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Reliability Index for Buckling Restrained Braced Frame

Malavika G Babu
M tech Student [Structural Engineering]Dept of Civil Engineering Younus College of Engineering and Technology Kollam, India

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ABSTRACT—Structural demands in high seismic zones require the use of strong lateral framing systems. The structure must have adequate strength and stiffness to resist smaller, frequent earthquakes with limited damage, but must also be able to sustain large inelastic cyclic deformations to economically assure safety and stability during large, infrequent earthquakes. To overcome these problems a new type of braces called buckling restrained braces (BRBs) were introduced. They are structural steel frames that provide lateral resistance to buckling during seismic activity. This study aims to assess the seismic performance of buckling restrained braced frames (BRBFs) by Eigen value modal analysis, equivalent static analysis and time history plots should be created by spectral matching to find out peak response of the building. The reliability index can be calculated by varying building height and plotting the safety margin curves. The modeling and analysis of building is carried out using ETABS software.

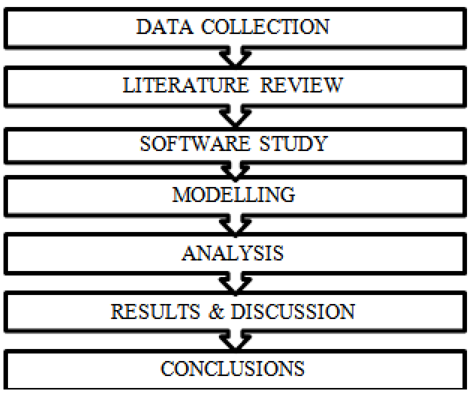
Keywords— Buckling restrained braced frames (BRBFs), Eigen value modal analysis, ETABS software, Reliability index.

I. INTRODUCTION

Earthquake causes economic losses as well as losses of lives due to the collapse of structures. During strong seismic waves structural elements like beams and columns are seriously affected. Under moderate to severe earthquakes conventional lateral load resisting systems are not effective to overcome these problems, a new type of braces called buckling restrained braces (BRBs) were introduced. The main components of braces are steel core, bond-preventing layer and outer casing. The steel core is able to resist axial force acting on bracings. Core is divided into three parts, central yielding part and rigid non yielding parts at both ends. The bond preventing layer separates core and casing. It allows free expansion and contraction of core during tension and compression. The casing envelops the inner parts and restraining the steel core from buckling

In this work the seismic performance of a10 storey I shaped BRBF building is evaluated by equivalent static analysis, Eigen value model analysis. Time history data collected for spectral matching and peak response of building is obtained. Reliability index of structure can be calculated by plotting safety margin curves for differentbuilding height.

II. METHODOLOGY



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III. MODELLING

A 10 storey I shaped building is modelled using ETABS software. The materials used are M30 grade concrete and Fe415 grade steel. Height of each storey is 3 m. Number of bays in X and Y direction are 7 and 4 respectively. The span of each bay is 3m.The beam section of size 250 mm x 250 mm and Column of size 500 mm x 500 mm is used. Here the provided Slab thickness is 120 mm.

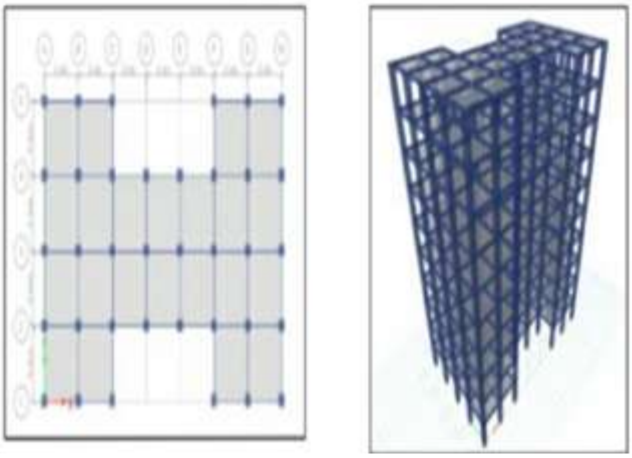

Fig.1. Plan and Elevation of building

TABLE I. DEAD LOAD (IS 875: 1987 PART 1)

