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**Research Paper**

# BEHAVIOUR OF TORSIONAL REINFORCEMENT IN R.C SLAB WITH TWO ENDS DISCONTINUOUS AND OTHER ENDS CONTINUOUS

V. Selvan[a*], Dr. R. Sundararajan[b]

**Address for Correspondence**

[a*]Department of Civil Engineering, Sri Ramakrishna Engineering College, Coimbatore-22, Tamilnadu, India.

[b]Government College of Technology, Coimbatore, Tamilnadu, India.

**ABSTRACT**

The present investigation is intended to study the influence of torsion reinforcement in reinforced concrete slab along with diverse load and Torsion reinforcement in order to retrieve corner uplift for all corners and central deflection. To survey the influence of torsion reinforcement in reinforced concrete slab with end condition, two ends discontinuous and other ends continuous under uniformly distributed load by varying the percentage of torsional reinforcement from 0%, 20%, 25%, 30%, 35% and 75% of the main reinforcement required for short span bending moment, 6 slabs were casted and tested with the size of 1500mm x 1500 mm x 60 mm. By varying the torsion reinforcement, the corresponding corner uplift and central deflection were noted for each incremental load up to ultimate load and the results are plotted. In order to discern test performance of unconsidered values between those considered input load and torsion reinforcement artificial intelligence techniques are utilized.

**KEYWORDS**: Torsion reinforcement, Artificial Intelligence, Two ends discontinuous.

## 1. INTRODUCTION

Torsion is a basic structural action to be considered in the design. But due to its complex nature and occurrence with other basic forces, it is ignored by the designers. Increased service loads, aging of structures, Manmade havocs, natural calamities and updates in the codes have necessitated many of the structures to be retrofitted. Reinforced concrete slabs are used in floors, roofs and walls of buildings and as the decks of bridges. Reinforcement detailing of a slab is done based on its support conditions. Slab may be supported on walls or beams or columns. Slab supported directly by columns are called flat slab.

Slab supported on all four sides and bending take place in two directions are said to be Two Way Slab. The slabs having ratio of longer length to its shorter length ($L_y/L_x$) greater than 2 is called one way slab otherwise as two way slab. In one way slab main reinforcement is parallel to shorter direction and the reinforcement parallel to longer direction is called distribution steel. In two way slab main reinforcement is provided along both directions. In two way slab the corners may be held down by restraints or may be allowed to lift up. Additional torsion reinforcement is required at corners when it is restrained against uplifting.

**Torsion reinforcement** shall be provided at any corner where the slab is simply supported on both edges meeting at that corner and is prevented from lifting unless the consequences of cracking are negligible. It shall consist of top and bottom reinforcement, each with layer of bars placed parallel to the sides of the slab and extending from the edges a minimum distance of one fifth of the shorter span. The area of reinforcement per unit width in each of these four layers shall be three quarters of the area required for the maximum mid-span moment per unit width in the slab. Torsion reinforcement equal to half that described above shall be provided at a corner contained by edges over only one of which the slab is continuous.

Recently, artificial neural network (ANN) models have been widely applied to various relevant civil engineering areas such as geotechnical engineering, water resources and coastal engineering. In this paper, an artificial neural network is developed for the prediction of the corner uplift and central deflection of reinforced concrete slabs by varying the percentage of reinforcement and the results obtained are compared with those determined according to the ACI code for reinforced concrete slabs experimentally for slab with end condition, two ends discontinuous and other ends continuous under uniformly distributed load by varying the percentage of torsional reinforcement from 0%, 20%, 25%, 30%, 35% and 75% of the main reinforcement required for short span bending moment diverse end conditions.

## 2. EXPERIMENTAL

The size of the square slab specimens was 1500 x 1500 x 60 mm (thickness). The reinforcement was provided in the form of 6 mm diameter Grade I steel 125 mm centre to centre spacing. The clear cover to the reinforcement is 15 mm. The reinforcement details are shown in Fig. 4.1. The descriptions of the square slabs are shown below. Minimum Reinforcements are provided in the form of 6 mm diameter Grade I steel having yield strength of 252 $N/mm^2$ is used as a main reinforcement and both 6 mm diameter Grade I steel and weld mesh made up of mild steel of yield strength of $250N/mm^2$ are used as torsion reinforcement.

