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## Summary

The structural parameters of the damaged structures, usually, cannot be assessed by precise values. The paper describes a method for the analysis of structures having the parameters defined by nondeterministic values. Using nondeterministic algebra operations rules, the method computes directly the nondeterministic values of the displacements and stresses. The confidence functions of the input parameters are processed to derive the confidence functions of the structural response. The method, based on general principles, has a broad application, for all the types of practical structural analysis.

## 1. Nondeterministic models

The nondeterministic approach can give qualitative and quantitative information about the confidence in the computed response of the structure. Starting from the nondeterministic values of the input data, the nondeterministic values of the displacements and stresses are derived. The nondeterministic data are defined by the crisp support $x$ and the confidence function $\varphi(x)$. The confidence function $\varphi(x)$ and its definition interval $[x_{\inf}, x_{\sup}]$ can be defined according to the following nondeterministic models: the random model, the fuzzy model and the heterogeneous model. The random model is effective if the probability density function can be derived from a large enough number of sampled values. The fuzzy model has a broad applicability because it does not depend on the number of sampled values for the nondeterministic variable. The unified approach of the two above models, the random model and the fuzzy model, gives the possibility to use random and fuzzy variables together, during the same processing.

## 2. Nondeterministic computing method

The assessment of the confidence function is one of the most important features of the nondeterministic structural analysis. In the case of random variables, the confidence function, represented by the probability function is derived starting from the relative frequencies. In the case of fuzzy variables the confidence function is defined by the following methods: (1) The prototype method; (2) The method of the relative membership.

To perform a nondeterministic algebraic operation it is necessary to find out the deterministic support and the confidence function of the operation result.

*The deterministic support* issues from the following operations: (a) for discrete operands $x, y$:

$z = x \ op \ y$; (b) for intervals, $J$: $J_Z = J_X \ op \ J_Y$, where the result of the operation is the margins of the $J_Z$ interval.
*The confidence function* is approximated on subintervals, by piece-wise linearisation. For two subintervals of the operands $x$ and $y$, the linear functions are $f(x) = a \cdot x + b$; and $f(y) = c \cdot y + d$, respectively. The confidence function, $f(z)$ results according to specific composition laws: (a) for random operands, $f(z) = f(x) \cdot f(y)$; (b) for fuzzy operands, $f(z) = \lambda_x \cdot f(x) + \lambda_y \cdot f(y)$; $\lambda_x, \lambda_y$ are weight functions, specific to the operations.

## 3. Example

The method application is exemplified for the nondeterministic analysis of a reinforced concrete plane frame (fig.1). The frame was subjected in the past to strong earthquake motions which caused partial damages. The existing cracks, especially at the members' ends decrease the stiffness, so that the end-connections behave like partial hinges. Because the stiffness value of members and connections is uncertain, they were defined as nondeterministic variables (fig.2, table 1). As a result, the member stresses have nondeterministic values( fig. 3, table 2). According to the Romanian Code P100-91, the interstorey drift condition, is: $\Delta_r / H_e \leq 0.0035$. The condition checked at the first floor, for the values of the displacements is as follows:
$\Delta_r / H_e = \{0.748\backslash 0.00419, 0.849\backslash 0.00304, 0.803\backslash 0.00229, 0.736\backslash 0.00209, 0.698\backslash 0.00201\} \leq 0.0035$
The result is: 0.849*TRUE*. Finally, the drift condition is satisfied if $0.849 \geq \mu_{min}$, where $\mu_{min}$ is the minimum value required for the confidence degree of the condition.

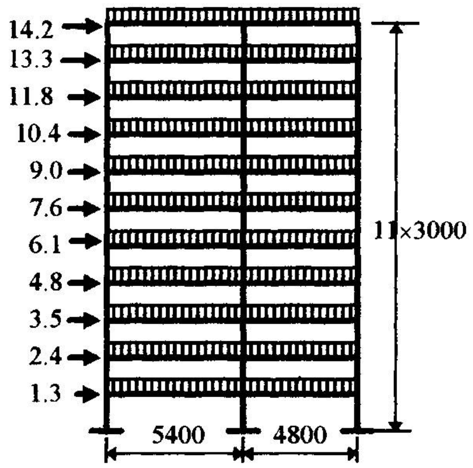


*Fig.1 RC Plane Frame*

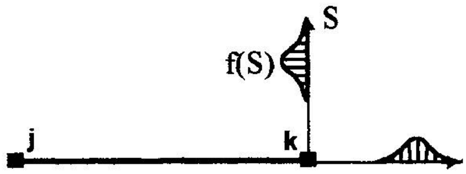


*Fig.2 Nondeterministic Stiffness*

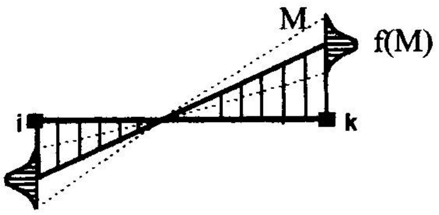


*Fig.3 Nondeterministic Bending Moment*

*Table 1. Nondeterministic Stiffness.*

| Member | | Values at the interval boundary | | | | |
|---|---|---|---|---|---|---|
| 1 | f(S) | 0.689 | 0.797 | 0.895 | 0.741 | 0.653 |
| | S | 123435 | 98132 | 91540 | 87243 | 83356 |

*Table 2. Nondeterministic Bending Moment.*

| Member / Joint | | Values at the interval boundary | | | | |
|---|---|---|---|---|---|---|
| 1 | f(S) | 0.742 | 0.863 | 0.826 | 0.773 | 0.692 |
| 4 | S | 169.3 | 156.2 | 143.4 | 139.2 | 127.6 |