Parapet	2KN/m
Wall Load	12 KN/m
Floor finish	$1KN/m^2$

TABLE II. LIVE LOAD (IS 875: 1987 PART 2)

Residential building	$2\ KN/m^2$
Roof	$1.5\ KN/m^2$

TABLE III. WIND LOAD (IS 875: PART 3)

Risk factor,(k_1)	1.0
Topography factor,(k_2)	1.0
Terrain factor,(k_3)	1.0
Terrain category	2
Building class	B

TABLE IV. SEISMIC LOAD (IS1893:2002)

Seismic zone factor, Z	0.16
Importance factor, I	1
Response reduction factor ,R	5

TABLE V. LOAD COMBINATIONS (IS 1893: 2002 PART 1)

1.5 DL	0.9 DL + 1.5 WL-Y
1.5 (DL + LL)	1.2 (DL + LL + EQX)
1.2 (DL + LL + WLX)	1.2 (DL + LL + EQ-X)
1.2 (DL + LL + WL-X)	1.2 (DL + LL + EQY)
1.2 (DL + LL + WLY)	1..2 (DL + LL + EQ-Y)
1.2 (DL + LL + WL-Y)	1.5 (DL + EQX)
1.5 (DL + WLX)	1.5 (DL + EQ-X)
1.5 (DL + WL-X)	1.5 (DL + EQY)

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1.5 (DL + WL-Y)	1.5 (DL + EQ-Y)
0.9 (DL + 1.5 WLX)	0.9 (DL + 1.5 EQX)
0.9 (DL + 1.5 WL-X)	0.9 (DL + 1.5 EQ-X)
0.9 (DL + 1.5 WLY)	0.9 (DL + 1.5 EQY)
1.5 (DL + WLY)	0.9 (DL + 1.5 EQ-Y)

IV. ANALYSIS

A. Buckling Analysis

Buckling analysis is carried out to predict the maximum load a structure can support prior to instability or Collapse The colored portions indicates regions with buckling load is maximum. The buckling load factors can be obtained from the software.

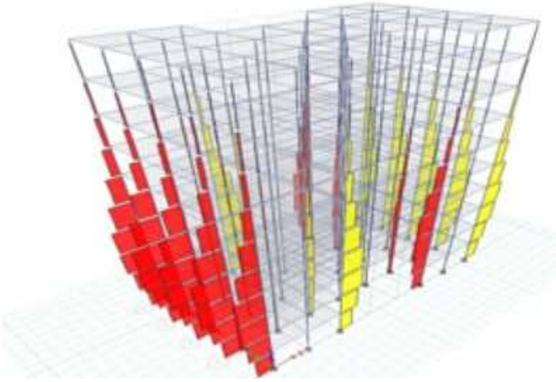

Fig.2.Column axial load

In conventional method, to avoid buckling we should multiply these buckling load factors as factor of safety to the loads acting on the building and design as per the resultant loads. Instead of this, the provision of using buckling restrained braced frame on the building should be analyzed.

BUCKLING RESTRAINED BRACED FRAME

Star Seismic is an international manufacturer of Buckling restrained braces. The details of braces can be collected from star seismic manual. Star Seismic sections of size 1 inch^2 to 52 inch^2 are available. By selecting auto selection option the software itself select the suitable section for the structure. Here Star BRB of cross section 26.5 inch^2 is selected. This process is called optimization of BRB.

TABLE VI. BRBF MATERIAL PROPERTIES

Core Material Density	7850 KN/m^3
Modulus of Elasticity	2x10^5 MPa
Poisson's Ratio	0.3
Shear Modulus	76903.07 MPa
Minimum Yield stress	262 MPa
Minimum Tensile Stress	399.9 MPa
Effective Yield Stress	327.5 MPa
Effective Tensile Strength	499.87 MPa

TABLEVII. BRBF SECTION DETAIL

Weight	25.54 kN
Depth	406.4 mm
Width	304.8 mm
Area of yielding core	171 cm2
Stiffness of elastic segment	4334353.557 kN/m
Length of yielding core	4.2672
Length of elastic segment	2.2713
Linear Effective Axial Stiffness	676133.98 kN/m

B. Equivalent Static Analysis

Here parameters like storey displacement, storey drift and storey shear values of Conventional Buckling resistance building and BRBF building are compared.

