RELIABILITY ON ANN FOR ANALYSIS OF HIGH-RISE BUILDING USING ETABS

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ABSTRACT

The analytical technique is relied upon by the majority of designers and researchers in order to determine the reaction of the structure, which will then allow them to build the structure. Many pieces of software have been developed to better understand the structural behaviour of structures exposed to seismic loads. The problem of using this analytical method is that the models fail to clearly reflect critical qualities such as the linear behaviour of a structural system over time or the rate of change with time in the models, which are critical properties. Artificial neural networks (ANNs) are becoming more popular in the prediction of the behaviour of structures, according to recent analytical study. ETABS findings were utilised to train the ANN model, which was used to predict the displacement of the structure in the present analytical tests. The ANN model was trained using the results of the current analytical experiments. Two models of reinforced concrete frame buildings with 20 and 40 storeys are simulated in ETABS, and the results are confirmed using the ANN model. It is composed of three layers: an input layer, a hidden layer, and an output layer, which are all interconnected. Comparisons were made between the performance of the models using statistical metrics such as the correlation coefficient (R2), root-mean-squared error (RMSE), and scatter index (SI).

KEYWORDS: Artificial neutral network, earthquake load, story drift

I.INTRODUCTION

1.1 GENERAL

Undoubtedly the most destructive, unavoidable, and unforeseen natural calamity that has ever happened in human history, earthquakes are unavoidable. Every year, earthquakes claim the lives of thousands of people and wreak millions of dollars in property damage all over the world. They are also responsible for a broad variety of multi-hazard effects. The size of the earthquake, which results in the imposition of an overly unexpected lateral load on the structure, is the most common cause of structural damage in the majority of instances. Over the course of the past century, significant breakthroughs were achieved in the realm of seismic design rules, which are now undergoing revision. As a consequence, the structural system must be sufficiently robust to withstand the weight of the vehicle. In that context, it was described and recommended that seismic zonal (ISO: 1893-2016) based damage assessment of reinforced concrete buildings with various structural configurations is required for accurate damage assessment of structures in earthquake-prone areas, and that the use of seismic zonal damage assessment is recommended.

Fig 1.1 With a magnitude of 6.4 on the Richter scale, the 2021 Assam earthquake hit 11 kilometres (7 miles) distant from Dhekiajuli, Assam, India on April 28, 2021 at 07:51 local time (IST). The earthquake occurred at a depth of 34 kilometres (21 miles), 140 kilometres (86 kilometres) north of the state capital of Guwahati. It led in the deaths of two people and the injury of at least twelve more.

1.2 EARTHQUAKE

Earthquake definition: An earthquake is a surface vibration of the earth generated by the elasticity or isostatic adjustment of the rocks under the earth's surface. An earthquake may occur anywhere on the planet. Both human and natural activity have the potential to cause it to occur.

The 'focus' of an earthquake is the location at which seismic (earthquake) waves begin, and it occurs under the level of the earth's surface. The 'epicentre', on the other hand, is the location on the surface of the earth that is perpendicular to the focus and where the initial tremors of an earthquake are felt for the first time after an earthquake. Elastic energy is the term used to describe the energy that is wasted away from the focus. Seismic waves are the waves that are formed during an earthquake and are distinguished from other types of waves.

1.2.1 Three different types of waves:

Longitudinal waves, commonly known as P-Waves, are longitudinal waves that are equivalent to sound waves in their characteristics.

Secondary or Transverse Waves (also known as S-Waves) are transversal waves that are akin to light waves in their characteristics.

Long-period waves, also known as surface waves or L-waves, are generated when the surface wave, or 'P' wave, strikes the surface.

In the field of earthquake research, the term "Seismograph" describes an equipment that is sensitive to seismic waves and may be used to determine the severity of an earthquake. It is possible to estimate the strength of earthquakes using a variety of scales, including the Rossi-Forel Scale, the Mercalli Scale, and the Richter Scale, among others.

1.2.2 List of Earthquake (Seismic) Zones in India

Based on the nation's seismic history, the Bureau of Indian Standards divided the country into four seismic zones, which are designated as Zone-II, Zone-III, Zone-IV, and Zone-V, respectively. Zone-V is the most seismically active area among the four zones, whilst Zone-II is the least seismically active.

Seismic Zone	Intensity on M.M Scale
Zone-II (Low-Intensity Zone)	6 (or less)
Zone-III (Moderate Intensity Zone)	7
Zone-IV (Severe Intensity Zone)	8
Zone-V (Very Severe Intensity Zone)	9 (and above)

Table 1.1: Types of Zones and with their Intensity

1.2.3 Regions that fall under the Earthquake (seismic) Zones in India

A large part like norther nation, etc as terms of section anyway jammu, lhasa, andhra pradesh (including kund sure cuttack throughout gujarat), northwest bjp (including perform these functions like idukki throughout gujarat), or the andaman islands are also included in zone-v.

In zone-iv, that whole remaining pieces after all j&k, lhasa, or arunachal pradesh, this same municipal corporation sure chennai, kashmir, northern half anyway andhra pradesh, maharashtra, but rather bengal, components sure surat, but instead tiny portions anyway karnataka located on the western shores but instead jaipur are also included. Zone-iv this not only will include sections of indian says yeah pradesh, punjab, but instead meghalaya.

Kerala, ajmer, a maldives island nations, it and remaining portion like andhra pradesh, maharashtra, but rather allahabad, etc as segments after all bihar, jodhpur, andhra pradesh, punjab, bihar, district, karnataka, bihar, pradesh, madurai, as well as kerala, were included in the areas – iv of such indian ocean.

Zone-II encompasses the remaining regions of the nation.

The seismic zoning map of India aids in the identification of the most dangerous or earthquake-prone places in India, including the lowest, moderate, and highest risk sectors. Aside from that, such maps are utilised or examined before to the construction of high-rise buildings in order to determine the amount of seismic activity in a certain location. Over time, this contributes to the saving of lives.

