International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 11 | Nov 2020 www.irjet.net p-ISSN: 2395-0072

# EFFECTIVENESS OF SEISMIC RETROFITTING OF STIFFNESS IMBALANCED REINFORCED CONCRETE BUILDING USING FRAGILITY CURVES

**Ms. Sharayu Joshi[1], Dr. V. S. Patil[2]**

*[1]Sharayu joshi, Student, Kolhapur*
*[2]V. S. Patil, Associate Professor, Kolhapur*
*[1,2]Department of Civil Engineering, Sanjay Ghodawat Group of Institutions, (Kolhapur), Atigre - India.*

---***---

**Abstract:-***Old buildings are not earthquake resistant, some of them we cannot dismantle. Retrofitting is technique which is beneficial for such structures. . In the present study G+12 building present in Mumbai (Zone III) is taken for the study. Nonlinear modeling was carried out and building was analyzed using pushover analysis in SAP2000 to identify seismic deficiency. The retrofitting techniques such as shear wall, steel bracing were suggested for improvement. It has been observed that the performance of the building was improved. Thus, it can be concluded that the building retrofitted with shear wall is most effective in present case to improve the performance locally as well as globally*

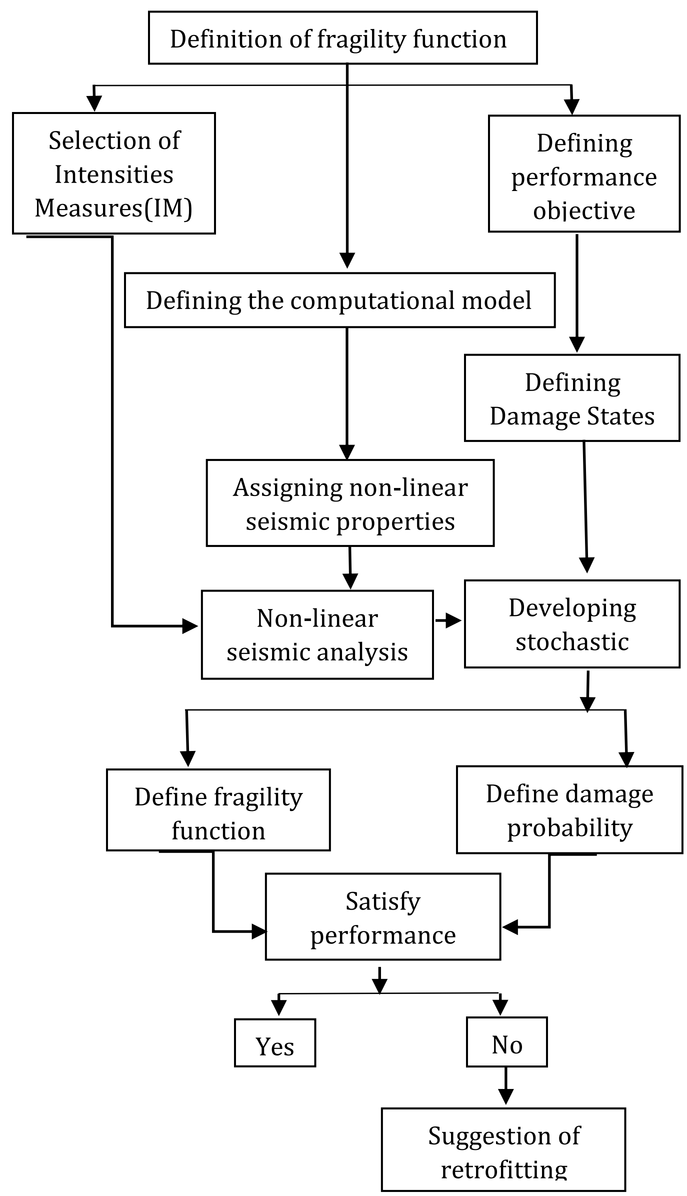
***Key words***:- Fragility function, Pushover analysis

## 1. INTRODUCTION

The older buildings which are constructed in 1980s are constructed without considering design provisions. The design criteria for earthquake resisting to deal with earthquake calamity the structure could be retrofitted according to needs because in many of the cases we cannot demolish the whole structure and reconstruct it. Considering this scope scientist is developing the many methodologies to assess the future performance of existing structures in case of earthquake.