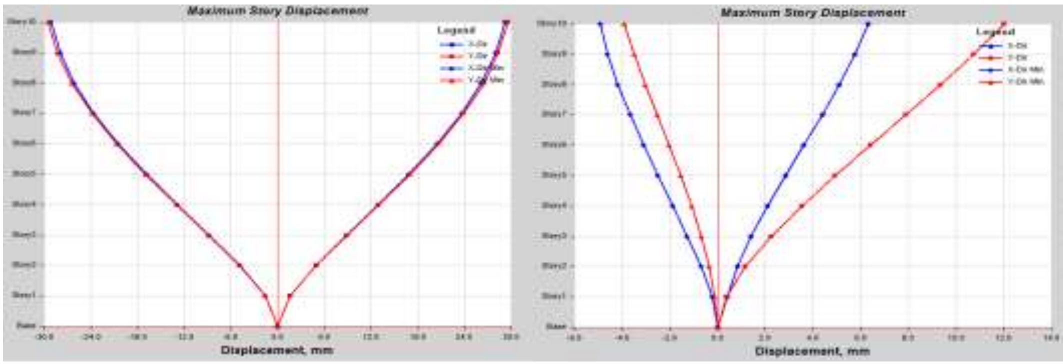

Fig.3. Storey displacement without BRB and with BRB

Maximum value of storey displacement for conventional building is 29.57 mm and for building with BRB the maximum storey displacement is 12.02 mm.

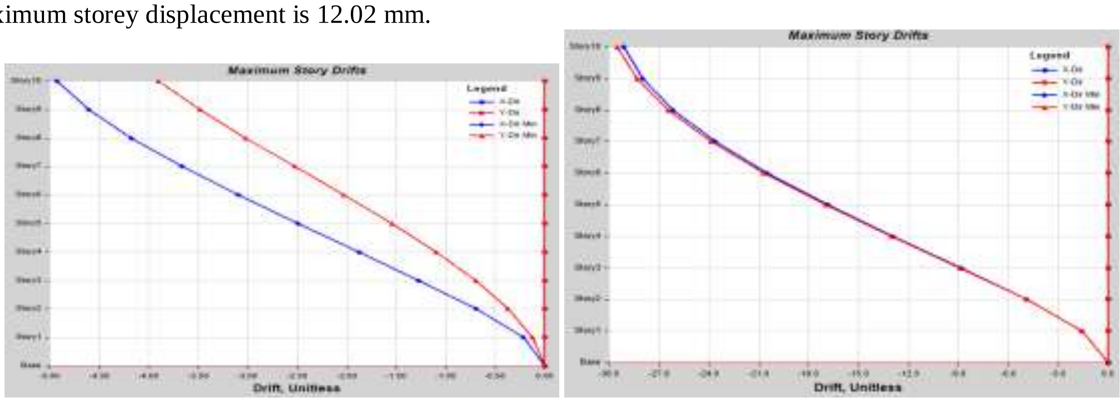

Fig 4. Storey drift without BRB and with BRB

Maximum value of storey drift for building without is 29.5mm and maximum value of storey drift for building with BRB is 4.92 mm.