Earthquakes have occurred in the Indian subcontinent in the past. The Indian plate is moving towards Asia at a pace of around 47 millimetres per year, which is responsible for the earthquakes' great intensity and frequency. The return period of the seismic area is shown in the second diagram.

Seismic Region	No. of Earthquakes of Magnitude				Return Period
	5.0-5.9	6.0-6.9	7.0-7.9	8.0+	
Kashmir & Western Himalayas	25	7	2	1	2.5-3 yrs.
Central Himalayas	68	28	4	1	1 yrs.
North East India	200	128	15	4	<4 months
Indo-Gangetic Basin and Rajasthan	14	6	-	-	5 yrs
Cambay and Rann of Kutch	4	4	1	1	20 yrs.
Peninsualr India	31	10	-	-	2.5-3 yrs.
Andaman & Nicobar	80	68	1	1	<8 months

Fig 1.2: return period of earthquake (source: ndma.gov.in)

1.3 ETABS

1.3.1 Finite Element Method:

In the present state of the art, the FEM approach is the most accurate method known for calculating the storey drift of multi-story structures.

There are several FEM software packages that have been created and are readily accessible on the market for Civil Engineering applications. As illustrated in figure 1.3, the acronym ETABS is short for "Extended Three-dimensional Analysis of Building System." ETABS is an abbreviation for "Extended Three-dimensional Analysis of Building System." In addition, CSi America markets ETABS, a well-known product of CSi that is used for structural analysis, especially building structure, and is offered by CSi America (Computers and Structures, Inc). A premier programme for building structure analysis, ETABS is the most popular structural engineering analysis and design software used across the globe, particularly in structural and seismic engineering.

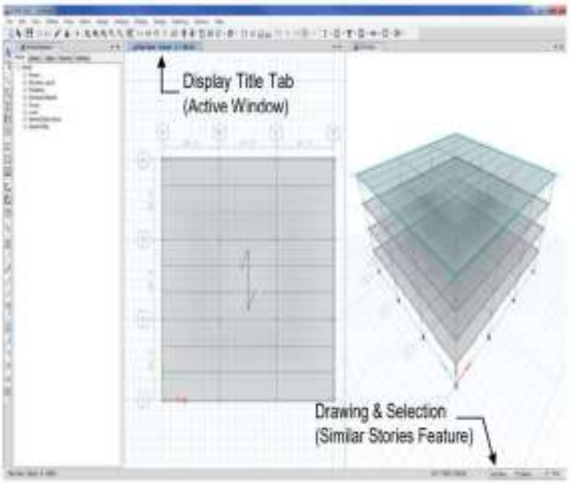


Fig 1.3: Graphical User Interface (GUI) of ETABS

In addition to an easy and powerful graphical interface, ETABS provides unparalleled modelling, analytical, design, and detailing methods, all of which are connected via the use of a shared database. Although it is fast and simple to use for small buildings, ETABS is capable of handling the biggest and most complicated building models, including a broad variety of linear behaviours required for performance-based design, making it the tool of choice for structural engineers in the construction sector.

Precision modelling and performing analysis for building structures in FEM software, on the other hand, takes a significant amount of time, particularly for linear and dynamic analysis methods. Despite the fact that the Finite Element Method for structural analysis is correct, it is a slow method.

LITERATURE REVIEW

In one of his recent projects, Pritam Hait at.al Arjun Sil worked on "Seismic damage assessment and prediction using artificial neural network of RC building taking anomalies into consideration." They recommended that global DI (GDI) be estimated for both regular and irregular structures, respectively. They discovered that the bottom level suffers the most amount of damage, whilst the roof suffers the least amount of damage. And they came to the conclusion that the ground floor suffers the most damage, which results in the greatest contribution to GDI. This suggests that the bottom floor of a structure is the most fragile, and that little damage noticed on the roof is mostly due to the influence of drift. Additionally, U and L-shaped buildings are the most vulnerable, while rectangular-shaped buildings are the least vulnerable.

The project "The Application of Artificial Neural Networks in Predicting Structural Response of Multi-story Buildings in The Region of Sumatra Island," which is titled "The Application of Artificial Neural Networks in Predicting Structural Response of Multi-storey Buildings in The Region of Sumatra Island," has been completed by Reni Suryanita at.al Hendra Jingga. [2] Reni Suryanita at.al Hendra Jingga

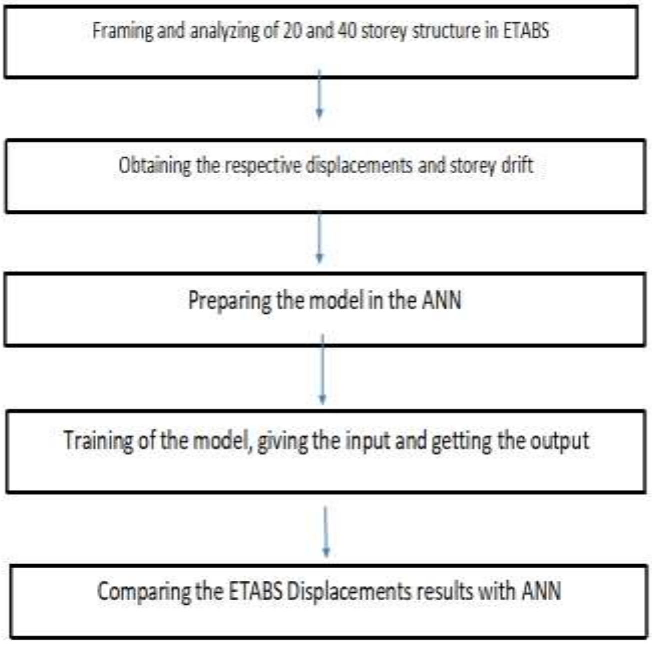
Whenever an earthquake occurs in the area of Sumatera Island, scientists employ artificial neural networks to predict the structural response (storey drift) of multi-story reinforced concrete structures that are under strain.