With structures getting old and the increasing bar for the developed structures the old structures have begun to show a genuine need of additional repairs. Retrofitting of structures like building, which incorporates rehabilitation, maintenance and strengthening of the structure, isn't just a need in construction and management in urban territories, yet additionally an issue which arises to structural engineer in property management fields.

## 2. METHODOLOGY



## 3. RETROFITTING TECHNIQUES

- Shear wall: - RCC wall provide in building till full height to resist earthquake.
- Steel bracing: - Steel braced frame provide in building.

## 4. PUSHOVER ANALYSIS

### 4.1 Purpose of pushover analysis

By the estimation and the deformation of the any structure one can assess the future performance of building by using the pushover analysis. It is useful for the design of building as an earthquake resistant structure. In this the load is applied on the structure until the weak links in the structure is found. The process of application of loads will continue until yield pattern of the entire structure under the seismic loading is defined. It is useful for the finding the seismic capacity of the structure. Pushover analysis is appeared in guidelines for retrofit seismic designs in the several types of codes of practice. Parameters like global drift, also the drift it which occurs between the stories of the building, the deformation which happen in the elements of the structure it could be absolute or it could be with the respect to yield value and the deformation in the element and their connection forces such that the connection which are not capable to sustain the inelastic type of deformation are the bases for the assessing the performance of any structure.

Pushover analysis is done using 2 methods

(1) Capacity spectrum method
(2) Displacement coefficient method

Here only capacity spectrum method is used.

### 4.2 Capacity Spectrum Method:

Nonlinear models normally produce more sensible seismic reaction analysis than elastic models. Notwithstanding, nonlinear dynamic examinations of whole structures require a calculation efforts. These calculation efforts can be considerably decreased when the calculation is restricted to a nonlinear static analysis joined with a system to decide the maximum deformation for the nonlinear static analysis. Utilizing that approach, the seismic reaction of a RC structure may be assessed, for a definitive reaction as well as for different effect levels.

In the non-linear pushover analysis the seismic response of the structure is analyzed by the method called as CSM (Capacity Spectrum Method). This method was developed by S. A. Freeman [Freeman, 1998] for analysis of frame buildings. Its concept have been introduced in the NEHRP guidelines for the seismic rehabilitation of buildings [FEMA-273, 1997] and in several US guidelines for seismic evaluations such as the ATC-40 [Applied Technology Council, 1996]. The permits for describing the seismic performance effectively as well as the response of the structure in the case of earthquake are analyzed by the help of CSM.

## 5. FRAGILITY CURVES:

Fragility curves represent the probability that a structure exceeds a given state of damage as a function of a parameter that defines the seismic intensity. These curves are used to estimate the seismic risk of groups of buildings with similar structural features. Fragility curves can be generated from field observations, based on the opinion of experts and using analytical methods. Where there is insufficient information in the field, the fragility curves can be generated analytically by means of simulation. In our case, the parameter that defines the seismic intensity is the spectral displacement Sd. Fragility curves follow a lognormal probability distribution define by two important parameters, the mean spectral displacement $\bar{S}_{d,ds}$ and the standard deviation $\beta_{ds}$. For a given damage state $d_s$, the fragility curve is given by:

$$P[d_s/S_d] = Ø\left[\frac{1}{\beta_{ds}} \ln\left(\frac{S_d}{\bar{S}_{d,ds}}\right)\right] \text{..............................(a)}$$

Where,

$\bar{S}_{d,ds}$ : The median value of spectral displacement at which the building reaches a certain threshold of the damage state $d_s$, $\beta_{ds}$.

Ø : The standard normal cumulative distribution function

$S_d$ : The spectral displacement.

According to the European macro seismic scale (1998), the seismic damage of existing building follow a binomial probability distribution (Beta distribution) used to calculate the continuous damage probability matrix for every vulnerability class. The approach assumes that the probability of each damage state at its spectral displacement is the 50% and the probability of the other damage states follows the Beta distribution. Table given below summarized the probability distribution for each damage state.