## 3. RESULTS AND DISCUSSION

To survey the influence of torsion reinforcement in reinforced concrete slab with end condition, two ends discontinuous and other ends continuous under uniformly distributed load by varying the percentage of torsional reinforcement from 0%, 20%, 25%, 30%, 35% and 75% of the main reinforcement required for short span bending moment, 6 slabs were casted and tested with the size of 1500mm x 1500 mm x 60 mm. By varying the torsion reinforcement the corner uplift and central deflection were measured.

The corresponding corner uplift and central deflection were noted for each incremental load up to ultimate load and the results are plotted.

The figure shows the cracks observed at the bottom surface of the specimen. The behaviour of torsional reinforcement from 20% to 35% was compared with 0% and 75% and the graphs were plotted. The average cube compression strength attained from the companion specimens tested was 24.98 $N/mm^2$.

**Fig 3.1 Reinforcement details**

**Fig 3.2 Crack Pattern in the Bottom Surface**

### 3.1 Corner uplift and central deflection of Slabs with end condition of two ends discontinuous and other ends continuous

The present investigation is intended to study the influence of torsion reinforcement in reinforced concrete slab with end condition two ends discontinuous and other ends continuous under uniformly distributed load. By varying the percentage of torsional reinforcement as 0%, 20%, 25%, 30%, 35% and 75%, and increasing the load from 0 to 7.33 KN/m$^2$, central deflections and all corner uplift for corners A, B and C to be evaluated. The results obtained from the test specimens were plotted in the graph. Uplift of corner starts at a load of 0.8 KN/m$^2$. Maximum uplift was obtained at an ultimate load.

#### 3.1.1 Load Vs Corner Uplift at Corner A

In figure 3.1.1, it is shown that the load Vs corner uplift of a corner A for each torsional reinforcement percentage 0%, 20%, 25%, 30%, 35%, and 75% varies respectively. The Uplift of corner starts at a load of 0.13KN/m$^2$ and the maximum uplift are obtained at ultimate loads.

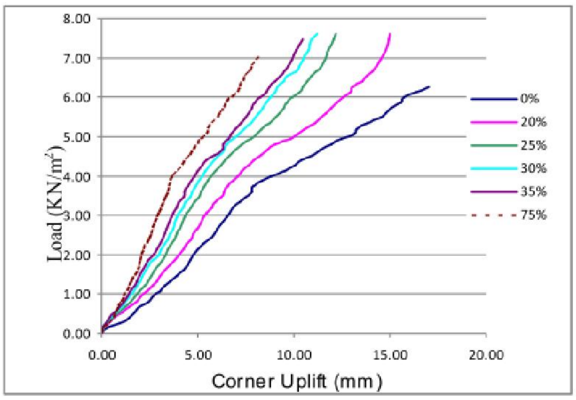


**Figure 3.1.1 Load Vs Corner Uplift at Corner A**

When the load increases the corner uplift also increases. As compared to the solid slab, with increase in the percentages of torsional reinforcement, there is a reduction in the central deflection and the corner uplift, but when the percentage of torsional reinforcement increases, the load carrying capacity of the slab also increases. The load basics vary only when corner uplift varies.

In corner A, for the load applied 0.67 KN/m$^2$ the corner uplift is 1.95mm, and the load is increased as 0.80 KN/m$^2$, 0.93 KN/m$^2$ etc. When the variance in load is from 0.80 KN/m$^2$ to 0.93 KN/m$^2$, the corner uplift difference is 22% and when the load varies the difference also varies. As the Load increases from 6.0 KN/m$^2$ to 6.13 KN/m$^2$ the corner uplift difference becomes 56%. When torsional reinforcement percentage is increased, the corner uplift is decreased. When the load 0.13 KN/m$^2$ is applied for the torsional reinforcement of 20% the corner uplift is 0.12mm. In 25% torsional reinforcement the corner uplift is 0.1mm and from 25% to 30% with the load at 6.13 KN/m$^2$ the corner uplift is 12%. In 75% the load attains only the minimized corner uplift.

#### 3.1.2 Load Vs Corner Uplift at Corner B

In figure 3.1.2, it is shown that the load Vs corner uplift of a corner B for each torsional reinforcement percentage varies by 0%, 20%, 25%, 30%, 35%, and 75%. The Uplift of corner starts at a load of 0.13KN/m$^2$ and the maximum uplift are obtained at the ultimate loads. In corner B for the load applied 0.67 KN/m$^2$ the uplift is 1.55mm, and then the load is increased as 0.80 KN/m$^2$, 0.93 KN/m$^2$ etc.

