STRUCTURAL RELIABILITY ASSESSMENT WITH STOCHASTIC PARAMETERS

Biswajit Barman
Asst. Prof., Dept. of Civil Engineering,
Bengal College of Engineering &Technology, Durgapur, West Bengal, India.

ABSTRACT

The performance of a structure [23] is assessed by its safety [1], serviceability [1] and economy [1]. Since we do not know the exact details of loads [4] acting on a structure at any time, there is always some uncertainty about the total loads on structure. Thus random variables (means stochastic variable) of loads and other parameters are the main criteria of design variables [18]. They vary with space and time. The input variables is never certain and complete. The safety factor provided in the existing codes and standers primarily based on practice, judgment and experience, may not be adequate and economical. Using the techniques presented earlier, we can design or analyze individual members in the contest of structural reliability [2][3][22][24]. However we are not examined how the system performs [23] or how to calculate the reliability of the structure as a whole.

KEYWORDS: *Economy, Loads, Random Variables, Reliability, Stochastic, Safety, Uncertainty.*

I. INTRODUCTION

The design parameters[21] of loading and load carrying capacities of structural members are not deterministic[20] quantities, but variable quantities except dead load (i.e. self weight of structure). Since we do not know the exact details of loads acting on a structure at any time, there is always some uncertainty about the total loads on structure. Thus random variable of loads are the main criterion of design variables. Hence safety of structure is uncertain. A reasonable safety level is always accepted which recommends IS Code. When safety of structure becomes certain, there is zero probability of failure[12]. It means that reducing the probability of failure is the increasing of reliability i.e. structural safety[12] level.

II. PROBABILITY THEORY

Partially knowing about an event sometimes we make statements are probabilistic[8][15][19][20] in nature, such as a child to born will be a son, or it may rain tomorrow, or India will win in a cricket match, or a bus will arrive on time, and so on. Now questions may arise, what is the characteristic feature in all the above phenomena? Answer is that they all lack a deterministic nature. The above phenomena are random phenomena. In the deterministic study parameters, parameters may be considered as a function of time (i.e. time variant). Similarly probabilistic study are time variant but in some cases it is time variant (e.g. Wind load, earthquake load etc.). When a random variable assumes values as a function of time the variable is called a stochastic variables

III. LITERATURE REVIEW

In the earlier days engineers were not confident to applying probability theory or evaluating of safety. A master builder often tried to copy a successful structure. Heavy stone arches often had a considerable safety reserve. Actually the procedure was essentially trial and error method. The first mathematical formulation of structural safety problem can be attributed to *Mayer(1926), Streletzki(1947).* They recognized that load and resistance parameters are random variables and therefore, for each structure, there is a finite probability of failure. It was further developed by *Freudenthal (1950)*

Deepthi C. Epaarachchi et .al.(2002) develops a probabilistic model to estimate the probability of structural collapse significant proportion of reinforced concrete Building structural failures occur during construction *Carper 1997* observe, a system failure will occur when the slab capacity in flexure or shear is exceeded. Failure of shores or re-shore nonstructural element failure is not considered a system failure unless it leads to structural failure of the slab. *J.W. van de Lindt et .al.(2004)* develops a basic method to better estimate the effect of earthquake duration on structural reliability using (1) an ultimate strength and a (2) low-cycle structural damage-based on limit state function. This study is unique in that it allows variation in the peaks of the highly non-linear structural response without actually performing time domain analyses, which are commonly employed in earthquake engineering analysis. A simple measure was introduced and termed the duration effect factor (DEF_β) and is defined as the slope of a best-fit line for multiple reliability indices plotted against duration.

IV. OVERVIEW

PROBABILITY DENSITY FUNCTION (PDF):

For continuous random variables, the probability density function (PDF) is defined as the first derivative of cumulative distribution function(CDF). The PDF [fx(x)] and the CDF [Fx (x)] for continuous random variables are related as follows.

Standard deviation of random variable, 'X.' The standard deviation of X is defined as the positive square root of the variance:

$$\sigma_x = \sqrt{\sigma_x^2}$$

The non dimensional co-efficient of variation Vx, is defined as the standard deviation divided by the mean

$$V_x = \sigma_x/\mu_x$$

This parameter is always taken to be positive by convention even through the mean may be negative.