**Table no.:-1** Probabilities by beta distribution

| Condition | $P_\beta$ (1) | $P_\beta$ (2) | $P_\beta$ (3) | $P_\beta$ (4) |
|---|---|---|---|---|
| $P_\beta$ (1) | 0.500 | 0.119 | 0.012 | 0.00 |
| $P_\beta$ (2) | 0.896 | 0.500 | 0.135 | 0.008 |
| $P_\beta$ (3) | 0.992 | 0.866 | 0.500 | 0.104 |
| $P_\beta$ (4) | 1.000 | 0.988 | 0.881 | 0.500 |

Fragility curves will be obtained, starting from a bilinear representation of the capacity curves. Figure below shows the values of the thresholds $\overline{S}_{d,ds}$ and their values are given in the following equation:

$\overline{S}_{d1} = 0.7\ D_y$ Slight

$\overline{S}_{d2} = D_y$ Moderate

$\overline{S}_{d3} = D_y + 0.25\ (D_u - D_y)$ Complete

$\overline{S}_{d4} = D_u$ Severe

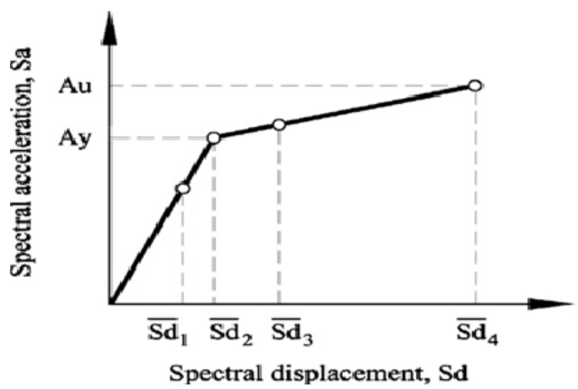



**Fig 1.** Damage state thresholds from capacity spectrum

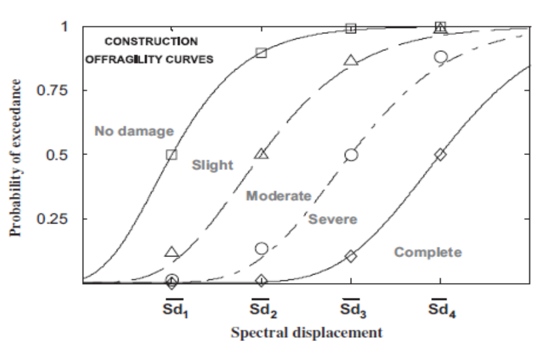



**Fig 2.** Example of fragility curves construction

### 5.1 Fragility Curves in Push X Direction:

Pushover analysis is done in the X direction and from the bilinear curve the data is taken. After that using that data in the equation of the fragility all the values for the condition of slight, moderate, severe and complete is calculated. The retrofitting strategies which are used namely shear wall, steel bracing are compared by the graph which is shown as below:

#### 5.1.1 Fragility Curves for slight condition

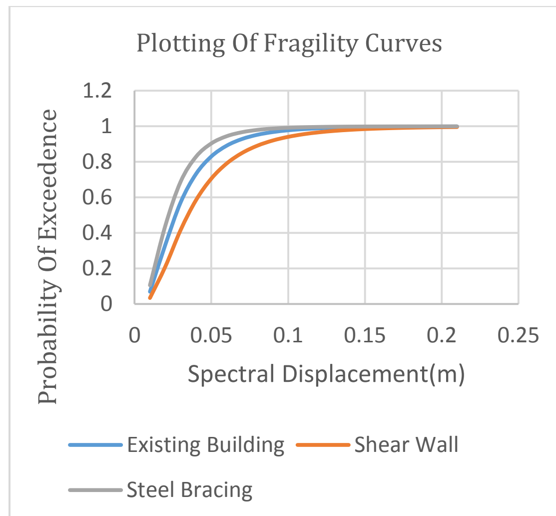



**Fig 3.** Fragility Curves Construction

From the graph it could be understand that the shear wall is showing better seismic performance than the steel bracing. It reduces the damage probability.

#### 5.1.2 Fragility Curves for moderate condition:

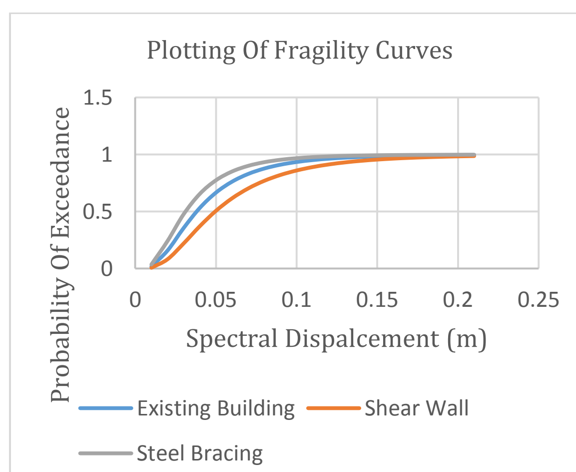



**Fig 4.** Fragility Curves Construction

From the graph it is seen that in moderate condition shear wall is superior than the steel bracing.

