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RELIABILITY AND DURABILITY ESTIMATION OF ANTISEISMIC STRUCTURES BY MEANS OF MARKOV'S CHAIN.

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ABSTRACT

Estimation problem of reliability and durability statically indeterminate complex elastic systems (frames,trusses and other rod systems) is sharply complicated due to indefinability of bonds for subsystems and elements, number and sequences for types of failures as well as probability of external factors and internal parameters.At the same time special difficulty lies in estimation of probability state for a system at any instant of performance up to the estimation of durability.

KEYWORDS

Estimation reliability,durability,composite system,of Markov's chain,failure,recovery.

METHODS

All above mentioned difficulties are getting over by taking a possible approach to determination of indices and characteristics of reliability for rod systems of frame type on the model of Markov's finite chain . The examined rod system is resented as composed from compressed and bending elements of different liability.Possible failure of elements at a random instant of perforance is supposed.

Certain assumptions were taken to solve such a complicated problem:
- a composite system may be divided basing on the concepts of decomposition and system approach into simplier subsystems (superelements - SEL) with maximum autonomous properties and minimum possible bonds,taking into consideration zero moment points from horizontal (seismic) forces ;
- an element failure event is taken both independent and dependent onother element failure;
- t- floor state (t=2,3,...,n; n - number of floors) depends on the state of t-1 loor;
- the intensity of failure (λ) and recovery (γ) of each element is assumed as given;
- the probability character of external effects and internal properties were considered as certain (on the given stage of research).

Basing on the above mentioned assumptions, the algorithm of probability estimation for reliability and durability of statically indeterminate structures is proposed on principles of Markov's finite chain. Aspects of solving problems on seismic stability of free frame and box-frame systems by means of opening definitions, coming out from the theory of Markov's chain, were examined. This enabled to determine the initial distribution, transitional and final matrices.

WAYS OF PUTTING AND SOLVING THE PROBLEM.

Probability of failure free performance for a lower t-1 - floor of a high-rise structure is determined by breaking the initial frame down to subsystems $R_{1,n}$ and calculating:

$$R_{s_{[r,n]}} = \sum_{i=r}^{m_2} (-1)^{i-r} C_{i-1}^{r-1} R_{ss}^{n} \qquad (1)$$

Knowing probability of failure free performance for a Π-shaped frame composed of three elements

$$R_{ni} = P_3^i(e_{3/\bar{1}})[P_1^i(e_{1/\bar{2}})(1-P_2^i(\bar{e}_2)) + P_2^i(e_{2/\bar{1}})\cdot(1-P_1^i(\bar{e}_1))] + P_1^i(e_1)P_2^i(e_2)P_3^i(e_3)$$

One can find probability of failure free performance for the 1-floor

$$R_{f1} = R_{f1[1,n]} = \sum_{i-r_1}^{n} (-1)^{i-r_1} C_{i-1}^{r_1-1} \sum_{J_i} \prod_{j=1}^{i} R_{nj}$$

One can find probability of failure free performance for the i-floor

$$R_{ss}^{\square} = P_3(e_{3/\bar{1}})P_4(e_{4/\bar{1}})[P_2(e_{2/1})(1-P_1(e_1)+(\bar{e}_{1/\bar{2}})(1-P_2(e_2))] + P_1(e_{1/\bar{3}})P_2(e_{2/\bar{3}})P_4(e_{4/\bar{3}})\cdot$$
$$\cdot(1-P_3(e_3)) + P_1(e_{1/\bar{4}})P_2(e_{2/\bar{4}})P_3(e_{3/\bar{4}})(1-P_4(e_4)) + P_1(e_1)P_2(e_2)P_3(e_3)P_4(e_4)$$

and (1)

$$R_{fi}^{\square} = \sum_{i=r}^{n-1} (-1)^{i-r} C_{i-1}^{r-1} \sum_{J_i}^{i} \prod_{j=1}^{i} R_{\square i}$$

where $R_{sj}^{\square}$ is probability of j-contour for t-floor; t=1,T. For the 2d floor from closed frames:

$$R_{f2}^{\square} = \sum_{i-r_2}^{n-1} (-1)^{i-r_2} C_{i-1}^{r_2-1} \sum_{J_i}^{i} \prod_{j=1}^{i} R_{\square j}^{(2)}$$