An important relationship existing among the mean, variance, and second moment of a random variable X:

$$\sigma_x^2=[E(X^2) - \mu_x^2]$$

HYBRID SYSTEM ORCOMBINEDSYSTEM

Many structures can be considered as a combination of series and parallel systems. Such systems are referred to as hybrid or combined systems. The following figure is a schematic of a hybrid system in which elements **1** and **2** are in parallel, and the combination of **1** and **2** is in series with element 3**.**

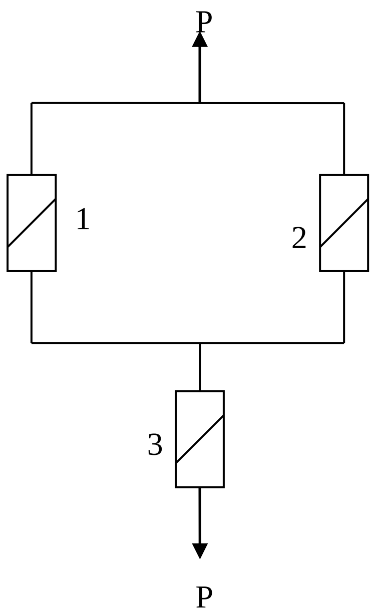

Fig 1: Hybrid System or Combined System

V. GENERAL DEFINITION OF RELIABILITY

In the definition, there are four significant elements viz. (i) Probability, (ii) Intended function, (iii) Time and (iv) Operating conditions. Because of the uncertainties, the reliability is a probability. A structure will reliable, if it perform a certain function or functions satisfactorily for which it has been designed i.e. safety against shear or flexure or torsion, etc. The reliability is always related with time. In case of structure, it is related to the lifetime of the structure. The operating conditions establishes the actions or stresses that will be imposed on the structure. These may be loads, temperature, shock, vibrations, etc. It is note that reliability is also changes with respect to quality control, workmanship, production procedure, inspection etc.

Let, R = reliability

P_f = Probability of failure

Reliability = 1/(Probability of failure)

or, $\mathbf{R = 1/ P_f}$.

Cornell first defined the reliability index, β

$$\beta = \mu_M/\sigma_M$$

Where μ_M and σ_M are the mean value and standard deviation of M.
When both basic variables R & Q are normal and independent,

$$\mu_M = \mu_R - \mu_Q$$

and $\sigma_M = (\sigma_R^2+\sigma_Q^2)^{1/2}$

So, $\beta = (\mu_R - \mu_Q) / \sqrt{(\sigma_R^2 + \sigma_Q^2)}$

For any specific value of $g((Z_R, Z_Q)$,the above eqn. represents a straight line in the space of reduced variables Z_R and Z_Q. The line of interest to us in reliability analysis is the line corresponding to g $(Z_R,Z_Q) = 0$ because this line separates the safe and failure domains in the space of reduced variables.

Table –1 : Values of Reliability Index, $\beta_{g(x)}$ with variable values of c.o.v.

C.O.V.	Mean Value ($\mu_{g(x)}$)	Standard Deviation ($\sigma_{g(x)}$)	Reliability Index ($\beta_{g(x)}$)	Probability of Failure (P_f)
5%	50.85 x 10^6	7.5848 x 10^6	6.71	0.000000001%
10%	50.85 x 10^6	15.1697 x 10^6	3.35	0.04%
15%	50.85 x 10^6	22.7545 x 10^6	2.24	1.25%
20%	*50.85 x 10^6*	*30.339 x 10^6*	*1.68*	*4.65%*
25%	50.85 x 10^6	37.924 x 10^6	1.34	9.01%
30%	50.85 x 10^6	45.509 x 10^6	1.12	13.1%

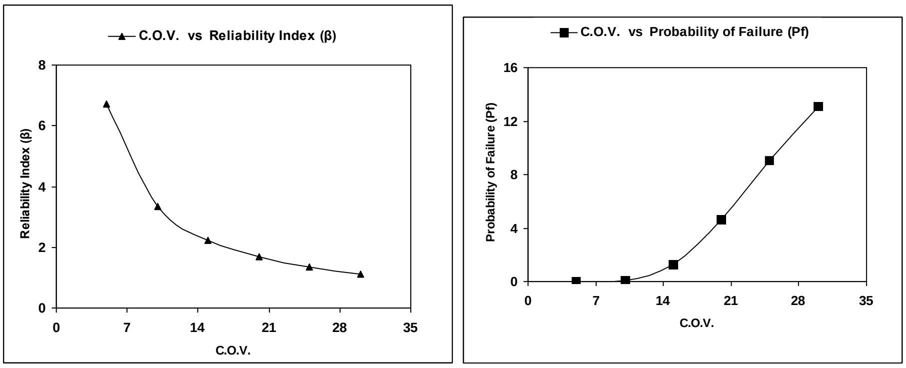

Fig 2 Variation of reliability index with respect to C.O.V.