### 5.2.3 Fragility Curves for Severe Condition:

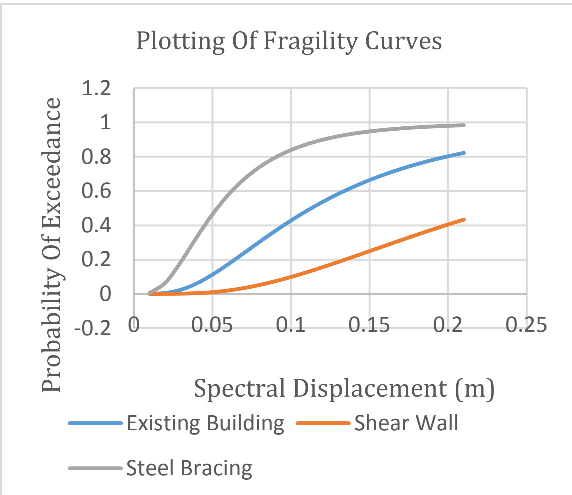



**Fig 5.** Fragility Curves Construction

From the graph it is observed that in the severe condition shear wall is the best suitable retrofitting strategy amongst all of the three techniques of retrofitting. But however the building which is retrofitted with the steel bracing is susceptible to the earthquake and it shows the more damage probability than the existing building and the building.

### 5.2.4 Fragility Curves for Complete Condition:

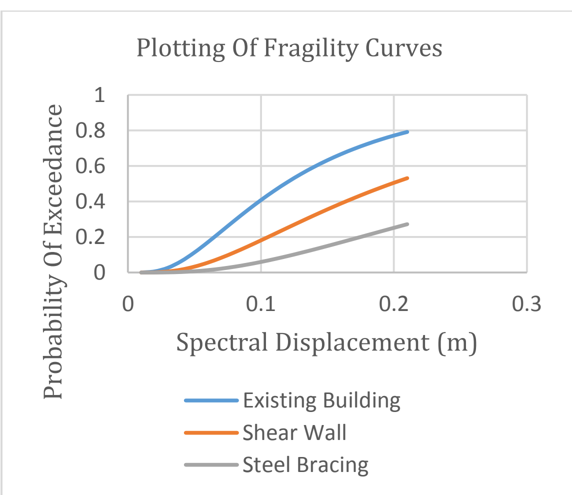



**Fig 6.** Fragility Curves Construction

From this graph it can be observed that the performance of the buildings with the steel bracing perform better than the building with shear wall.

### 5.2 Fragility Curves in Push Y Direction:

### 5.2.1 Fragility Curves for slight condition:

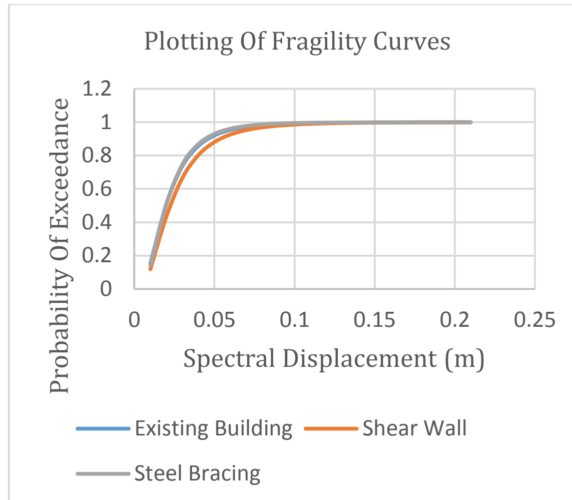



**Fig 7.** Fragility Curves Construction

From observing the above graph for the buildings it is clear that when pushover analysis is done in the Y direction for slight condition the building having shear wall perform better than the other buildings.