The input parameters for the ANN include earthquake load data collected from 11 locations on Sumatra Island, soil condition, and building geometry, among other things. For the ANN, the output parameter is called storey drift, and it is determined by the data that is fed into it. As a result of their research, they arrived to the conclusion that ANN is a very promising approach for generating early predictions on structural response such as storey drift at multi-story structures in the area of Sumatra Island, which can subsequently be utilised to help in future FEM analysis

III.METHODOLOGY

3.1Workflow

The sequence of work is shown in the flow chart.



The planned buildings are subjected to an earthquake-related study that has been carried out in conjunction with the design. The RC frame structures of 20 (model I) and 40(model II) stories were built at the ETABS. The structure is subjected to a variety of load situations, including dead, live, superimposed, and seismic load instances. The equivalent static approach as well as the response spectrum method are both used in the current investigation.

Beam size	230mmX380mm
Column size:	300mmX600mm
storey height	3m
Thickness of slabs	150mm
Clear cover	Beam= 25mm and column= 40mm

Table 3.1: Specifications of structural members

Grade of concrete (f_{ck})	30 MPa
Yield stress of main rebar fy	550 MPa
Yield stress of ties/stirrups (fyh)	550 MPa
(Modulus of elasticity of steel, (Es)	200,000 MPa
Modulus of elasticity of concrete, (Ec)	$5000\sqrt{f_{ck}}$ MPa
Poisson's ration of steel	0.3
Poisson's ration of concrete	0.15

Table 3.2: Material properties of steel and concrete

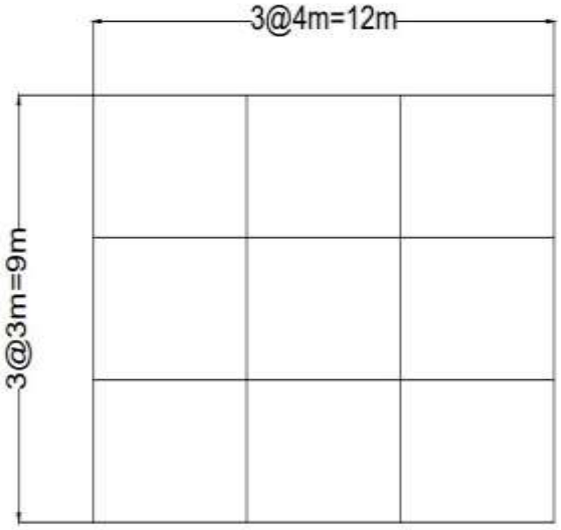


Fig 3.1: Model I 20 Storey Building

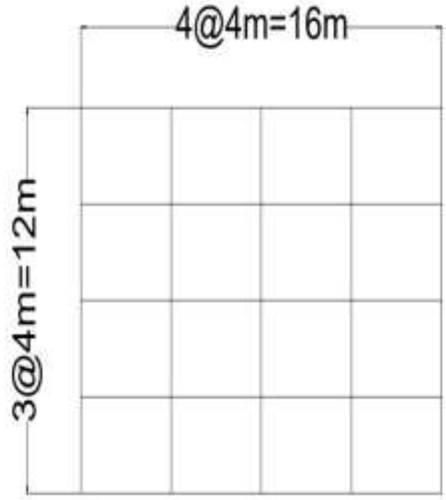


Fig 3.2: Model II 40 Storey Building

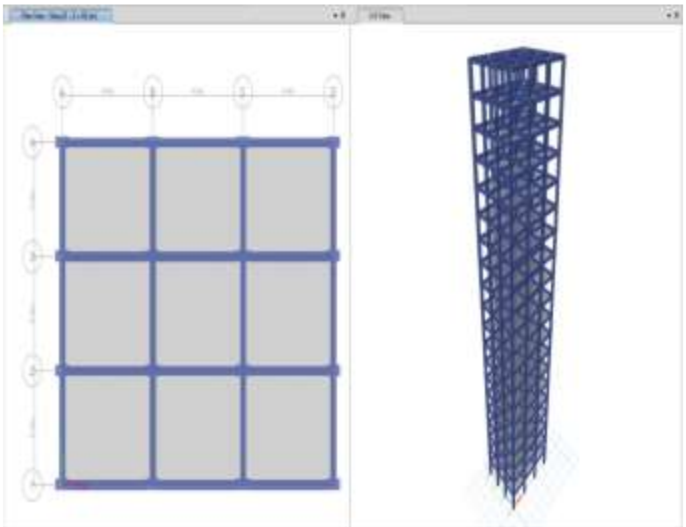


Fig 3.3: Plan And 3d View of Structure Of 20 Storey In ETABS

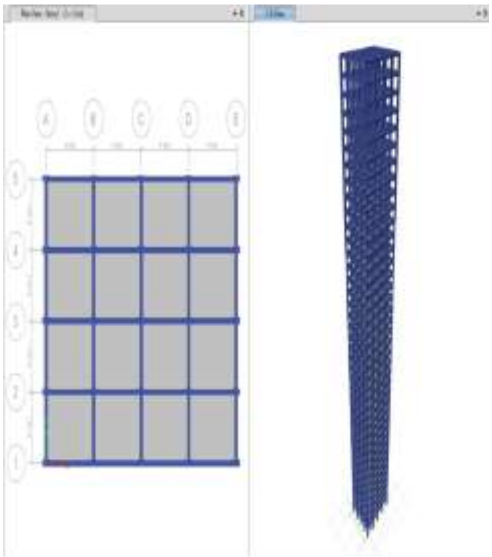


Fig 3.4: Plan And 3d View of Structure of 40 Storey in ETABS

3.2 DEFINING LOAD PATTERN:

LOAD PATTERN	DISCRIPTION
DEAD	self-weight multiplier is 1
Super imposed dead load	Is per 875 part 1 (wall load floor finishes)
Live load	Is per 875-part 2
Earthquake in x direction	1893(Part1):2016
Earthquake in y direction	1893(Part1):2016

Table 3.3: Load Pattern

3.4 DEFINING load cases:

Fig 3.5: Load Cases Define In ETABS.