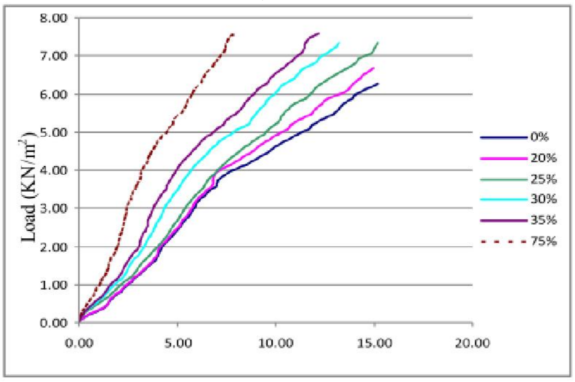


**Figure 3.1.2 Load Vs Corner Uplift at Corner B**

When the variation in load is from 0.80 KN/m$^2$ to 0.93 KN/m$^2$ the corner uplift difference becomes 41% and when the load varies the difference also varies. As the Load increases from 6.0 KN/m$^2$ to 6.13 KN/m$^2$ the corner uplift difference becomes 56%. When the torsional reinforcement percentage is increased, the corner uplift is decreased. When the load 0.13 KN/m$^2$ is applied and the torsional reinforcement is 20% the corner uplift is 0.8mm. In 25% torsional reinforcement the corner uplift is 0.35mm and at 25% to 30% with the load at 6.13 KN/m$^2$ the corner uplift is 17%. In 75% the load attains only the minimized corner uplift.

#### 3.1.3 Load Vs Corner Uplift At Corner C

In figure 3.1.3, it is shown that the load Vs corner uplift of a corner C for each torsional reinforcement percentage varies by 0%, 20%, 25%, 30%, 35%, 75%. The Uplift of corner starts at a load of 0.13KN/m$^2$ and maximum uplift is obtained at the ultimate loads. In corner C the load applied in 0.80 KN/m$^2$ is 2.64mm, then the load increases in 0.93 KN/m$^2$, 1.03 KN/m$^2$, 1.33 KN/m$^2$, etc. When varying the load from 1.47

KN/m$^2$ to 1.60 KN/m$^2$ the corner uplift difference becomes 39% and when the load varies the difference also varies.

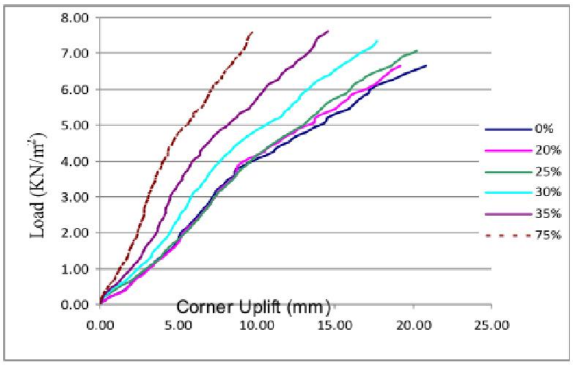


**Figure 3.1.3 Load Vs Corner Uplift At Corner C**

As the Load increases from 6.80 KN/m$^2$ to 6.93 KN/m$^2$ the corner uplift difference becomes 25%. When the torsional reinforcement percentage is increased, the corner uplift is decreased. When the load 0.53 KN/m$^2$ is applied with the torsional reinforcement 75% the corner uplift is 0.65mm and from 30% to 75% with the load at 0.93 KN/m$^2$ the corner uplift is 10%. In 75% the load attains only the minimized corner uplift.