Table – 2 : Values of Reliability Index, $\beta_{g(x)}$ with variable values of μ

Values of Load (μ_w)	Mean Value ($\mu_{g(x)}$)	Standard Deviation ($\sigma_{g(x)}$)	Reliability Index ($\beta_{g(x)}$)	Probability of Failure (P_f)
5	56.475x 10^6	15.2400 x 10^6	3.72	0.01%
10	50.85x 10^6	15.2060 x10^6	3.35	0.04%
15	45.225x 10^6	15.1546 x10^6	2.99	0.014%
20	39.6x 10^6	15.0814 x10^6	2.63	0.43%
25	33.975x 10^6	14.9870 x 10^6	2.27	1.16%
30	28.35x 10^6	14.8700 x 10^6	1.91	2.81%

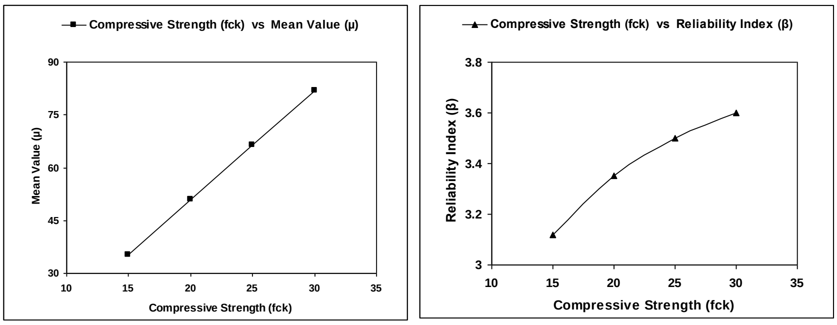

Figure 3 Viation of mean values with respect to compressive strength

Table – 3 Values of Reliability Index, $\beta_{g(x)}$ with variable values of μ_d

Values of Depth (μ_d)	Mean Value ($\mu_{g(x)}$)	Standard Deviation ($\sigma_{g(x)}$)	Reliability Index ($\beta_{g(x)}$)	Probability of Failure (P_f)
250	31.875x 10^6	10.5033x10^6	3.04	0.12%
300	50.85x 10^6	15.1697x10^6	3.35	0.04%
350	73.275x 10^6	20.6737x10^6	3.55	0.02%
400	99.15x 10^6	27.02x 10^6	3.67	0.01%
450	128.475x10^6	34.207x 10^6	3.76	0.01%
500	161.25x 10^6	42.239x 10^6	3.82	0.007%

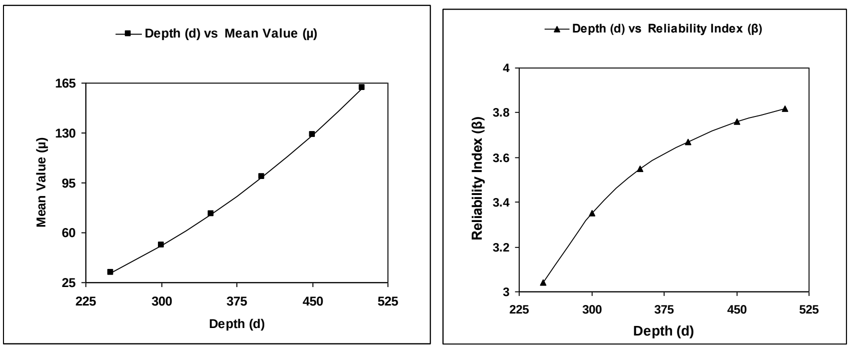

Figure 4 Variation of mean values with respect to depth

Table – 4 : Values of Reliability Index, $\beta_{g(x)}$ with variable values of **μ_d**