3.5 equivalent static method

To put it another way, the equivalent lateral force approach is designed to distribute a portion of the seismic force (base shear) to each level that is capable of transmitting lateral loads.

Because of this approach, static forces are created and applied to stiff (or semi-rigid) diaphragms or vertical parts (columns, wall) that are capable of carrying predicted forces, as shown in the figure.

IS:1893 seismic loads are based on Sections 6.4.2, 7.6.1, and 7.6.2 of IS:1893 code, and the corresponding static analysis will be done as per the succeeding stages. According to IS-1893 (part-I) 2016, the equivalent static analysis will be performed as per the subsequent stages. Calculating a period is done in the same way as was mentioned in the preceding section,

Table 3.5: Seismic Parameters

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Seismic zone	V
Zone factor (Z)	0.36
Site type Importance factor (I)	II for medium soil as per table 4 of IS1893(part1):2016 1.2 as per Cl.7.2.3 and table 8 of IS 1893(Part1):2016
System	SMRF (special moment resisting frame
Response Reduction factor(R)	5 as per Cl.7.2.6 and table 9 of of IS 1893(part1):2016
Damping ratio	5% as per cl.7.2.4 of IS 1893(part1):2016
Reduction of imposed load (live load)	0.5 as per table 10 IS 1893(part1):2016

Table 3.5: Seismic Parameters

3.7 Response spectrum method

The linear dynamic analysis approach is also known as the response spectrum method. According to Section 6.4.2 of the IS:1893 code, the response spectrum function of the IS:1893 code is based on Figure 2. According to Section 6.4.2, the digitalization of these response spectra is performed. The characteristics that must be considered include a seismic zone factor Z, the kind of soil, and the damping ratio of the structural elements of the building. These settings can be found in the appropriate parts of the IS:1893 code and may be chosen.

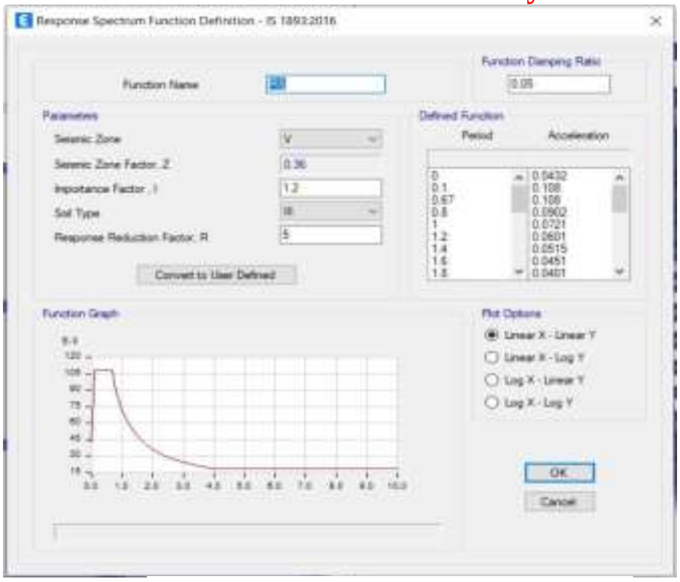


Fig 3.6: Response Secretum Functions In The ETABS

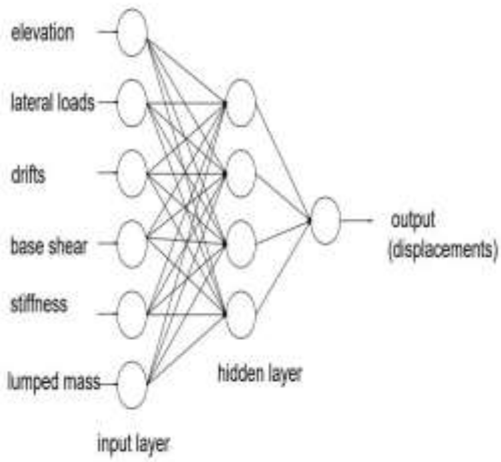
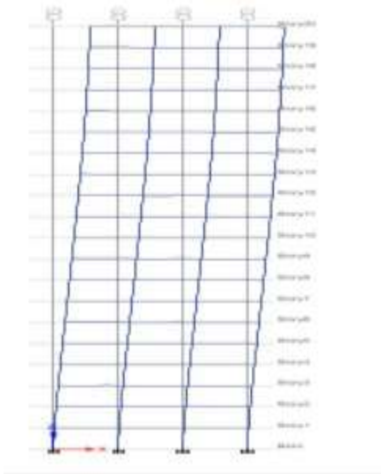


Fig 3.8: Neural network architecture that was used in modelling displacements of earthquake