### 5.2.2 Fragility Curves for moderate condition:

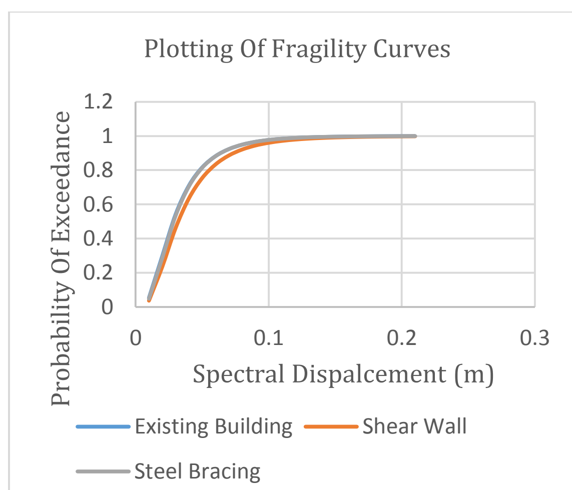



**Fig 8.** Fragility Curves Construction

In the moderate condition when graph is plotted for the buildings it is observed that building with shear wall is giving the good results in the comparison of the building with steel bracing.

### 5.2.3 Fragility Curves for severe condition:

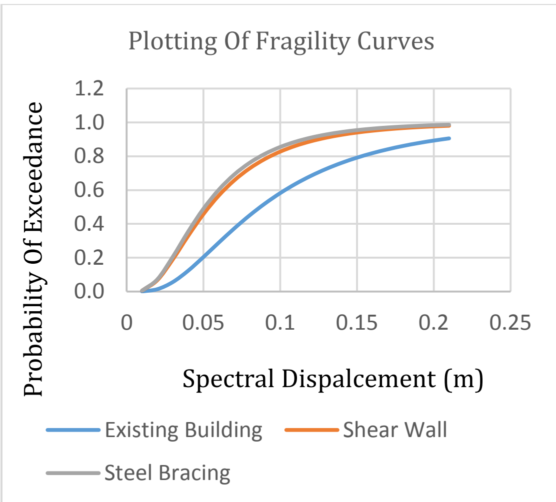



**Fig 9**. Fragility Curves Construction

From the above graph it can be understand when severe condition is there and the pushover analysis is done in the Y direction the building which has steel bracing can perform good as compare to the buildings with the shear wall

### 5.2.4 Fragility Curves for complete condition:

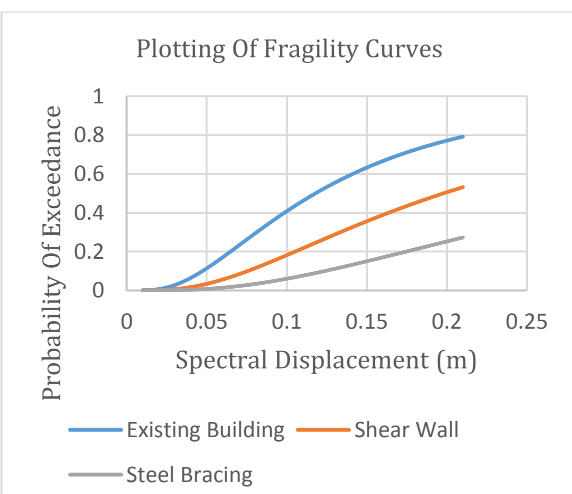



**Fig 10.** Fragility Curves Construction

When the pushover analysis in the Y direction is done for the complete condition the performance of the buildings is as shown in the above graph. The building with steel bracing shows the best performance than the building with shear wall. Hence there is need of retrofitting techniques to enhance the performance of the building and to impart the strength to existing building.

## 6. RESULT AND CONCLUSION

The effectiveness of seismic retrofitting strategies of stiffness imbalanced reinforced concrete building by using fragility curves has been studied. Following conclusions are drawn from the study.

1. Analysis results conclude that building retrofitted using shear wall improve the performance globally. As compare with original un-retrofitted building, time period reduced by 15%, initial lateral stiffness increased by 83%, lateral strength increased by 70%, ductility increased by 76% and performance point has been improved.

2. As compare with original un-retrofitted building, building retrofitted using steel bracing reduces the time period by 20.72%, initial lateral stiffness increased by 7.14 %, lateral strength increased by 70.9%, ductility increased by 81.69% and performance point has been improved.