Analogically, for the 3d floor:

$$R_{f3} = \sum_{i=r_3}^{n} (-1)^{i-r_3} C_{i-1}^{r_3-1} \sum_{J_i}^{i} \prod_{j=1}^{i} R_{\square j}^{(3)}$$

Totally, for odd floors we have:

$$R_{f(2k-1)}^{\square} = \sum_{i=r_{2k-1}}^{n} (-1)^{i-r_{2k-1}} C_{i-1}^{r_{(2k-1)}-1} \sum_{J_i} \prod_{j=1}^{i} R_{\square j}^{(2k-1)}, \quad k=2,3,\ldots$$

The same is for even floors with frame systems:

$$R_{f(2k)}^{\square} = \sum_{i=r_{2k}}^{n-1} (-1)^{i-r_{2k}} C_{i-1}^{r_{2k}-1} \sum_{J_i} \prod_{j=1}^{i} R_{\square j}^{(2k)}$$

$$R_{f(2k)} = R^{\square}_{f(2k)} (R'_{f(2k)})^{m-1}, \; k = 1,2,\ldots$$

Let's introduce function of failure free performance

$$y = \begin{cases} 0, \text{when t-floor is failure free;} \\ 1, \text{in case of t-floor failure.} \end{cases}$$

Then probability of failure free performance of a t-floor as structural reliability is defined:

$$P(y_1=0) \text{ or } P(y_t=1) = 1-R_{ft}$$

Thus, probability of failure free performance for each t-floor, as well as for the whole frame, is a function of SEL failure free performance, and they, in their turn, depend on arguments R_i.

Let's use the following assumptions for evaluation of the investigated compound system's state:
- state of the system depends not on the beginning of reading and function of faiure free performance is stationary;
- statistic characteristics, including the distribution law for no-failure function of systems, depend on probability properties of subsystems;
- behavior of failure free performance function is conditioned by the system state in a giveng moment and doesn't depend on the function behavior in previous period.

Random functions with such characteristics are well described by Markov's model and can be used in solving probability problems of structural mechanics. Therefore the examined function of failure free performance for t-floor depends on the probability state of (t-1 -floor, that enables to describe the problem by Markov's chain. Under such assumption, probability of transition from one state to another is characterized by the following:

$$P(y_2=0|y_1=0) = R_{f2}$$

$$P(y_2=1|y_1=0) = 1-R_{f2} \ldots$$

$$P(y_t=0|y_{t-1}=0) = R_{ft}, \; t=2,3,\ldots,T$$

$$P(y_t=1|y_{t-1}=0) = 1-R_{ft} \quad t=2,3,\ldots T$$

$$P(y_t=0|y_{t-1}=0) = 0, \; t=2,3,\ldots,T$$

Then probability of failure free state of the whole system is defined basing on condition of full probability of events

$$R_{ss} = P(y_1=0, y_2=0, \ldots, y_T=0) = P(y_1=0)\prod_{t=2}^{T} P(y_t=0|y_{t-1}=0) = \prod_{t=1}^{T} R_{ft}$$

In case when t_c - number of upper floors - is in failure state, but system as a whole is in working condition, probability of no-failure is defined according to the formula:

$$R^{t_0}_{ss} = \prod_{t=1}^{T-t_0} R_{ft} \prod_{t=(T-t_0+1)} (1-R_{ft})$$

As it can be observed, totally, probability of system's failure free performance depends to a greater degree on the given number t_c, and it is the more, the more is the number t_0.

Thus, the assumed breaking systems down to subsystems and applying principles of Markov's chains enables one to determine approximately, but simply enough, structural reliability index of a system.

Since the investigated problem is extremely complicated in the aspect of the degree, to which possibility and manipulation characteristics of factors have been studied as well as determination of reliability functions and durability, it can be solved step by step on personal computer .

RESULTS

Basing on the above mentioned algorithm, numerical results of reinforced rame calculation for loads and effects of static and seismic types with estimation of reliability and durability were obtained .

CONCLUSIONS

The authors received probability of failure free performance at the initial time of operation and estimation of durability for an aseismic system with exposing of its state at any instant. The proposed approach enables to carry out parameters optimization of aseismic structures using the model of controlled Markov's processes.