Reliability Analysis of Structural Beam Section Using First Order Reliability Method (FORM)

P. Hari Prasad 1, M. Tirumala Devi 2, T. Sumathi Uma Maheswari 2
1CVR College of Engineering, Hyderabad, Telangana, India
2Department of Mathematics, Kakatiya University, Warangal, Telangana, India

ABSTRACT

Reliability is the ability of the structure to meet the construction requirements set under specified conditions during the service life, according which it is designed. It refers to the capacity, serviceability and durability of construction and according to them different techniques of reliability can be defined. In this paper the reliability index $\beta$ is used to present the size of uncertainty in the theory of reliability. Two types of techniques are used to obtain the reliability index, which are First Order Reliability Method and Hosofier-Lind Method. The design of rectangular reinforced concrete section of beam is considered. The liability and flexural failure caused by tension of the beam section are discussed. The methodology involved in determining the reliability to the design variables which are bending moment, cross sectional area, specified yield strength, specified compressive strength of concrete.

Keywords: Structural reliability, First order reliability method, Hosofier-Lind method, Rectangular reinforced concrete section of the beam, Bending moment, Moment capacity.

I. INTRODUCTION

Reliability is defined as the probability that a system performs its intended function without failure during a specified time period. The subject of structural reliability provides the tools and methodology to explicitly determine the probability of such failures by taking into account all relevant uncertainties. These techniques can be used to design new structures with specified reliabilities, and to maintain existing structures at or above specified reliabilities. The study of structural reliability is concerned with the calculation and prediction of the probability of limit state for engineering structures at any stage. Reliability is therefore the branch of structural engineering which is concerned with the analysis and probabilistic assessment of design random variables in order to predict whether specified limit state would be violated.

This paper determines the reliability index for the rectangular reinforced concrete section of the beams in flexural limit state by failure due to tension. The problem is formulated as reliability problem and concerns the reliability of the beam in flexure. Various parameters like, bending moment, cross sectional area, specified yield strength, specified compressive strength of concrete are modeled as random variables. First Order Reliability Method (FORM) and Hosofier-Lind Method are used to determine the reliability Index.

There are several papers, which considered structural reliability problems. Gunjan Agarwal and Baidurya Bhattacharya (2010) studied partial safety factor design of rectangular partially prestressed concrete beams in ultimate flexural limit state. Antanas Kudzys and Romualdas Kliukas(2010) discussed the reliability index design in reinforced concrete structures of annular cross sections. S.Choi, R.V.Gradnhi and

II. STATISTICAL METHODOLOGY

If the system has a deterministic resistance (strength) \( X \), and a random applied load (stress) \( Y \) then the reliability of the system is the probability that the resistance is greater than the load, \( P(X > Y) \). Failure probability is the probability that the load is greater than the strength \( (Y > X) \). In the specific case of a Gaussian random variable the load \( Y \) can be reduced into standard normal variable \( y \),

\[
Y = \mu_Y + y\sigma_Y \Rightarrow y = \frac{Y - \mu_Y}{\sigma_Y} \quad (1)
\]

Where \( \mu_Y \) is the mean of \( Y \) and \( \sigma_Y \) is the standard deviation of \( Y \), then the Reliability of the system

\[
R = P(X > \mu_Y + y\sigma_Y) \\
\Rightarrow R = P((X - \mu_Y)/\sigma_Y > y) \\
\Rightarrow R = P(\beta > y)
\]

(2)

where \( \beta \) is the reliability index

In the single variable case, this inequality is a safe region. This region is the set of values of \( y \) for which the structure will not fail. The probability of failure is the complement of the reliability.

\[
P_f = 1 - R = 1 - P(\beta > y)
\]

(3)

The probability of failure \( P_f \) is the probability that the load is greater than the resistance, \( P(Y > X) \). Let \( f_X(x) \) and \( f_Y(y) \) are the probability density functions of strength \( X \) and load \( Y \) then the distribution function \( F \) is defined by

\[
F_Y(y) = P(Y \leq y) = \int_{-\infty}^{y} f_Y(u) du
\]