IV.EXPERMANTAL ANALYSIS

4.1 Deformed shape of models



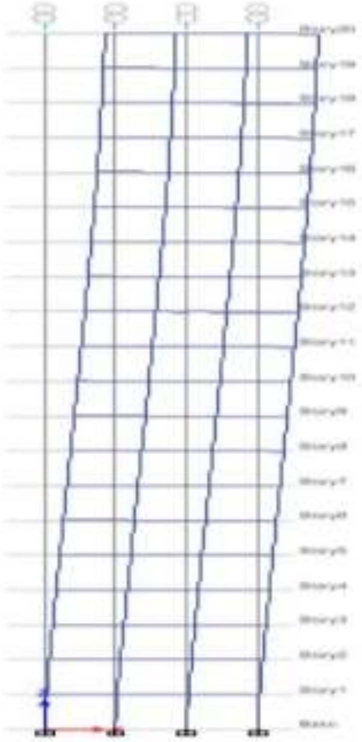


Fig 4.1: Model I Deformed Shape of Earthquake Loads For 20 Storey

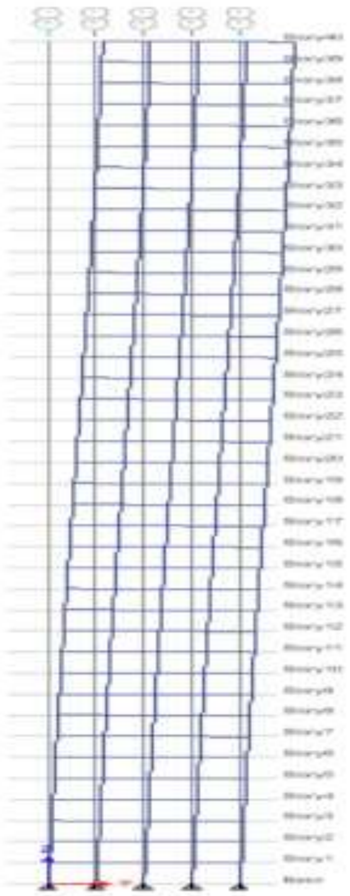


Fig 4.2: Model II Deformed Shape of Earthquake Loads For 40 Storey

4.2 RESPONSE PLOTS:

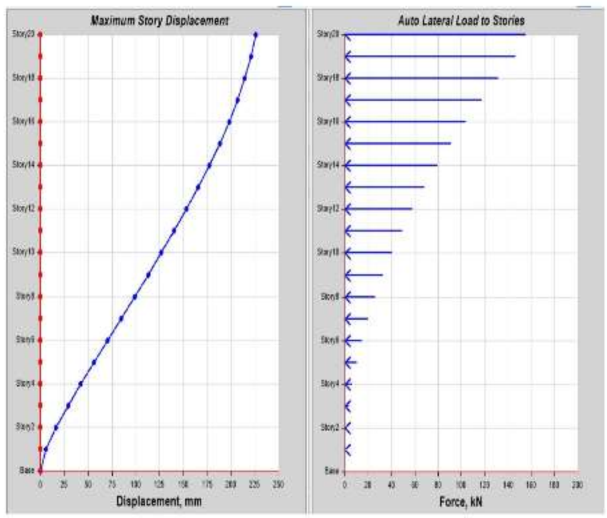


Fig 4.3: Profile of Storey Displacements and Storey Lateral Load

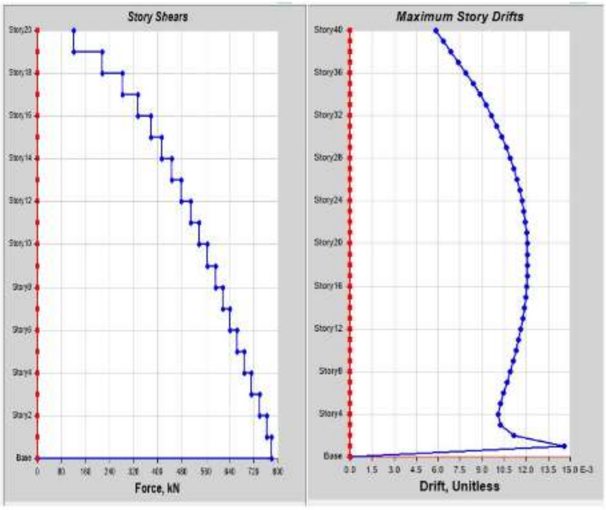


Fig 4.4: Profile of Storey Shear and Storey Drifts.

4.3 DATA FOR TRAINING

Table 4.1: Results of 20 Story Equivalent Static Method for X Direction

Elevation	Lateral loads	Drifts	base shear	Stiffness	Mass	Displacements
60	155.715	0.001681	-155.715	30869.338	236456.77	225.777
57	146.7019	0.002088	-302.4169	48276.481	246836.74	220.733
54	131.666	0.002528	-434.0829	57233.365	246836.74	214.469
51	117.4428	0.002943	-551.5257	62461.061	246836.74	206.884
48	104.0324	0.003316	-655.5581	65899.041	246836.74	198.054
45	91.4347	0.003641	-746.9928	68378.259	246836.74	188.106
42	79.6498	0.00392	-826.6426	70295.816	246836.74	177.182
39	68.6776	0.004153	-895.3202	71867.184	246836.74	165.422
36	58.5182	0.004342	-953.8384	73222.373	246836.74	152.965
33	49.1716	0.004491	-1003.01	74447.455	246836.74	139.938
30	40.6376	0.004601	-1043.6476	75604.514	246836.74	126.465
27	32.9165	0.004676	-1076.5641	76742.931	246836.74	112.661
24	26.0081	0.004717	-1102.5722	77908.196	246836.74	98.633
21	19.9124	0.004727	-1122.4846	79154.401	246836.74	84.481
18	14.6296	0.004704	-1137.1142	80573.726	246836.74	70.3
15	10.1594	0.004642	-1147.2736	82382.52	246836.74	56.187
12	6.502	0.004514	-1153.7756	85196.761	246836.74	42.261
9	3.6574	0.004238	-1157.433	91036.908	246836.74	28.718
6	1.6255	0.003566	-1159.0585	108333.33	246836.74	16.005
3	0.4064	0.001769	-1159.4649	218538.221	246836.74	5.306

Table 4.2: Results Of 20 Story Equivalent Static Method for Y Direction

Elevation	Lateral loads	Drifts	Base shear	Stiffness	Mass	Displacements
60	155.715	0.002357	-155.715	22023.543	236456.77	284.328
57	146.7019	0.002908	-302.4169	34667.274	246836.74	277.258
54	131.666	0.003436	-434.0829	42105.333	246836.74	268.535
51	117.4428	0.003906	-551.5257	47068.379	246836.74	258.225
48	104.0324	0.004315	-655.5581	50636.805	246836.74	246.508
45	91.4347	0.004666	-746.9928	53359.202	246836.74	233.561
42	79.6498	0.004961	-826.6426	55543.151	246836.74	219.562
39	68.6776	0.005201	-895.3202	57378.978	246836.74	204.679
36	58.5182	0.00539	-953.8384	58993.026	246836.74	189.076
33	49.1716	0.005529	-1003.01	60475.099	246836.74	172.907
30	40.6376	0.005621	-1043.647	61893.506	246836.74	156.321
27	32.9165	0.005669	-1076.564	63303.998	246836.74	139.459
24	26.0081	0.005676	-1102.572	64755.488	246836.74	122.453
21	19.9124	0.005644	-1122.484	66294.079	246836.74	105.426
18	14.6296	0.005577	-1137.114	67966.341	246836.74	88.495
15	10.1594	0.005477	-1147.273	69824.643	246836.74	71.764
12	6.502	0.005345	-1153.776	71948.742	246836.74	55.333
9	3.6574	0.005168	-1157.433	74650.718	246836.74	39.297
6	1.6255	0.004815	-1159.058	80239.047	246836.74	23.793
3	0.4064	0.003116	-1159.464	124040.93	246836.74	9.347

Table 4.3: Results of 20 Story Response Spectrum Method for X Direction.