### 3.1.4 Load Vs Central Deflection

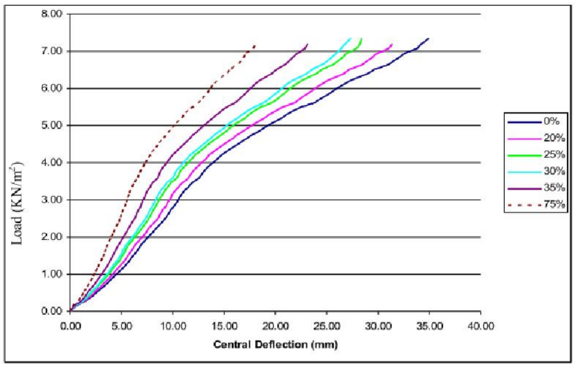


**Figure 3.1.4 Load Vs Central Deflection**

Figure 3.1.4 shows the representation of Load Vs central deflection of Slabs with two ends discontinuous and other ends continuous. If the load increases the central deflection also increases. The maximum central deflection of 28.76 mm is reached at the failure load. Central deflection of a slab starts from the load 0.13KN/m$^2$. For the load applied 0.13KN/m$^2$ at 0% of torsion reinforcement the central deflection is 0.50mm and for the same load at 75% the central deflection is 0.26mm. For the load applied of 7.33 KN/m$^2$ at 0% of torsion reinforcement, the central deflection is 34.74mm. As the Load increases from 6.0 KN/m$^2$ to 6.13 KN/m$^2$ the central deflection difference becomes 79%. When the load 0.53 KN/m$^2$ is applied with the torsional reinforcement of 75% the central deflection is 1.40mm and from 30% to 75% for the load at 0.93mm the central deflection is 81%. From the graph it is observed that at 75 % of torsion reinforcement the load attains only the minimum central deflection. When torsional reinforcement percentage is increased, central deflection is found to decrease.

### 3.1.5 Comparison of the corner uplift (A, B, C) and central deflection of Slabs with two ends discontinuous and other ends continuous

For the torsional reinforcements varying from 0 to 75 %, the corner uplift and central deflection are compared for different corners A, B, C, D. The corner uplift is taken along the X axis and the central deflection along the Y axis. The performance is found to be high in corner A when compared to the other corners B, C and D.