(4)

The probability of failure becomes

\[
P_f = P(Y > X) = \int_{0}^{\infty} F_X(y) f_Y(y) dy
\]

\[
= \int_{0}^{\infty} \int_{-\infty}^{y} f_X(u) f_Y(y) du dy
\]

(5)

A. First Order Reliability Technique

Let \( (X_1, X_2, ... , X_n) \) be the set of random variables (structural design variables). The limit state equation for the failure surface of the structure is

\[
g(X_1, X_2, ... , X_n) = 0 \quad (6)
\]

Collapse of the structure or failure is defined by the failure condition as \( g(X_1, X_2, ... , X_n) < 0 \).

Probability of failure is

\[
P_f = P(g(X_1, X_2, ... , X_n) < 0) \quad (7)
\]

Methods for the determination of this probability depend on the complexity of the limit state function. The limit state function is the limit at which the performance transits from acceptable to unacceptable. There are different types of limit states: strength or ultimate limit states, serviceability limit states, fatigue limit states, and extreme event limit states. The limit state function \( g \) is given as:

\[
g = S - Q
\]

(7)

In the above expression \( S \) and \( Q \) are random variables. \( S \) is the resistance (strength of the system) and \( Q \) is the load (stress). If \( g < 0 \) it leads to breakage of the structure i.e. failure and if \( g \geq 0 \) then the structural reliability is high. In case of bending of beams \( S \) represents the ultimate moment capacity and \( Q \) represents the bending moment. In the case of serviceability limit state of deflection, \( S \) represents the maximum acceptable deflection and \( Q \) represents the deflection caused by the load.

Hasofer- Lind performed the transformation limit state function in the standard normal variable. The
random variables $S$ and $Q$ are reduced into SNV $S_1$ and $Q_1$:

$$S_1 = \frac{S - \mu_S}{\sigma_S} \Rightarrow S = S_1\sigma_S + \mu_S$$

$$Q_1 = \frac{Q - \mu_Q}{\sigma_Q} \Rightarrow Q = Q_1\sigma_Q + \mu_Q$$

(8) \hspace{2cm} (9)

$$g = S - Q = (S_1\sigma_S + \mu_S) - (Q_1\sigma_Q + \mu_Q)$$

$$g = (\mu_S - \mu_Q) + S_1\sigma_S - Q_1\sigma_Q$$

(10)

The line in reliability analysis is the line corresponding to $g(S_1, Q_1) = 0$ because this line separates the safe and failure region in the normal space. From the above the reliability index $\beta$ is the shortest distance from origin of reduced variables to the line of $g(S_1, Q_1) = 0$ (Hasofer-Lind method, 1974).

$$\beta = \frac{\mu_S - \mu_Q}{\sqrt{\sigma_S^2 + \sigma_Q^2}} = \frac{\bar{S} - \bar{Q}}{\sqrt{\sigma_S^2 + \sigma_Q^2}}$$

(11)

Where $\mu_S$ and $\mu_Q$ are the mean values of $S$ and $Q$ respectively; $\sigma_S^2$ and $\sigma_Q^2$ are their variance values.

If the random variables $S$ and $Q$ have the log-normal distribution, then the reliability index is given by:

$$\beta = \frac{w_S - w_Q}{\sqrt{\sigma_{wS}^2 + \sigma_{wQ}^2}}$$

(12)

where $w_S = \ln S$ and $w_Q = \ln Q$. $\bar{w_S}$ and $\bar{w_Q}$ are the mean values of $w_S$ and $w_Q$; $\sigma_{wS}^2$ and $\sigma_{wQ}^2$ are their variance values.