4.4 Modelling in MATLAB in ANN

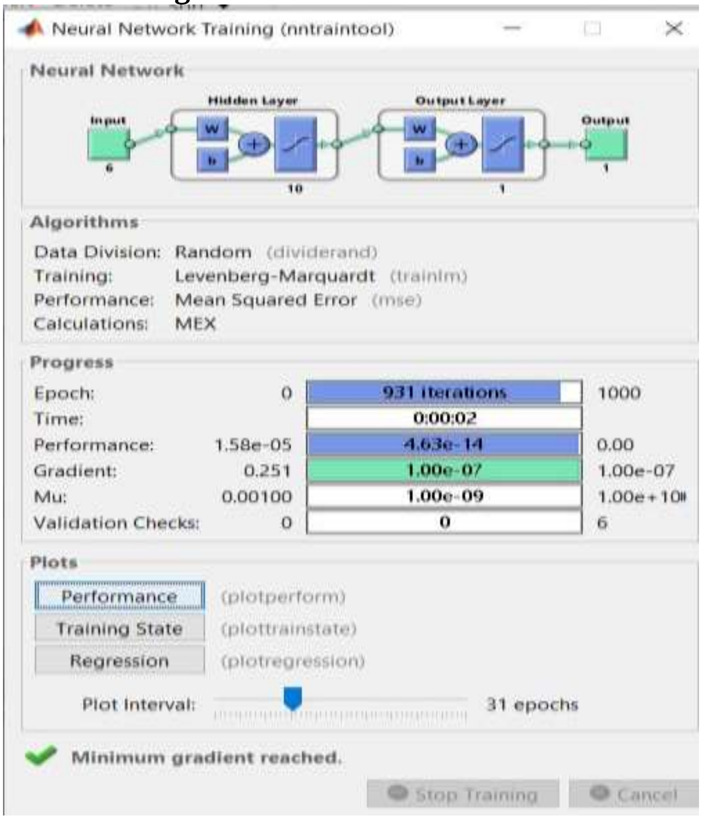


Fig 4.5: Neutral Network Training in nntool

V. RESULTS AND DISCUSSION

In the present research, the input variables are defined as elevation, lateral loads, drifts, base shear, stiffness, and mass, while the output variable is defined as displacements. The calculation of the corelation coefficient (R2) is used as a performance benchmark for comparing the outcomes of different experiments.

$$R^2 = \frac{\left[\sum_{i=1}^{n}(y_i - \bar{y})(\hat{y}_i - \bar{\hat{y}})\right]^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2 \sum_{i=1}^{n}(\hat{y}_i - \bar{\hat{y}})^2}$$

Where ‘‘yi ” is really the found to predict factor that directly affects anyway ‘‘ith” sample was placed esta is just the averaging nearly projected factor that directly affects, ‘‘yi” has been the real result in an incorrect anyway ‘‘i”th sample was placed, but also l o has been the summed precise displacements Furthermore, or mean square gaffe (rmse) were indeed decided for all of the other designs, and or the equation of one is seen in the along interaction increases.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2}$$

where Oi and Pi are respectively the calculated and the predicted values of displacements in a particular MODEL, N is the total number of validation samples.