Values of Depth (μ_d)	Mean Value ($\mu_{g(x)}$)	Standard Deviation ($\sigma_{g(x)}$)	Reliability Index ($\beta_{g(x)}$)	Probability of Failure (P_f)
250	$31.875x\ 10^6$	$10.5033x10^6$	3.04	0.12%
300	$50.85x\ 10^6$	$15.1697x10^6$	3.35	0.04%
350	$73.275x\ 10^6$	$20.6737x10^6$	3.55	0.02%
400	$99.15x\ 10^6$	$27.02x\ 10^6$	3.67	0.01%
450	$128.475x10^6$	$34.207x\ 10^6$	3.76	0.01%
500	$161.25x\ 10^6$	$42.239x\ 10^6$	3.82	0.007%

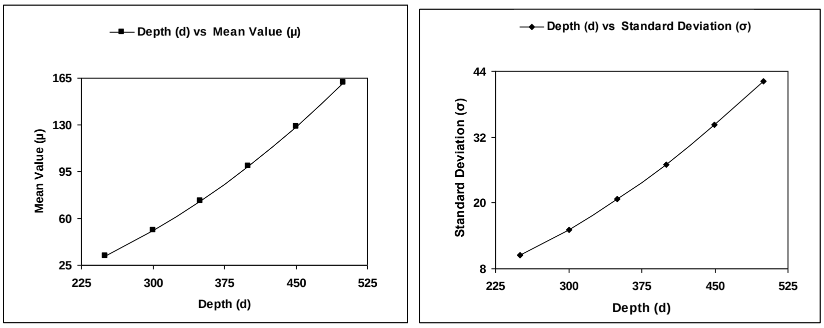

Figure 5 Variation of mean values with respect to depth

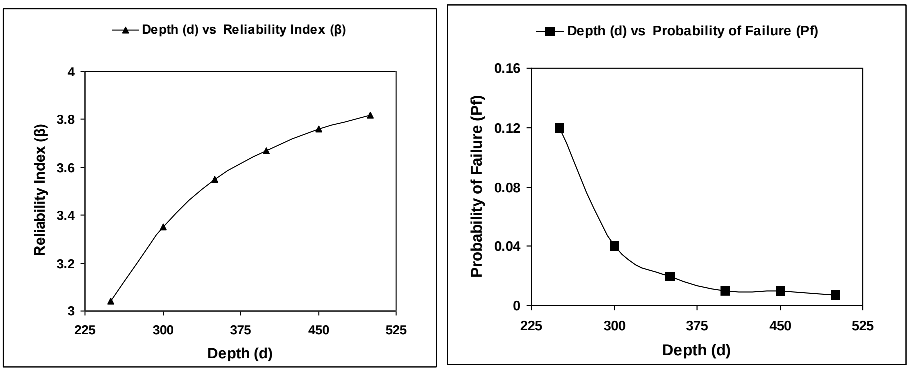

Figure 6 Variation of reliability index with respect to depth

VI. OBSERVATION

1) Mean Value is constant with increasing of C.O.V.
2) Standard deviation is increasing with increasing of C.O.V.
3) Standard deviation is increasing with increasing of compressive strength
4) The reliability index is remarkably decreasing up to first 10% increasing of c.o.v. and then decreasing very slowly with further increasing of c.o.v.

VII. CONCLUSION

The results are the nature of variation are consistent with result obtained by *Schueremans (Int. conf.,Canada, 1999)* The decreasing safety index is found to be remarkably more after certain level of load and uncertainty(instead of a straight line) variation. Hence sensitivity of reliability index is widely varying depending on the uncertainty and parametric values. Hence extrapolating of reliability index without knowing its variation is dangerous.

Future Scope of Work: To incorporate different types of uncertainty

Application on realistic structures, e.g. building frame under seismic excitation**.**

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SAMPLE AUTHORS BIOGRAPHY

BISWAJIT BARMAN, was born in MALDA, West Bengal, India ,in the Year. 8th January 1964. Passed BE(Civil Engg.) from Jalpaiguri Govt. Engg. College, Jalpaiguri under the University of North Bengal in 1989. And passed ME(in Structure) from BESU, Shibpur, Howrahin the year 2008 Presently I am working as an Asst. Prof. in CE Dept. at MCET, Berhampur, Murshidabad West Bengal, India and try to complete my Ph. D. Work from NIT Durgapur.