Then the probability of failure is

$$P_f = P((S - Q) < 0) = P(g < 0)$$

(13)

$$P_f = \phi(-\beta)$$

and $1 - P_f$ is the probability of safety. Where $\phi$ and $\phi^{-1}$ are the standard normal cumulative distribution function and its inverse.

B. The Hasofer-Lind Method (limit state function as a linear expression)

In some situations the failure surface is expressed as linear combination of random variables.

$$g(X) = \alpha_0 + \alpha_1X_1 + \alpha_2X_2 + \ldots + \alpha_nX_n$$

$$g(X) = \alpha_0 + \sum_{i=1}^{n} \alpha_iX_i$$

(15)

Where $\alpha_i$'s are constants.

After normalization of variables, the equation of limit state (failure surface) becomes

$$\sum_{i=1}^{n} \alpha_i\sigma_{x_i}x_i + \sum_{i=1}^{n} \alpha_i\bar{x_i} + \alpha_0 = 0$$

(16)

where SNV, $x_i = \frac{X_i - \bar{x_i}}{\sigma_{X_i}}$, $\bar{x_i}$ is the mean value and $\sigma_{X_i}$ is the standard deviation of the random variable $X_i$. The reliability index $\beta$ can be determined from the geometry

$$\beta = \frac{\sum_{i=1}^{n} \alpha_i\bar{x_i} + \alpha_0}{\sqrt{\sum_{i=1}^{n} \alpha_i^2\sigma_{x_i}^2}} = \frac{-\bar{g}}{\sqrt{\sum_{i=1}^{n} \alpha_i^2\sigma_{x_i}^2}}$$

(17)

Where $\bar{g} = \alpha_0 + \sum_{i=0}^{n} \alpha_i\bar{x_i}$ is the mean value of $g$. (18)
C. The Hasofer-Lind Method (limit state is a nonlinear)

This is the simplest first order second moment reliability method (FOSM RM) used to evaluate reliability. This technique approximates the failure surface by a hyperplane tangent to the failure surface. Consider a limit state (failure surface) equation of random variables $X_1, X_2, \ldots, X_n$.

$$g(X_1, X_2, \ldots, X) = \bar{g} + \sum_{i=1}^{n} (X_i - \bar{x}_i) \frac{\partial g}{\partial X_i} = 0$$  \hspace{1cm} (19)

Where $\bar{g}$ the mean value of $g$: $\bar{g} = g(x_1, x_2, \ldots, x_n)$

The reliability index, $\beta = \frac{\bar{g}}{\sqrt{\sum_{i=1}^{n} (\alpha_i X_i)^2}}$ with

$$\alpha_i = \frac{\bar{g}}{\partial X_i}$$  \hspace{1cm} (20)

The reliability index $\beta$ is a measure of reliability of the system. Table 1 shows the values of $R$ for selected values of $\beta$, given in the limits that are applied in engineering.

**Table 1. Probability of success for selected value of reliability index**

<table>
<thead>
<tr>
<th>S.No</th>
<th>$\beta$</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.81</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>0.9332</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0.9772</td>
</tr>
<tr>
<td>4</td>
<td>2.5</td>
<td>0.99379</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>0.99865</td>
</tr>
<tr>
<td>6</td>
<td>3.5</td>
<td>0.999767</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>0.9999683</td>
</tr>
<tr>
<td>8</td>
<td>4.5</td>
<td>0.9999996</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>0.999999713</td>
</tr>
<tr>
<td>10</td>
<td>5.5</td>
<td>0.999999981</td>
</tr>
</tbody>
</table>

III. FLEXURAL FAILURE OF A RECTANGULAR REINFORCED CONCRETE SECTION OF THE BEAM

The design of different rectangular reinforced concrete section of beam is considered. The main task of a structural engineer is the analysis and design of structures. The design of a section implies that the external moment is known, and it is required to compute the dimensions of an adequate concrete section and the amount of steel reinforcement. Concrete strength and yield of steel used are assumed. The dimensions and steel used in the section are given. It is required to calculate the ultimate moment capacity of the section.