5.1 Predicted And Training Results For Model I

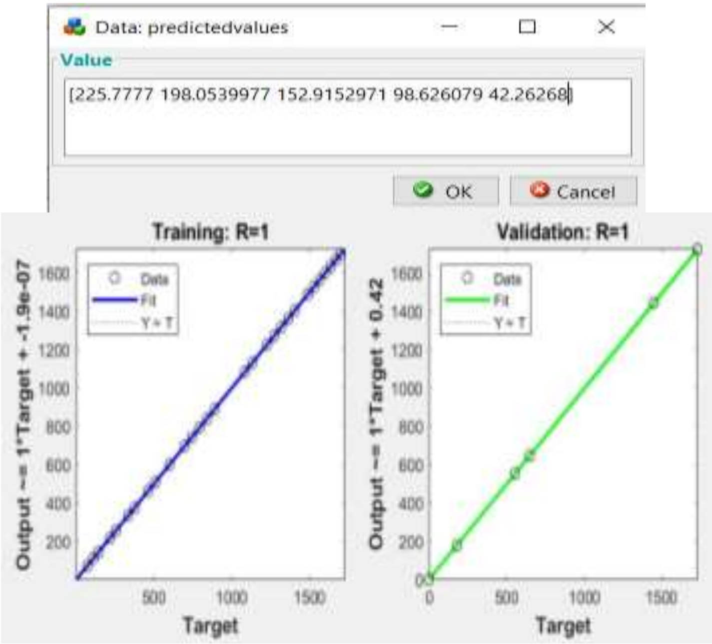


Fig 5.1: Results of 20 Story Equivalent Static Method X Direction

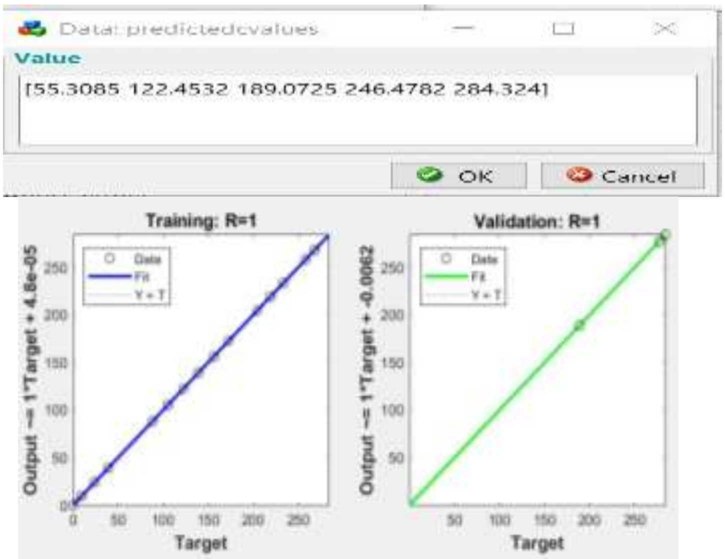


Fig 5.2: Results of 20 Story Equivalent Static Method Y Direction

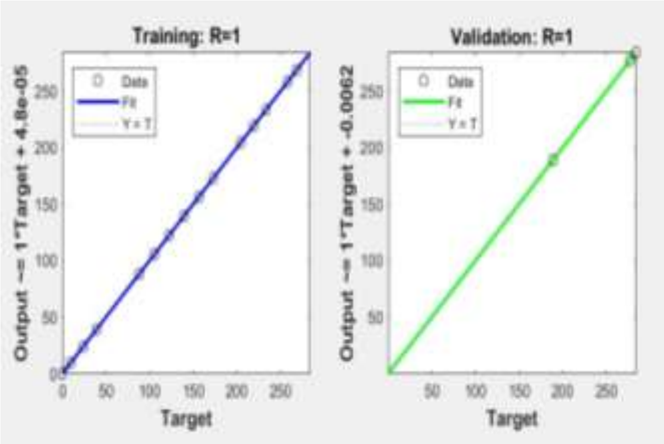


Fig 5.3: Results of 20 Story Response Spectrum Method X Direction

Fig 1

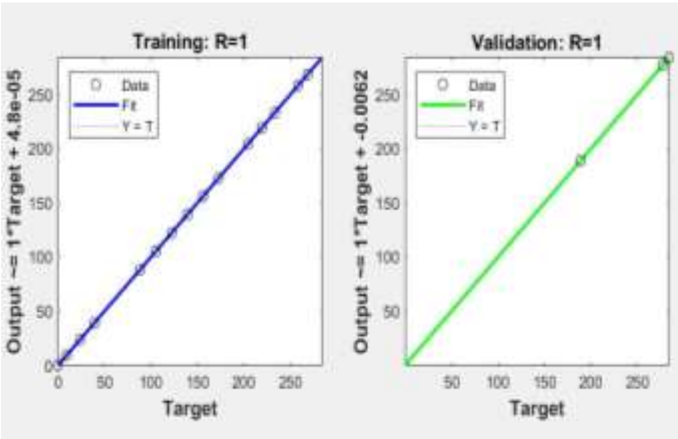


Fig 5.4: Results of 20 Story Response Spectrum Method X Direction

5.2 Predicted And Training Results For Model II

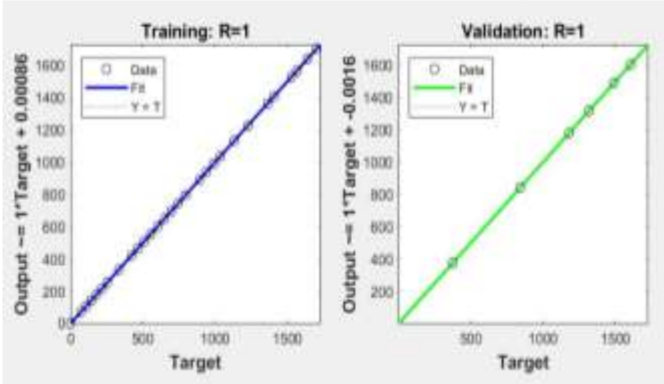
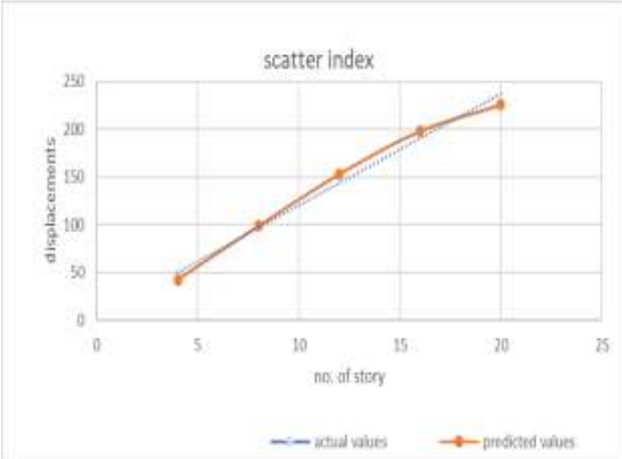


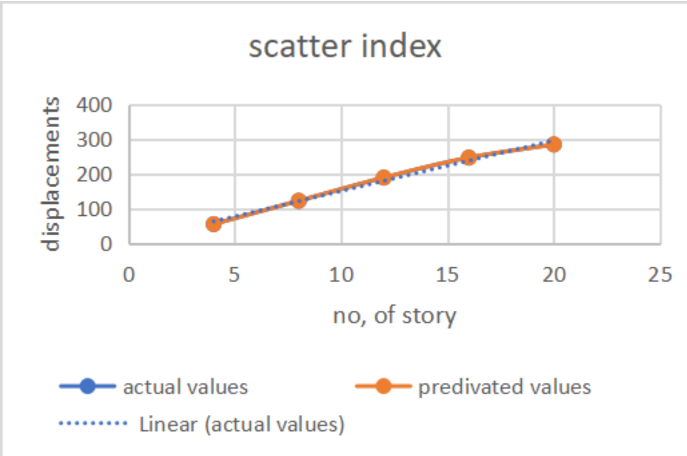
Fig 5.5: Results of 40 Story Equivalent Static Method X Direction