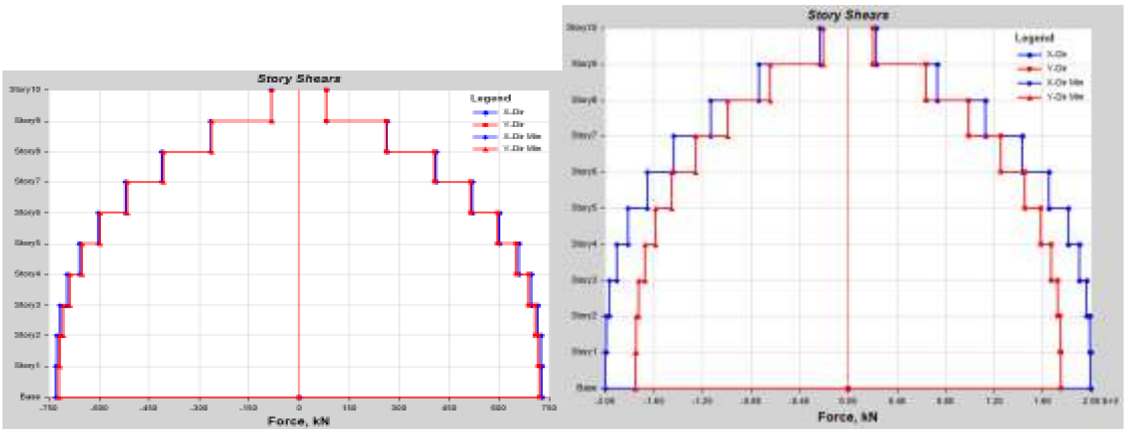

Fig.5. Storey shear without BRB and with BRB

Maximum storey shear for building Without BRB is 726.78 KN and Maximum storey shear for building with BRB 1990 KN. Maximum Displacement and Story Drift get reduced when BRB sections wereprovided.The Base shear increases with increase in weight.

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C. Eigen Value Modal Analysis

Case	Mode	Period sec	Frequency cyc/sec	Circular Frequency	Eigenvalue rad^2/sec^2
Modal	1	1.87	0.535	3.3594	11.2858
Modal	2	1.851	0.54	3.3941	11.5198
Modal	3	1.728	0.579	3.6366	13.2247
Modal	4	0.573	1.746	10.9735	120.4184
Modal	5	0.568	1.761	11.0657	122.4498
Modal	6	0.532	1.88	11.8106	139.4891
Modal	7	0.301	3.326	20.898	436.7257
Modal	8	0.299	3.345	21.0152	441.6394
Modal	9	0.282	3.552	22.3155	497.9811
Modal	10	0.187	5.334	33.5175	1123.4222
Modal	11	0.187	5.357	33.657	1132.7951
Modal	12	0.176	5.671	35.6337	1269.7571
Modal	13	0.128	7.782	48.8978	2390.9923
Modal	14	0.128	7.806	49.0423	2405.1456
Modal	15	0.121	8.248	51.8231	2685.6304
Modal	16	0.094	10.59	66.5365	4427.1054
Modal	17	0.094	10.611	66.6702	4444.9111
Modal	18	0.089	11.202	70.3852	4954.0776
Modal	19	0.073	13.621	85.5823	7324.3329
Modal	20	0.073	13.636	85.6782	7340.7585

Fig.6 .Building With BRBF

Case	Mode	Period sec	Frequency cyc/sec	Circular Frequency	Eigenvalue rad^2/sec^2
Modal	1	0.619	1.615	10.1474	102.9697
Modal	2	0.481	2.081	13.0742	170.934
Modal	3	0.356	2.806	17.6332	310.93
Modal	4	0.166	6.023	37.8438	1432.1457
Modal	5	0.148	6.741	42.3529	1793.7663
Modal	6	0.114	8.805	55.3239	3060.7345
Modal	7	0.081	12.382	77.8003	6052.8827
Modal	8	0.079	12.638	79.4074	6305.541
Modal	9	0.061	16.297	102.3964	10485.0145
Modal	10	0.055	18.153	114.0587	13009.3814
Modal	11	0.053	18.748	117.7985	13876.4974
Modal	12	0.043	23.358	146.7631	21539.4079
Modal	13	0.042	23.534	147.8672	21864.6965
Modal	14	0.04	24.822	155.9625	24324.2945
Modal	15	0.035	28.395	178.4132	31831.2551

Fig 7 .Building Without BRBF

For building without BRBF, the modal participating mass ratio becomes 99% atMode 20 andfor building with BRBF the modal participating mass ratio becomes99% atMode 15. Less the number of modes, less will be the distortion of building.Circular frequency zero means applied load is close to critical buckling load.

TARGET RESPONSE SPECTRUM

According to IS 1893 there are four seismic zones in India.Code provide acceleration time graph for each seismic zone based on previousearthquake datas.

TIME HISTORY DATA FROM STRONG MOTION VIRTUAL DATA CENTRE

Collect datas of past 12earthquake occurredin India from strong motion virtual data centre.