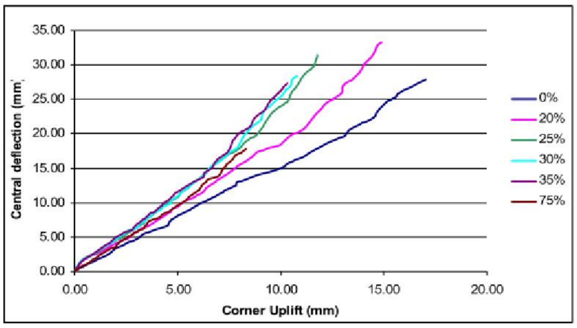


**Figure 3.1.5 Central Deflection Vs Corner Uplift at Corner A**

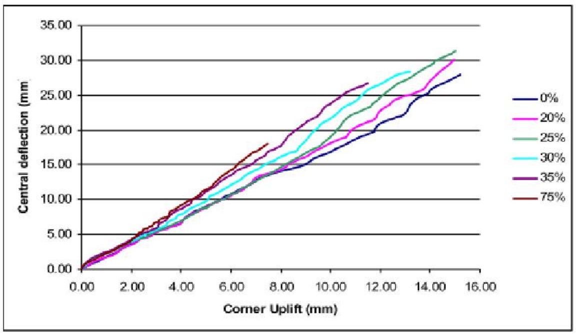


**Figure 3.1.6 Central Deflection Vs Corner Uplift at Corner B**

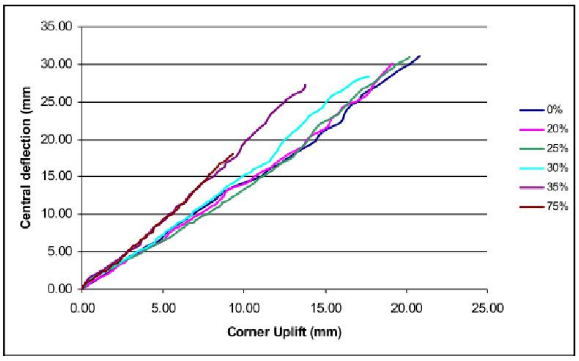


**Figure 3.1.7 Central Deflection Vs Corner Uplift at Corner C**

Figure 3.1.5 -3.1.7 shows the central deflection Vs. corner uplift of Slabs with two ends discontinuous and other ends continuous. In all corners A, B and C the performance is to be analyzed for different torsional reinforcement. The graph is plotted between corner uplift and central deflection and it found to be linear. As compared to the solid slab, with increase in the percentages of torsional reinforcement, there is a reduction in the central deflection and the corner uplift, but when the percentage of torsional reinforcement increases. As per the code the torsion reinforcement provided will be 75% of main reinforcement at free edges and 50% of this reinforcement should be carried over to other discontinuous edges. By providing additional torsional reinforcement the load carrying capacity of the slab increases. Simply supported slab without torsion reinforcement were casted and tested and the corner uplift and central deflection were compared with the slabs with various percentages of torsional reinforcement. While providing 75% of torsional reinforcement it was observed that the deflection was about 47% whereas at 35% the deflection was about 32%. While providing 75% of torsional reinforcement it was observed that the corner uplift about 58% whereas at 35% the corner uplift was about 41%. For two edges discontinuous and other edges continuous, by varying the percentage of torsion reinforcement from 20% to 35%, the uplift and central deflection were observed to be decreasing.

**3.1.6 Comparison graph for different algorithm of Corner uplift and central deflection**

Different training algorithm are compared and the minimum error vale is obtained in each corner A, B ,C and central deflection of Slabs with two ends discontinuous and other ends continuous. The error value is contradictory in each algorithm, and from this the best minimum error value is obtained.

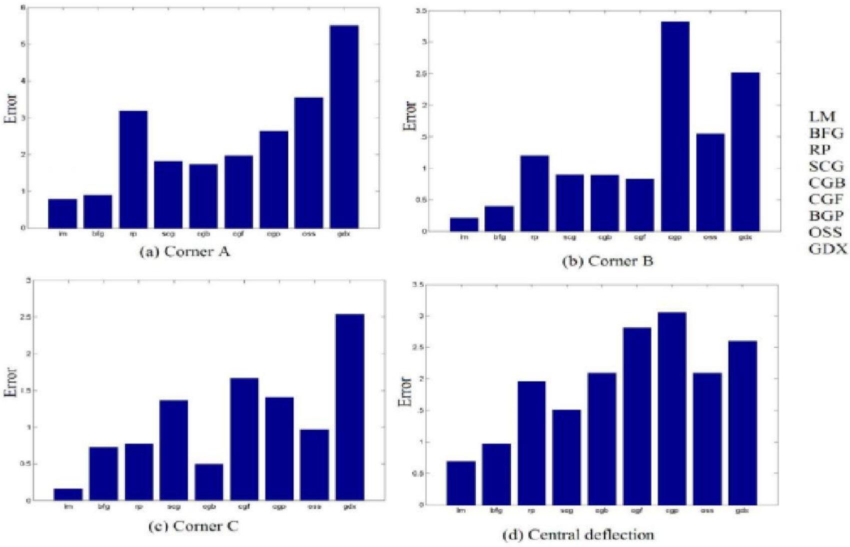


**Fig 3.1.6 Comparison graph for different algorithm in Slabs with two ends discontinuous and other ends continuous**

Figure 3.1.6 represents the corner uplift and central deflection of Slabs with two ends discontinuous and other ends continuous. The algorithms such as LM, BFG, RP, SCG, CGB, CGF, CGP, OSS and GDX are compared then the minimum error attained. In all corners and central deflections the minimum error value attained algorithm is LM and the maximum error value attained algorithm is GDX in Corner A and C. In Corner B the central deflection maximum error value attained algorithm is CGP.

In corner A, the minimum error ranges from 0 to 1 and BFG is compared with LM which is nearly 10% minimized in LM. Similarly the minimizations for RP, SCG, CGB, CGF, CGP, OSS and GDX are 72%, 50%, 47%, 55%, 64%, 74% and 84%.

In Corner B the minimum error ranges from 0 to 0.5 and BFG is compared with LM which is nearly 25% minimized in LM. Similarly, the minimizations for RP, SCG, CGB, CGF, CGP, OSS and GDX are 77%, 66%, 66%, 63%, 91%, 80% and 88% respectively.

In Corner C the minimum error value ranges from 0 to 0.5 and BFG is compared with LM which is nearly 62% minimized in LM. Similarly the minimizations for RP, SCG, CGB, CGF, CGP, OSS, and GDX are 66%, 79%, 40%, 81%, 80%, 66% and 78%.