5.3 SCATTER INDEX GRAPH

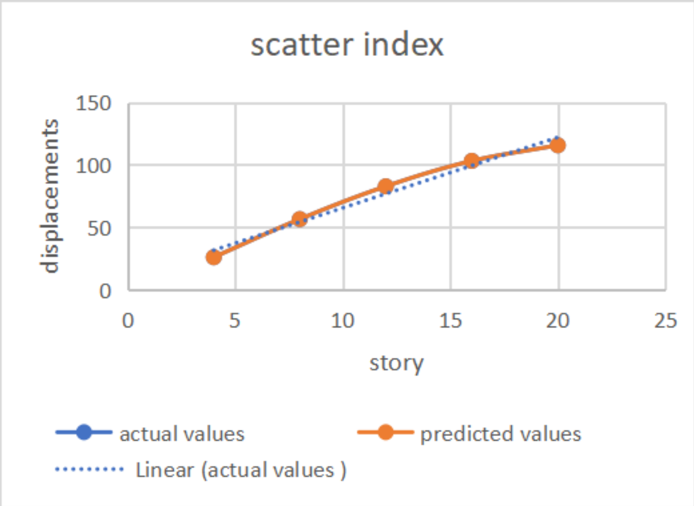
5.3.1 FOR MODEL I



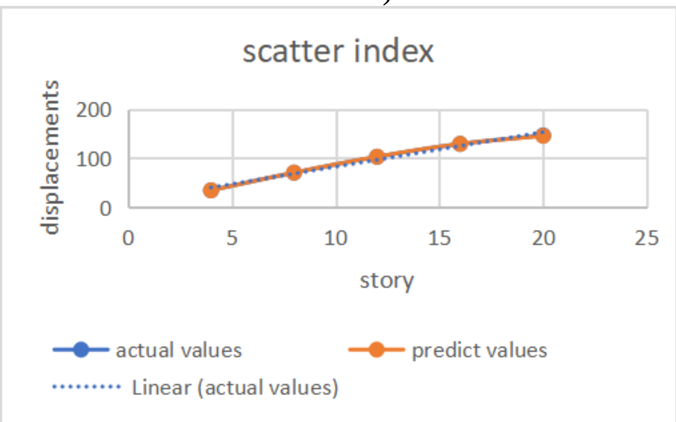
GRAPH 5.1: FOR X DIRECTION (static method)



GRAPH 5.2: FOR Y DIRECTION (static method)



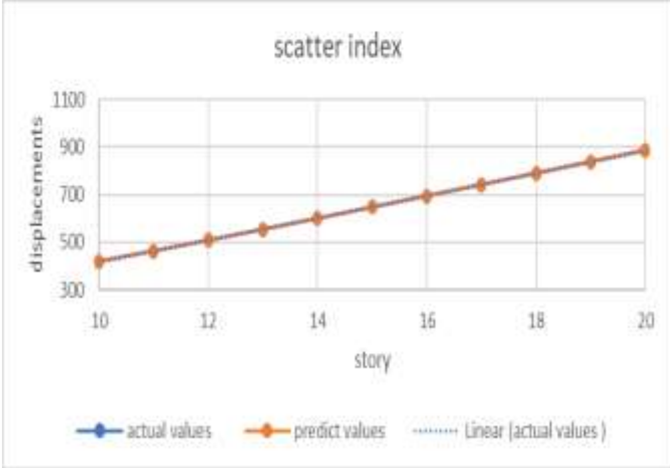
GRAPH 5.3: FOR X DIRECTION (response method)



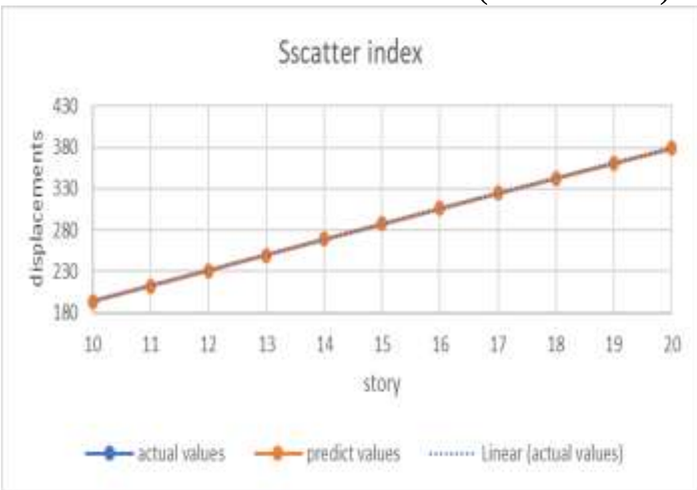
GRAPH 5.4: FOR Y DIRECTION (response method)

5.3.2 FOR MODEL II

GRAPH 5.4: FOR X DIRECTION (static method)



GRAPH 5.6: FOR Y DIRECTION (static method)



GRAPH 5.7: FOR X DIRECTION (response method)

GRAPH 5.8: FOR Y DIRECTION (response method)

ANN model	No, of iteration	corelation coefficient (R^2)	RMSE
For model 1			
Static in x	931	0.999999957	0.022454075

direction			
Static in y direction	625	0.999999989	0.01741597
Response in x direction	820	1	0.010458298
Response in y direction	**1000**	**0.999973641**	**0.42049287**
For model 2			
Static in x direction	881	1	0.001321363
Static in y direction	1000	1	0.000187617
Response in x direction	844	1	0.001809887
Response in x direction	1000	1	0.014484239

VI.CONCLUSIONS

- In the present study when compared with different model the maximum RMSE values occurred for model I in the response spectrum method of y direction is given by **0.42049287**
- Min Correlation Coefficient (R) observed to be in model I of response spectrum method of y direction that is **0.999973641**
- So, the conclusion is ANN model gives best predicted of ETABS, so ETABS can be used for ANN model.
- Hence, both the predicted values and theoretical values are matching and we can reliable on ANN for doing tedious ETABS problems.

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