SPECTRAL MATCHING

In spectral matching the response spectrum for different seismic zones provided by the code combines with acceleration time graph of various earthquakes collected from strong motion virtual data centre

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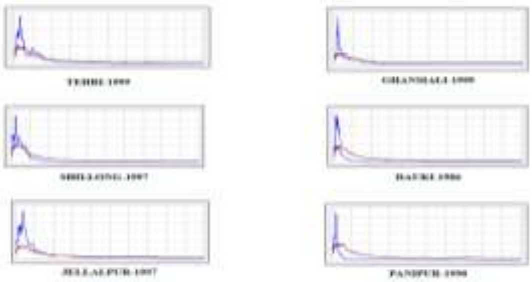

Fig 8. Matched Response Spectrum

RELIABILITY INDEX

As per IS1893, total drift of the building should not exceed 0.004 times the buildingheight.The reliability index β is typically used to measure the reliability of the building ,by using the maximum roof displacement of the building.

MARGIN OF SAFETY

The margin of safety of a building is given by the following equation:

$$M = \Delta - \delta \qquad (1)$$

where,

Δ = allowable drift

δ = maximum roof displacement

maximum roof displacement for building at different heights are Plotted.

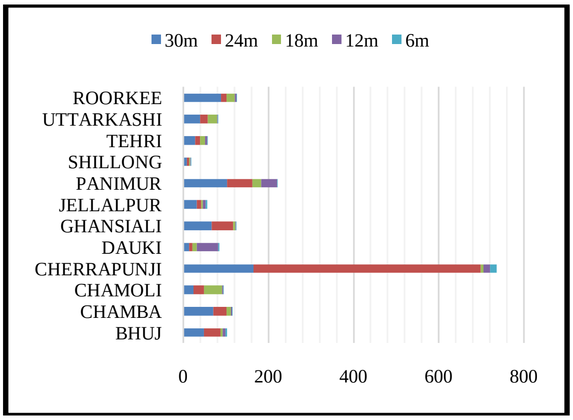

Fig.9. Roof displacement in x direction(mm)

For building with more height ,displacement is less because lateral load get diminished along the height. The Cherrapunji earthquake induce more roof displacement and Shillong earthquake induce least roof displacement.

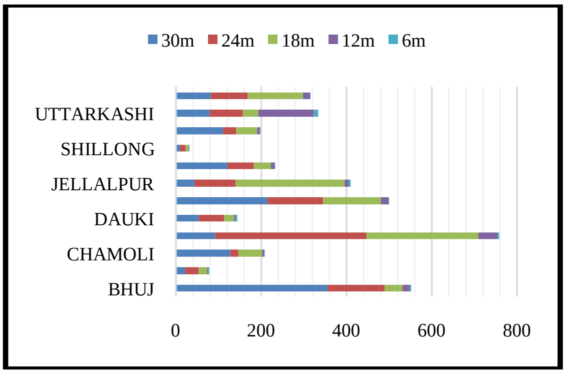

Fig 10.Roof displacement in y-direction (mm)

The Cherrapunji earthquake induce more roof displacement and Shillong earthquake induce least roof displacement.

International Journal of Advances in Engineering and Management (IJAEM)
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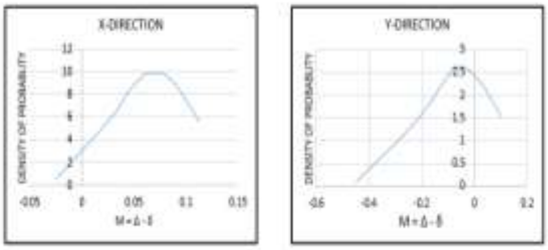

Fig.11.Safety margin curve for 6 m building

Safety margin curve for 6 m height building is plotted.The standard deviation value is .004 and mean value is 0.021 and reliability index value is 5.27 along X direction.For Y direction the standard deviation value is 0.003 mean value is 0.021 and reliability index is 8.05.