The assumptions are made in flexural theory are

(i) Plane section is remain same after bending.

(ii) Strain in concrete is the same as in reinforcing bars, provided that the bond between the steel and concrete is sufficient to keep them acting together under the different load stages i.e., no slip can occur between the two materials.

(iii) The stress-strain curves for the steel and concrete are known.

(iv) The tensile strength of concrete may be neglected.

(v) At ultimate strength, the maximum strain at the extreme compression fiber is assumed to 0.003. The assumption of plane sections remaining plane (Bernoulli’s principle) means that strains above and below the neutral axis NA is proportional to the distance from the neutral axis.

A. Tension Failure

If the steel content of the section is small (an under-reinforced concrete section), the steel will reach its yield strength before the concrete reaches its maximum capacity. The flexural strength of the section is reached when the strain in the extreme compression fiber of the concrete is approximately 0.003, Fig.2. With further increase in strain, the moment of resistance reduces, and crushing
commences in the compressed region of the concrete. This type of failure, because it is initiated by yielding of the tension steel, could be referred to as a tension failure.

In tensile failure $h_y = h_y$; D=T;

$$T = B_s h_y$$ and $D = 0.67h_{cu}ba$ (21)

From the above equation

$$B_s h_y = 0.67h_{cu}ba$$

$$a = \frac{B_s h_y}{0.67h_{cu}b}$$ (22)

The nominal strength of the cross section $N_u$ (capacity of the cross section) is

$$N_u = T(d - 0.5a) = B_s h_y \left[ d - \frac{B_s h_y}{1.34h_{cu}b} \right]$$ (23)

where $B_s =$cross sectional area, $h_y =$specified yield strength, $h_{cu} =$specified compressive strength of concrete, $N_u =$Ultimate moment capacity of the cross section, $d=$distance between the steel reinforcement and the extreme compressive fiber, $b=$ width of the section.

B. Reliability Calculations for Flexural Failure of a Rectangular Reinforced Concrete Section

The flexural limit state function for rectangular reinforced concrete section is

$$g = S - Q$$ (24)

Where $S$ is the strength of the cross section (the Ultimate moment capacity that it can carry) and $Q$ is the bending moment.

$$g = B_s h_y \left[ d - \frac{B_s h_y}{1.34h_{cu}b} \right] - Q$$ (25)

Design parameter’s variability: The application of the reliability model assumes that the covariances of the parameters are known so that the design parameter’s variability can be estimated. The coefficient of variance of specified yield strength is 10% to 12%. The cross sectional area has a coefficient of variance of 2 to 5%. The coefficient of variance of specified compressive strength of concrete is 10% to 15%. The coefficient of variance of bending moment is 8% to 10%. Table 2 shows the coefficient of variance of the design parameters.

**Table 2. Summary of Design Parameter and Coefficient of variance**

<table>
<thead>
<tr>
<th>Design parameter</th>
<th>Cov (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross sectional area</td>
<td>2.17</td>
</tr>
<tr>
<td>Specified yield strength</td>
<td>11.5</td>
</tr>
<tr>
<td>Specified compressive strength of concrete</td>
<td>14.28</td>
</tr>
<tr>
<td>Bending moment</td>
<td>8</td>
</tr>
</tbody>
</table>

Consider the cross section area $2.3 \times 10^{-3} m^2$, specified yield strength is 350MPa, specified compressive strength 28MPa, bending moment is $250 \times 10^3 Nm$, width of the section is 0.25 and $d=0.42$. $B_s, h_y, h_{cu}, Q$ are the random variables normally distributed having mean and SD values: $B_s = 2.3 \times 10^{-3} m^2$; $\sigma_{B_s} = 0.00005 m^2$; $h_y = 350MPa$; $\sigma_{h_y} = 40MPa$; $h_{cu} = 28MPa$; $\sigma_{h_{cu}} = 4MPa$; $Q = 200 \times 10^3 Nm$; $\sigma_Q = 16 \times 10^3 Nm$.

