tym dotychczasowe znaczenie społeczno-gospodarcze i szersze implikacje społeczne projektu)

In order to address the shortcomings of the available structural analysis packages, a new analysis method is developed which employs hybrid Artificial Neural Network - Finite Element Analysis (ANN-FEA) models for simulating RC frames. The proposed method provides a way of enhancing the capability of current structural analysis tools employed in practice, enabling them to accurately predict the behavior of RC structures, even when characterized by brittle (catastrophic) modes of failure, without requiring high computational resources or lengthy analysis time. Adopting the proposed analysis procedure is expected to benefit society, in general, and structural engineering, in particular, allowing for the development of both economic and safe design solutions capable of effectively safeguarding structural integrity and resilience. Overall, the use of the work in practice will result in improved safety at a reduced cost for both the construction of new RC structures and the rehabilitation of existing ones.

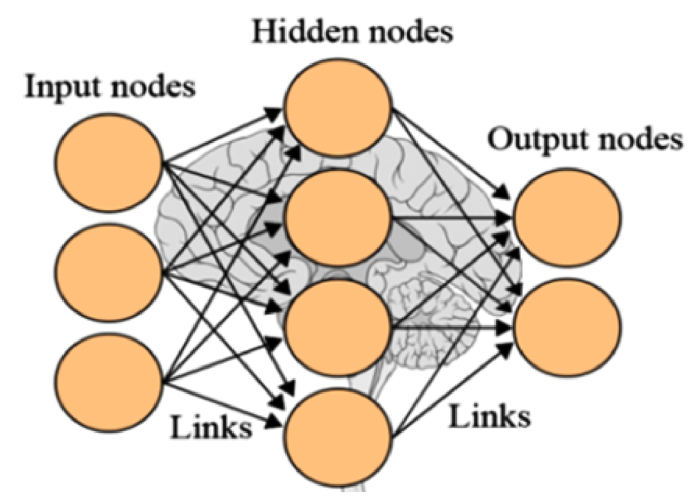

Figure 1: Schematic representation of an Artificial Neural Network (ANN)

Figure 3: Examples of RC structures exhibiting brittle modes of failure

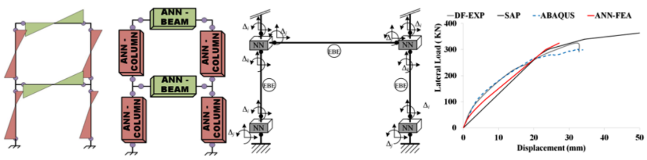

Figure 2: ANN-FEA model of an RC frame and its predictions

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Permalink: https://cordis.europa.eu/project/id/660545/reporting/pl