For the central deflection of Slabs with two ends discontinuous and other ends continuous the minimum error value ranges from 0 to 1, and BFG are compared with LM which is nearly 33% minimized in LM. Similarly, the minimizations for RP, SCG, CGB, CGF, CGP, OSS and GDX are 70%, 60%, 74%, 78%, 80%, 70% and 76%.

**3.1.7 LM algorithm hidden layer and neuron varying in Corner uplift and central deflection**

In the LM training algorithm hidden layer and neuron are varied to evaluate the minimum error value of corner uplift and central deflection in Slabs with two ends discontinuous and other ends continuous is shown in figure 3.1.7. In each Corner A, B, C central deflection of the slab and the minimum error value are found. In the event of any variations in the number of neurons and hidden layers, the best performance value is obtained. in this minimum error value is attained in corner C. In all corners and central deflections the hidden layer is varied from 1 to 4 and the neuron from 1 to 30.

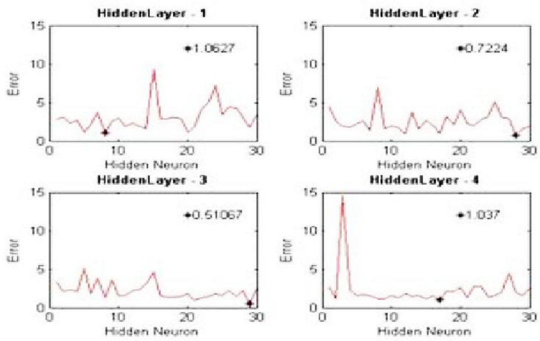


**Fig 3.1.7 (a) LM algorithm hidden layer and neuron varying in Slabs with two ends discontinuous and other ends continuous Corner A**

In corner A the error values for the hidden layers 1, 2, 3 and 4 based on the neuron are 1.0627, 0.7224, 0.51067 and 1.037 respectively. In corner A the minimum error value is attained in hidden layer 3 which is 0.51067.

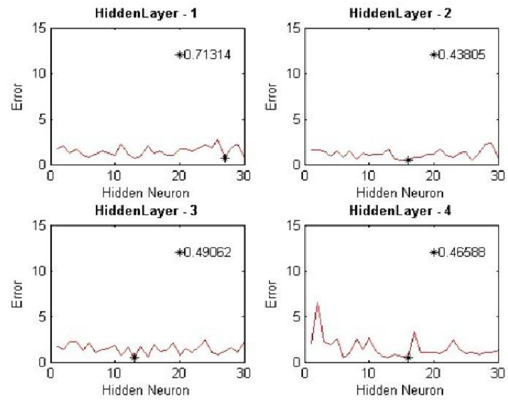


**Fig 3.1.7(b) LM algorithm hidden layer and neuron varying in Slabs with two ends discontinuous and other ends continuous Corner B**

In corner B the error values for the hidden layers 1, 2, 3 and 4 based on the neuron are 0.71314, 0.43805, 0.49062 and 0.46588 respectively. In corner B the minimum error value is attained in hidden layer 2 which is 0.43805. In corner C the error values for the hidden layers 1, 2, 3 and 4 based on the neuron are 0.18142, 0.25891, 0.20275, and 0.24552 respectively.

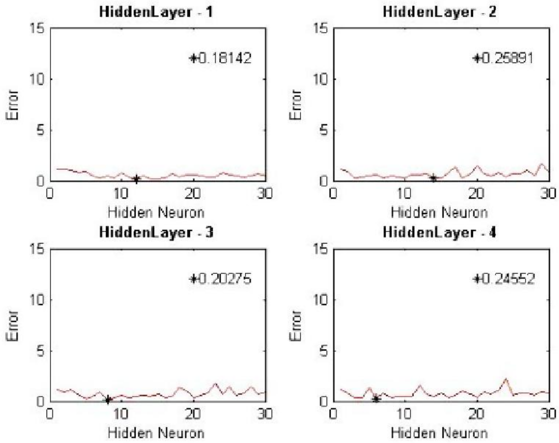


**Fig 3.1.7 (c) LM algorithm hidden layer and neuron varying in Slabs with two ends discontinuous and other ends continuous Corner C**

In corner C the minimum error value is attained in hidden layer 1 which is 0.18142.