The mean value of the limit state function

$$\bar{g} = B_s h_y \left[ d - \frac{B_s h_y}{1.34h_{cu}b} \right] - Q = 69.0142 \times 10^3 Nm$$

The partial derivatives at the mean values are

$$\alpha_1 = \frac{\partial g}{\partial X_1} = \frac{\partial g}{\partial B_s} = 86925373 N/m$$
\[ \alpha_2 = \frac{\partial g}{\partial X_2} = \frac{\partial g}{\partial h_y} = 571.2 \times 10^{-6} \text{ m}^3 \]

\[ \alpha_3 = \frac{\partial g}{\partial X_3} = \frac{\partial g}{\partial h_{cu}} = 2467 \times 10^{-6} \text{ m}^3 \]

\[ \alpha_4 = \frac{\partial g}{\partial X_4} = \frac{\partial g}{\partial Q} = -1 \]

The reliability index result is \( \beta = \frac{-g}{\sqrt{\sum (\alpha_i X_i)^2}} \)

=2.3077

The reliability of the flexural rectangular concrete section and probability of failure are

Reliability=0.9896, \( P_f = 10.4 \times 10^{-3} \).

Table 3, shows the values of reliability index and probability of failure when cross sectional area, specified yield strength, specified compressive strength of concrete, distance and width of the section are constant and bending moment changing. It is observed that reliability decreasing as shown in fig 3. So that for the design of the structure, the bending moment should lies between 180000Nm and 280000Nm.

![Figure 3. Reliability and bending moment](image)

From table 4, it is obtained the reliability index and probability of failure when bending moment, specified yield strength, specified compressive strength of concrete, distance and width of the beam are changing and cross sectional area is changing. It is observed that reliability is increased as shown in fig 4.

**Table 4**

Cross sectional area is changing and other parameters keeping constant

<table>
<thead>
<tr>
<th>Bs</th>
<th>( g )</th>
<th>( \beta )</th>
<th>( P_f )</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0018</td>
<td>2286.5671</td>
<td>0.0816</td>
<td>0.4681</td>
<td>0.5319</td>
</tr>
<tr>
<td>0.0019</td>
<td>12154.4776</td>
<td>0.4248</td>
<td>0.336</td>
<td>0.664</td>
</tr>
<tr>
<td>0.002</td>
<td>21761.19</td>
<td>0.7457</td>
<td>0.228</td>
<td>0.772</td>
</tr>
<tr>
<td>0.0021</td>
<td>31106.71</td>
<td>1.046</td>
<td>0.148</td>
<td>0.852</td>
</tr>
<tr>
<td>0.0022</td>
<td>40191.044</td>
<td>1.3276</td>
<td>0.0926</td>
<td>0.9074</td>
</tr>
<tr>
<td>0.0023</td>
<td>49014.17</td>
<td>1.5918</td>
<td>0.0559</td>
<td>0.9441</td>
</tr>
<tr>
<td>0.0024</td>
<td>57576.1194</td>
<td>1.8397</td>
<td>0.033</td>
<td>0.967</td>
</tr>
<tr>
<td>0.0025</td>
<td>65876.8565</td>
<td>2.0725</td>
<td>0.0192</td>
<td>0.9808</td>
</tr>
<tr>
<td>0.0026</td>
<td>73916.41</td>
<td>2.2908</td>
<td>0.011</td>
<td>0.989</td>
</tr>
<tr>
<td>0.0027</td>
<td>81694.77</td>
<td>2.4953</td>
<td>0.0064</td>
<td>0.9936</td>
</tr>
<tr>
<td>0.0028</td>
<td>89211.9403</td>
<td>2.6866</td>
<td>0.0037</td>
<td>0.9963</td>
</tr>
</tbody>
</table>
In table 5, when cross sectional area, specified compressive strength of concrete, distance and width of the section keeping constant and specified yield strength is increasing, it is observed that the reliability is increasing as shown in figure 5.

