

## Chapter three

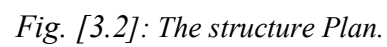
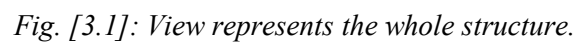
### **The Problem Statements**

#### **3.1 Introduction**

In this chapter the reliability assessment of a reinforced concrete structures with corroded reinforcement is presented. The reliability of the columns is calculated. It is assumed that after commencement of corrosion the reinforcement will deteriorate, which is associated with reduction in area of the steel. In addition, the considered corrosion type is local (pitting). The research includes several parameters like loads, material properties, and environmental actions and so on. Reliability is estimated for the two limit states, initiation of corrosion and ultimate strength of the column by using two computer programs named Etabs and Prokon to analyze and redesign the structure under consideration.

#### **3.2 Structure input data**

The structure nature which we considered in this research is subjected to deterioration due to corrosion of steel reinforcement in columns by corrosion rate in the area of reinforcement (see Appendix [A]); the critical column [CL 15] under consideration in this structure were the short and long columns in ground storey as illustrated in Fig. (3.1).



### 3.2.1 Geometrical and material properties

The structure loads are the following: dead load equal to 7 kN/mm<sup>2</sup> which represents partitions and finishes, self weight of structural (members) and live load equal to 2 kN/mm<sup>2</sup>. The main geometrical and material properties are summarized in Table (3.1).

**Table (3.1):** Geometrical data and material properties of the considered Column.

| Geometrical data                                  | Concrete                                                                           | Reinforcement                                                          |
|---------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Width = 250 mm<br>Height = 450 mm<br>Length = 3 m | Compr.strength, ( $f_{cu}$ ) = 25<br>$N/mm^2$<br>Concrete cover , ( $d_c$ ) = 25mm | 10 $\Phi 16$ , $F_y = 460 N/mm^2$<br>Links $\Phi 8$ , $F_y 250 N/mm^2$ |

### 3.2.2 The Iterative study

- **Case One:** Reduction of Steel area due to corrosion

**Table [3.2]:** Reduction of Geometrical.

| Corrosion Rate                       | 0%   | 2%   | 4%   | 6%   | 8%   | 10%  | 12%  | 14%  | 16%  | 18%  |
|--------------------------------------|------|------|------|------|------|------|------|------|------|------|
| Reduction of area (mm <sup>2</sup> ) | 2010 | 1960 | 1939 | 1887 | 1839 | 1815 | 1767 | 1720 | 1697 | 1651 |