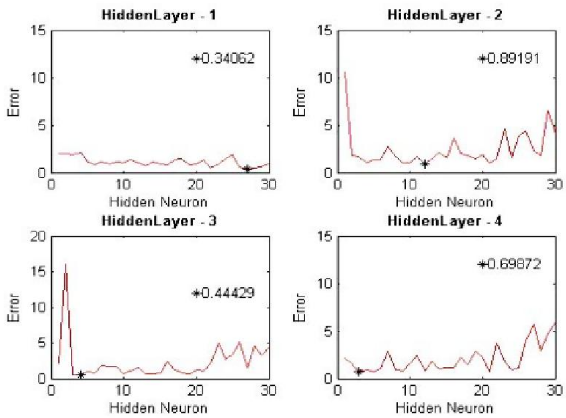


**Fig 3.1.7 (d) LM algorithm hidden layer and neuron varying in Slabs with two ends discontinuous and other ends continuous (Central deflection)**

In central deflection of Slabs with two ends discontinuous and other ends continuous the error values for the hidden layers 1, 2, 3 and 4 based on the neuron are 0.34062, 0.89191, 0.53655 and 0.44429 respectively. For the central deflection the minimum error value is attained in hidden layer 1 which 0.34062.

### 3.1.8 Optimal solution (Corner uplift of Slabs with two ends discontinuous and other ends continuous in optimal solution)

Corner uplift of the intermittent corner (A, B and C) of Slabs with two ends discontinuous and other ends continuous assesses the optimal error and the optimal error values are determined by the genetic algorithm and the training strategy FFBN. In every corner the optimal error value is changing, when used by GA with FFBN the error value approaches zero.

Figure 3.1.8 exhibits that the error value in a corner uplift of the all corners in Slabs with two ends discontinuous and other ends continuous. The graph plotted by the data and the error, the input data base alone fluctuating the error. Training strategy FFBN is used to assess the corner uplift in cube compressive quality where the error value is higher.

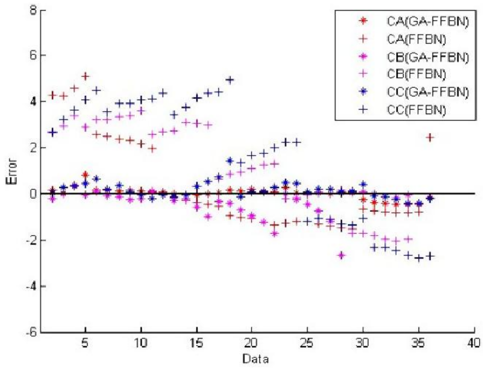


**Fig 3.1.8 Optimal solution of corner uplift in Slabs with two ends discontinuous and other ends continuous**

For the cube compressive quality 24.98N/mm$^2$ in the error estimation of corner A in FFBN training strategy the error value is assumed by the red shade plus symbol, the esteem in a negative and positive area, being used by the GA with FFBN to discern the optimal error value, where the error value approaches zero, it is specified by the red color star symbol. In corner B which uses FFBN training algorithm the error value is specified by the pink shade add symbol, the esteem in a booth (negative and positive) positions, being used by the GA with FFBN to determine the optimal error value, where the error value is nearly zero, it is indicated by the pink color star symbol. Approximately the error values just in a negative locale employ the GA algorithm. In corner C based on FFBN training algorithm the error value is specified by the blue color add symbol, the esteem in a both position, being used by the GA with FFBN to ascertain the optimal error value, where the error value approaches zero, it is indicated by blue shade star image.

### 3.1.9 Result from optimal neural network structure

Corner uplift and central deflection of anticipated outcomes in Slabs with the end two ends discontinuous and other ends continuous are ascertained. The error value is based on the anticipated results within corners corner A, B, C and central deflection.

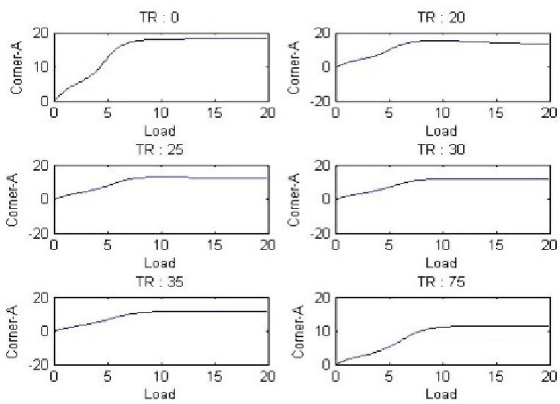


**Fig 3.1.9 (a) Corner uplift in Slabs with two ends discontinuous and other ends continuous Corner A**

In this anticipated result the load fluctuating and torsional support of an each one corners (A, B, C) and central deflection of Slabs with two ends discontinuous and other ends continuous indicated in figure 3.1.9. The corner uplift and central deflection determine the obscure values, for the obscure load values the torsional fortification changes 0%, 20%, 25%, 30%, 35% and 75%. The obscure load value differs in 0 to 20 for every torsional support.