3. Building retrofitted using concrete shear wall in present case is most effective to improve the seismic performance locally as well as globally.

## 7. REFERENCES

1. Applied Technology Council, ATC 40 (1996), "Seismic evaluation and retrofit of concrete buildings", ATC, Redwood City, California.

2. ASCE/SEI 41-06 (2007), "Seismic rehabilitation of existing buildings", ASCE standard, American society of civil engineers, Reston, Virginia, United States.

3. Barbat, A.H., Pujades, L.G. and Lantada, N., 2008. Seismic damage evaluation in urban areas using the capacity spectrum method: application to Barcelona. Soil Dynamics and Earthquake Engineering, 28(10-11), pp.851-865.

4. Bhosale A. S., Davis R. and Sarkar P. (2017), "Vertical Irregularity of Buildings : Regularity Index versus Seismic Risk",ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, PartA: Civil Engineering, ISSN:2376-7642.

5. Bracci J. M., Reinhorn A. M. and Mander J. B. (1995), "Seismic retrofit of reinforced concrete buildings designed for gravity loads: performance of structural model", ACI structural Journal, vol.92 No.6.

6. Eurocode 8(2005), I.S. EN 1998-3:2005: Design of structures for earthquake resistance part3: assessment and retrofitting of buildings.

7. FEMA-356 (2000), "Pre-standard and commentary for the seismic rehabilitation of buildings", Federal Emergency Management Agency, Washington, D.C., United States.

8. FEMA P695 (2009), "Quantification of building seismic performance factors", Federal Emergency Management Agency, Washington, D.C., United States.

9. HAZUS®MHMR4, Technical manual (2003), "Multi-hazard loss estimation methodology earthquake model", Federal Emergency Management Agency, Washington, D.C., United States.

10. IS 1893 Part 1 (2002), Indian Standard – "Criteria for earthquake resistant design of structures" part 1: General provisions and buildings (fifth revision), Bureau of Indian Standards, New Delhi.

11. IS13920 (1993), Indian Standard – "Ductile detailing of reinforced concrete structures subjected to seismic forces, code of practice", Bureau of Indian Standards, New Delhi.

12. IS15988 (2013), Indian Standard – "Seismic evaluation and strengthening of existing reinforced concrete buildings -guidelines", Bureau of Indian Standards, New Delhi.

13. Jeong Seon - Hoong and Elnashai Amr S. (2006), "Probabilistic fragility analysis parameterized by fundamental response quantities ",Engineering Structures 29 (2007) 2172–2182.

14. Kim Sang-Hoon and Shinozuka Masanobu (2004), "Development of fragility curves of bridges retrofitted by column jacketing" Probabilistic Engineering Mechanics, 19 (2004) 105–112.

15. Murat S.K. and Zekeriya P. (2006), "Fragility analysis of mid-rise R/C frame buildings", Engineering Structures, 28, 2006, 1335-1345.

16. Raipure P. T. and Chaudhari D. J. (2015), "Seismic vulnerability assessment of open ground story RC buildings by using fragility curves ", Government College of Engineering, Amravati, M-Tech thesis, 2013-14.

17. Salem Y. S., Lucas A. B., and Ghada G. M. (2018), "Analytical Fragility Curves for Reinforced Concrete Dual System Subjected to Seismic Loads", facing the challenges in Structural Engineering, Sustainable Civil Infrastructures, DOI 10.1007/978-3-319- 61914-9_12.

18. Singh Varinder K., (2012) "Structural Repair and Rehabilitation of 3 no. (G + 8 ) Multistoried residential Building, at ONGC Colony at, Ahmadabad, Gujarat" SciVerse Science Direct, Procedia Engineering 51 (2013) 55-64.

19. Vamvatsikos D and Cornell C.A. (2002), "Incremental dynamic analysis", Earthquake Engineerin and Structural Dynamics:31(3):491_514.

20. Vazurkar U. Y. and Chaudhari, D. J.(2016) "Development of fragility curves for RC Buildings" International Journal of Engineering Research , Volume No.5 Issue: Special 3,pp: 591-594, ISSN:2319-6890

21. Wen Y. K., Ellingwood B.R., Bracci J. (2004), "Vulnerability function framework for consequence-based engineering", Vol. DS-4, MAE Center Project DS-4 Report.