**Table 5**

<table>
<thead>
<tr>
<th>Specified yield strength is increasing and other parameters keeping constant</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bs=0.0025,hcu=28<em>10^6,d=0.42,b=0.25,Q=220</em>10^3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hs</td>
<td>g</td>
<td>β</td>
<td>P_f</td>
<td>R</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>250*10^6</td>
<td>855.54371</td>
<td>0.0306</td>
<td>0.488</td>
<td>0.512</td>
</tr>
<tr>
<td>275*10^6</td>
<td>18360.20899</td>
<td>0.63357</td>
<td>0.2643</td>
<td>0.7357</td>
</tr>
<tr>
<td>300*10^6</td>
<td>35031.9829</td>
<td>1.1689</td>
<td>0.1215</td>
<td>0.8785</td>
</tr>
<tr>
<td>325*10^6</td>
<td>50870.8688</td>
<td>1.6462</td>
<td>0.05</td>
<td>0.95</td>
</tr>
<tr>
<td>350*10^6</td>
<td>65876.8656</td>
<td>2.0725</td>
<td>0.0192</td>
<td>0.9808</td>
</tr>
<tr>
<td>375*10^6</td>
<td>80049.9733</td>
<td>2.4527</td>
<td>0.0071</td>
<td>0.9929</td>
</tr>
<tr>
<td>400*10^6</td>
<td>93390.1919</td>
<td>2.79</td>
<td>0.0026</td>
<td>0.9974</td>
</tr>
<tr>
<td>425*10^6</td>
<td>105897.5213</td>
<td>3.0865</td>
<td>0.001</td>
<td>0.999</td>
</tr>
<tr>
<td>450*10^6</td>
<td>117571.9616</td>
<td>3.34279</td>
<td>0.0005</td>
<td>0.9995</td>
</tr>
<tr>
<td>475*10^6</td>
<td>128413.5128</td>
<td>3.5588</td>
<td>0.0002</td>
<td>0.9998</td>
</tr>
<tr>
<td>500*10^6</td>
<td>138422.1748</td>
<td>3.7341</td>
<td>1E-04</td>
<td>0.9999</td>
</tr>
</tbody>
</table>

In table 6, When Distance between the steel reinforcement and the extreme compressive fiber is changing and bending of beam, cross sectional area, specified yield strength, specified compressive strength of concrete keeping constant then the Reliability index is increasing as shown in figure 6.

**Table 6**

<p>| Distance between the steel reinforcement and the extreme compressive fiber is changing and other parameters keeping constant | | | | |
|Bs=0.0025,hs=350<em>10^6,hcu=28</em>10^6,b=0.25,Q=220*10^3 | | | | |</p>
<table>
<thead>
<tr>
<th>d</th>
<th>g</th>
<th>β</th>
<th>P_f</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>4626.8656</td>
<td>0.1721</td>
<td>0.4325</td>
<td>0.5675</td>
</tr>
<tr>
<td>0.37</td>
<td>22126.8657</td>
<td>0.7851</td>
<td>0.2177</td>
<td>0.7823</td>
</tr>
<tr>
<td>0.39</td>
<td>39626.8657</td>
<td>1.3399</td>
<td>0.0901</td>
<td>0.9099</td>
</tr>
<tr>
<td>0.41</td>
<td>57126.8657</td>
<td>1.8408</td>
<td>0.0329</td>
<td>0.9671</td>
</tr>
<tr>
<td>0.43</td>
<td>74626.8657</td>
<td>2.2924</td>
<td>0.011</td>
<td>0.989</td>
</tr>
<tr>
<td>0.45</td>
<td>92126.8657</td>
<td>2.6993</td>
<td>0.0035</td>
<td>0.9965</td>
</tr>
<tr>
<td>0.47</td>
<td>109626.866</td>
<td>3.0664</td>
<td>0.0013</td>
<td>0.9987</td>
</tr>
<tr>
<td>0.49</td>
<td>127126.866</td>
<td>3.3979</td>
<td>0.0012</td>
<td>0.9988</td>
</tr>
<tr>
<td>0.51</td>
<td>144626.866</td>
<td>3.6978</td>
<td>1E-04</td>
<td>0.9999</td>
</tr>
<tr>
<td>0.53</td>
<td>162126.866</td>
<td>3.9698</td>
<td>1E-04</td>
<td>0.9999</td>
</tr>
</tbody>
</table>
In table 7, when width of the section is increasing and rest are keeping constant, it is observed that the reliability index is increasing as shown in figure 7.