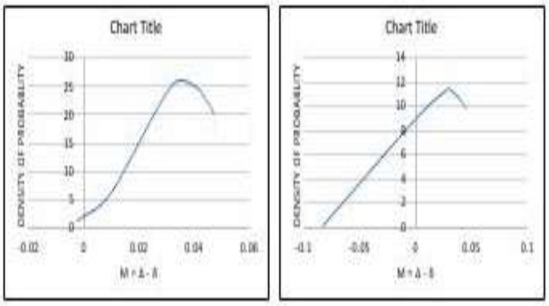

Fig.12. Safety margin curve for 12 m building

Safety margin curve for 12 m height building is plotted.The standard deviation value is 0.015 and mean value is 0.037 and reliability index value is 2.41 along X direction.For Y direction the standard deviation value is .035 mean value is .026 and reliability index is 0.76.

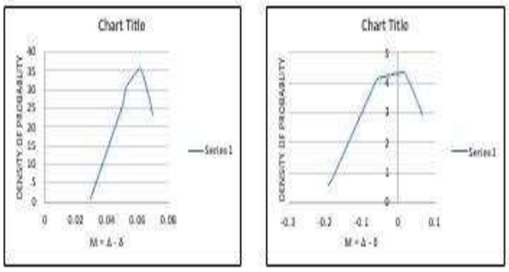

Fig.13.Safety margin curve for 18 m

Safety margin curve for 18 m height building is plotted.The standard deviation value is 0.011 and mean value is 0.059 and reliability index value is 5.34 along X direction.For Y direction the standard deviation value is 0.086 mean value is 0.016 and reliability index is 0.18.

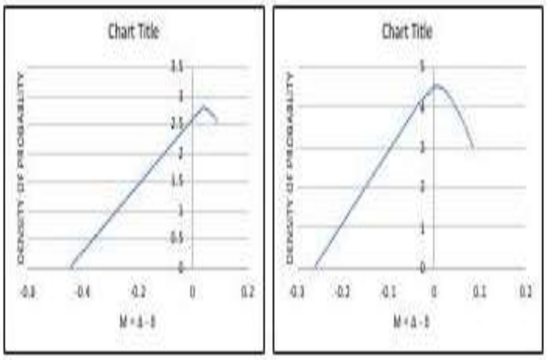

Fig.14.Safety margin curve for 24 m height building

Safety margin curve for 18 m height building is plotted.The standard deviation value is 0.142 and mean value is .029 and reliability index value is 0.20 along X direction.For Y direction the standard deviation value is 0.088 mean value is 0.005 and reliability index is 0.05.

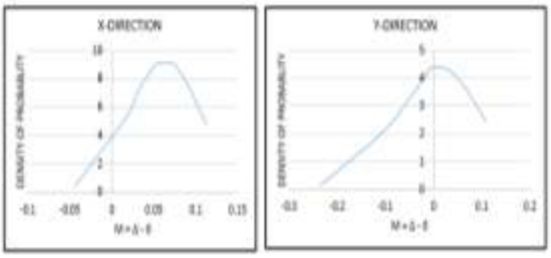

Fig.15.Safety margin curve for 30 m height building

Safety margin curve for 30 m height building is plotted.The standard deviation value is 0.043 and mean value is 0.063 and reliability index value is 1.47 along X direction.For Y direction the standard deviation value is 0.091 mean value is 0.010 and reliability index is 0.11.

TABLE VIII. DEVELOPED RELIABILTY INDEX FOR BRBF

Storey Height(m)	**Minimum Range**	**Maximum Range**
30	0.11	1.70
24	0.05	0.20
18	0.18	5.34
12	0.76	2.41
6	5.27	8.05

V. CONCLUSION

By using Buckling restrained braced frames 40% reduction in storey displacement and storey drift value became negligible when compared with conventional building.The storey shear of structure increases due to increase in weight. So BRBF is better than conventional buckling resisting buildings . FEMA356 recommends 99% mass participation is required to obtain requirednumber of modes in modal analysis.Less the number of modes, less will be the distortion of building. BRBF have less fundamental time period, higher circular frequency and higher eigenvalue, so BRBF is more buckling resistant.Here for 30 m building reliability index ranges from 0.11 to 1.7 and for 24 m building reliability index ranges from 0.50 to 0.2. For 18 m building reliability index varies from 0.18 to 5.34 and for 12 m building reliability index is from 0.76 to 2.41.In the case of 6 m heigh buiding the value varies from 5.27 to 8.05.The reliability index of a structure increases when the probability of failure reduces.

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