For the corner uplift of a corner A the normal error value is 1.11 and through this error value the corner uplift curves are acquired. At that point 25%, 30%, 35%, and 75% likewise the corner uplift is extended and becomes steady.

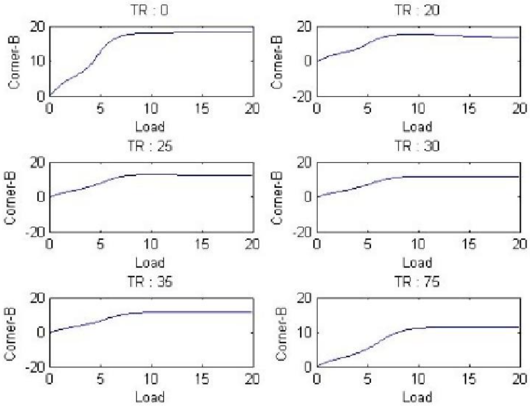


**Fig 3.1.9(b) Corner uplift in Slabs with two ends discontinuous and other ends continuous Corner B**

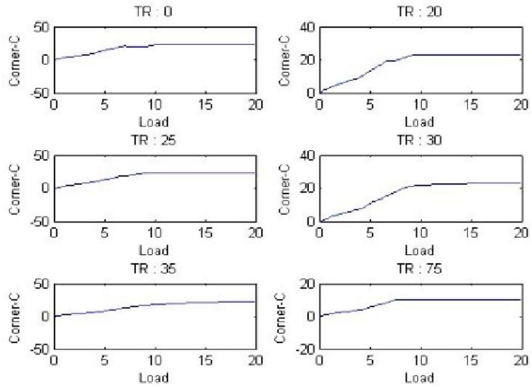


**Fig 3.1.9 (c) Corner uplift in Slabs with two ends discontinuous and other ends continuous Corner C**

Since the corner uplift of the corner B, the normal error value is $7.02e^{0.0008}$ and based on this error value the corner uplift curves are acquired. At 0% the corner uplift execution is expanded and after becoming minimum reaches the consistent quality, then 20%, 25%, 35%, and 75% additionally the corner uplift is expanded and diminished and reaches the steady state. In 30% corner uplift is incremented and remains steady.

For the corner uplift of a corner C the normal error value is $2.96e^{-1}$ and by this error value the corner uplift curves are developed. At 0% the corner uplift performance is maximized and reaches a steady value, in 20% likewise the corner uplift is expanded and remains consistent, at that point 25%, 30%, 35%, and 75% likewise corner uplift is extended then reaches the steady state.

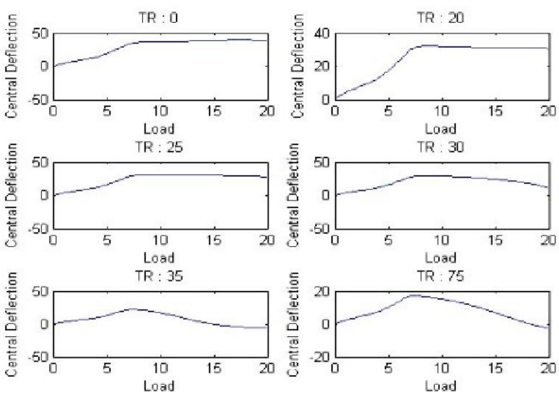


**Fig 3.1.9(d) Central deflection in Slabs with two ends discontinuous and other ends continuous**

Since the central deflection of Slabs with two ends discontinuous and other ends continuous the normal error value is 1.57 and through this error value the corner uplift curves are developed. In 0% the corner uplift execution is incremented and reaches a steady value, in 20% additionally the corner uplift are expanded and diminished then remains consistent. At that point 25%, 30%, 35%, and 75% likewise corner uplift is expanded and diminished then reaches the steady state.

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