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The loads and material strengths vary at random and in principle they can range from 0 to \( \infty \). For known or assumed distributions there are specific probabilities of loads and resistances reaching any predetermined higher or lesser values respectively for loads and resistances. Consequently there always exists a non-zero probability of the load exceeding the resistance and hence of failure. Therefore, safety itself is a probabilistic problem. The limit state design philosophy seeks to ensure acceptable levels of probability corresponding to various limit states.

The load effects (L) and Resistance (R) of a structure are assumed to be random variables. The failure event is \( \frac{R}{L} < 1 \) (or \( R-L < 0 \)). Due to general scarcity of data, it is difficult in many instances to determine the probability densities of individual variables, let alone the joint density functions. At very low risk levels the probability of failure is very sensitive to the exact forms of the distribution functions for Resistance (R) and load effects (L). For high risk conditions, say \( P_F > 10^{-3} \) failure probability is not significantly affected by the exact form of the distribution.

The CEB-FIP Unified Code (1978) aims for the achievement of acceptable probabilities that the structure being designed will not become unfit for the use for which it is required during some referende period and having regard to its intended life. Judgment has to be exercised in laying down the level of safety relevant to each category of structure or structural part. Three levels are identified for the treatment of structural safety. At all levels,
the statistical variations of strength and other properties of materials and the statistical variation of loads or actions on structures and other uncertainties are taken into account in order to ensure that the appropriate reliability level for any limit state considered may be obtained.

IS:456-1970, CP:110-1972 and several other National Codes have not explicitly defined, quantified and involved the acceptable probability of the various limit states being achieved. The partial safety factors for loads and material strengths are still largely arbitrary and empirical and currently calibrated with structural dimensions which we are used to through experience and cannot ensure either an optimum level of safety or economic criteria as the combined effect of the variability of loads and strengths is not directly taken into account in the calculations. Loads and strengths are considered separately and substituted in the design equation as characteristic value of maximum load and minimum strengths. In order to achieve an optimum level of safety, the criteria of reliability must be applied.

Most investigators have presented the analysis of safety and reliability of structures using the variables 'Resistance' (R) and 'Load effects' (L), and employing their first two moments (mean and variance), considering normal distributions for them or their transformations. Indeed, the level 2 methods are based on first order (linear) approximations. The non-normal distributions are transformed into normal distribution to avoid multi-dimensional integration. The transformation of non-normal variables to normality involves its own errors of approximation and the complexities of
deciding on a suitable transformation. Such transformation will be useful only if the variables are additive or subtractive. Some authors have even assumed deterministic nature of these variables which are in fact stochastic.

The evaluation of the results based on first two moments leaves little scope to investigate in detail the forms of distribution (in terms of skewness and kurtosis) and to explore distributions other than an arbitrarily assumed one. The evaluation of results up to the fourth moment not only gives an insight into the form of distribution and provides one with a choice out of a set of likely distribution forms, but also provides a basis for necessary adjustments to be made in the probability distribution.

The present work further extends the study of the distribution of parameters 'R' and 'L' to four moments (mean, variance, skewness and kurtosis) and allows us to look more deeply into the form of their distribution. Likewise, the distribution of 'safety factor' (R/L) and 'safety zone' (R-L) have been worked out considering variability in the individual primary variables rather than considering only the overall reliability in R and L individually.

The safety and reliability of a structure depends on the reliabilities of its components. As the information is seldom available for complete structures, the evaluation of safety of a structural system is carried out through deductive analysis based on the information available for its components.

The performance of a structural member depends on several parameters i.e., magnitudes and variations in dead load, live loads, strength of concrete and strength of steel, dimensional tolerances, reinforcement placement errors etc. In the present
study, the following primary random variables are considered: (i) Dead load, (ii) Live load, (iii) Strength of steel and (iv) Strength of concrete. The following predetermined variables are considered in the study to cover the practical range: (i) Percentage of steel, (ii) Ratios of dead load to live load, (iii) Coefficient of variation of random variables and (iv) Location of neutral axis (eccentricity of loads).

The probability distribution for dead load is assumed to be normal. The characteristic values are taken as per IS:1911-1967, with a coefficient of variation of 10%. The live load is assumed to be distributed lognormally. The characteristic values are taken as per IS:875-1964 with a coefficient of variation of 40%. The strength of 'Torsteel' confirming IS:1786-1979, is assumed to be normally distributed. Two different coefficient of variations of strength of steel are considered viz. 5% and 15% covering the possible range of variations. The strength of concrete is assumed to be distributed normally. The characteristic values recommended by IS:456-1978 and standard deviation suggested by IS:10262-1982 for different degrees of quality control are adopted. The worst and the best controls as envisaged in the Code (i.e., Fair control and very good control) are considered in the study to cover the entire range of the parameter.

The expression of probability of failure \( (P_f) \) is a multidimensional integral and a direct approach for the solution is exceedingly complex. Therefore, \( P_f \) has been estimated in the following two ways:

1) Simulation approach, and
2) Approximation based on higher order moments.
i) **Simulation approach**: The Monte Carlo Technique has been adopted for the generation of data. A sizeable data has been generated with 5000 simulation runs and the statistics of R, L, R/L and (R-L) and probability simulation for each case or combination of variables have been assessed.

ii) **Approximation based on higher order moments**: The approximations to the distributions of R/L and (R-L) have also been made based on the assumed forms of some common probability distributions conforming to the sample space. Since the exact expressions for moments of R and hence R/L and (R-L) are not explicitly available, the approximations for their moments have been made in terms of the first two known moments i.e., mean and standard deviation. To compute the probability of failure, the chi-square, gamma and lognormal distributions for R/L and Normal and Edgeworth distributions for (R-L) were fitted and the respective statistics compared with simulated values and the best fitting distribution chosen.