**Table-7**

<table>
<thead>
<tr>
<th>d</th>
<th>g</th>
<th>β</th>
<th>P_f</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>11461.4428</td>
<td>0.4025</td>
<td>0.3446</td>
<td>0.6554</td>
</tr>
<tr>
<td>0.2</td>
<td>45471.0821</td>
<td>1.5295</td>
<td>0.064</td>
<td>0.936</td>
</tr>
<tr>
<td>0.25</td>
<td>65876.8657</td>
<td>2.0725</td>
<td>0.0192</td>
<td>0.9808</td>
</tr>
<tr>
<td>0.3</td>
<td>79480.7214</td>
<td>2.3652</td>
<td>0.0091</td>
<td>0.9909</td>
</tr>
<tr>
<td>0.35</td>
<td>89197.7612</td>
<td>2.5422</td>
<td>0.0055</td>
<td>0.9945</td>
</tr>
<tr>
<td>0.4</td>
<td>96785.541</td>
<td>2.659</td>
<td>0.004</td>
<td>0.996</td>
</tr>
<tr>
<td>0.45</td>
<td>102153.814</td>
<td>2.74125</td>
<td>0.0031</td>
<td>0.9969</td>
</tr>
<tr>
<td>0.5</td>
<td>106688.433</td>
<td>2.80197</td>
<td>0.0026</td>
<td>0.9974</td>
</tr>
<tr>
<td>0.55</td>
<td>110398.575</td>
<td>2.8485</td>
<td>0.0023</td>
<td>0.9977</td>
</tr>
<tr>
<td>0.6</td>
<td>113490.361</td>
<td>2.8852</td>
<td>0.002</td>
<td>0.998</td>
</tr>
</tbody>
</table>

**IV. CONCLUSION**

One of the best ways of representing the capacity, serviceability and durability of the structure in the theory of reliability is the reliability index $\beta$. Most of the engineering constructions consist of a system with connected components and its elements. When thinking about the reliability of the system, it is important to note that whether failure of the individual elements cause a failure of the entire structure.

By using the Hasofer-Lind Method, the reliability of the structural design (A Rectangular Reinforced Concrete Section) was calculated for its capacity, durability and serviceability. Failure occurs due to the heavy bending moment of the rectangular concrete section. It is observed that if cross sectional area increased then the failure rate decreased. It is also observed that when the value of the other design parameters like specified yield strength, specified compressive strength of concrete, distance between reinforcement and the extreme compressive fiber and width of the section increased then the system reliability increased.
Several factors must be considered in the structure to improve system reliability; those are security, usability, strength and flammability of construction.

The structure should be designed and implemented in such a manner that during its life cycle, with a certain degree of reliability, it will not collapse due to an explosion, shock, loads or human error.

V. REFERENCES


[2]. T.micic,"Structural Reliability applications", Faculty of civil Engineering and architecture in University of Nis, Serbia 2012.


[12]. Antanas Kudzys and Romualdas Kliukas., "Reliability index design in Reinforced concrete structures of annular cross sections", ModernBuilding Materials and Techniques, the 10th International Conference, 2010, Lithuania.