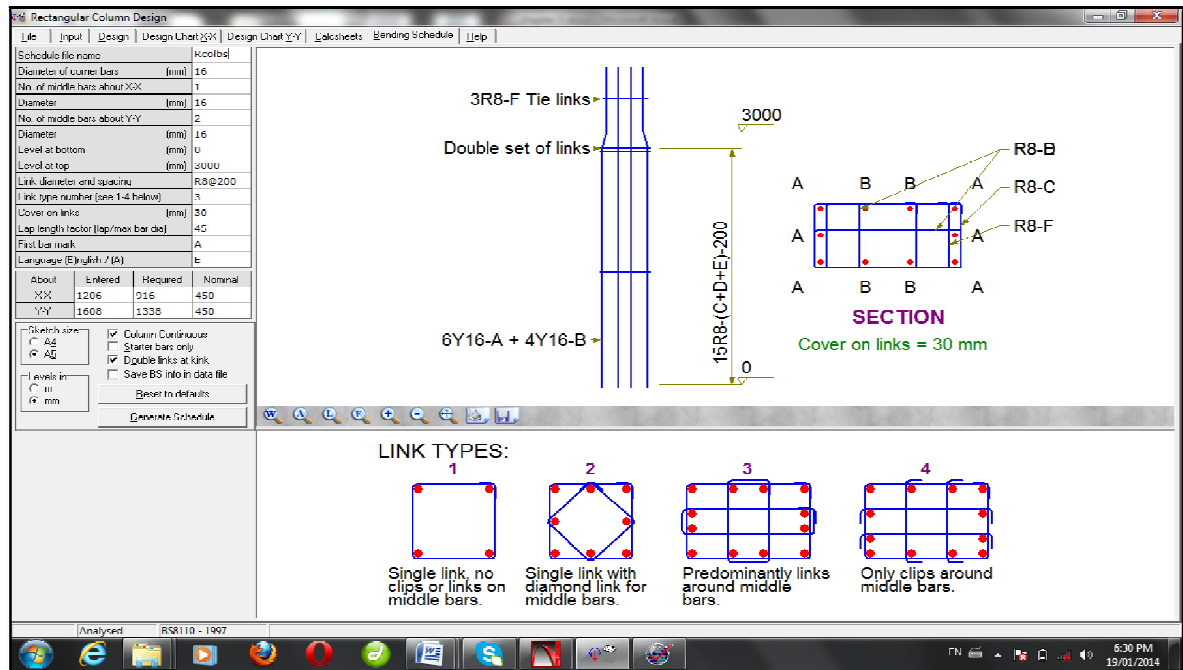


Fig. [3.3]: Bending Schedule for Control column with no ductility change.

▪ **Case Two:** Reduction of ductility and steel area

**Table [3.3]:** Reduction of ductility and steel area.

| Corrosion Rate                       | 0%   | 2%   | 4%   | 6%   | 8%   | 10%  | 12%  | 14%  | 16%  | 18%  |
|--------------------------------------|------|------|------|------|------|------|------|------|------|------|
| Reduction of area (mm <sup>2</sup> ) | 2010 | 1960 | 1939 | 1887 | 1839 | 1815 | 1767 | 1720 | 1697 | 1651 |
| Ductility reduction                  | 460  | 450  | 440  | 430  | 420  | 410  | 400  | 390  | 380  | 370  |

- In this research, the analysis of the model is carried out by using computer software named (Etabs). Furthermore, the design of the problem is carried out by using (Prokon) program as illustrated Table (5.1) to (5.10). The steps of Etabs program is described as follows:

- 1- Set the units (KN/m)
- 2- Draw the grid line
- 3- Define

### 3.1 Material properties

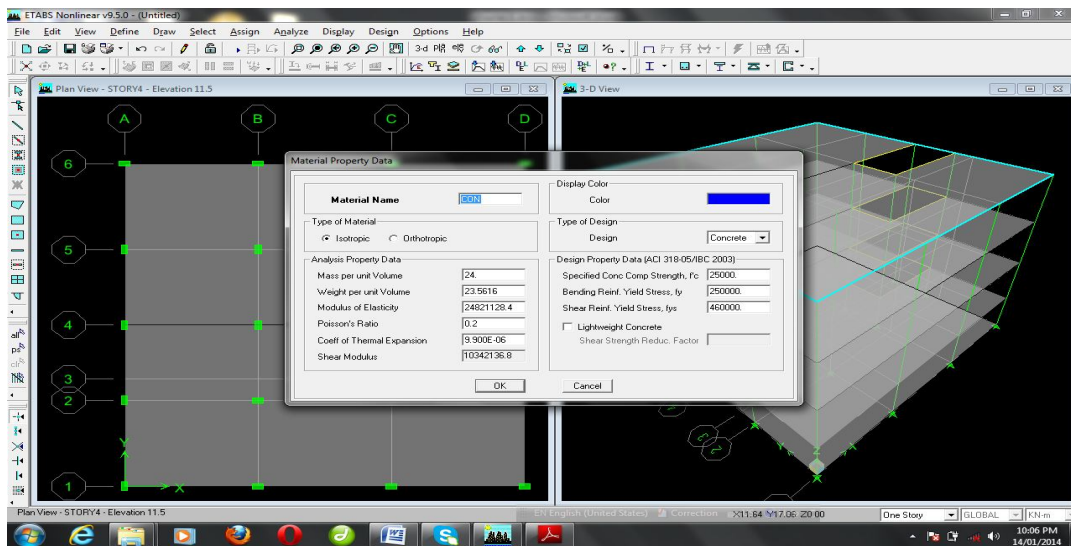


Fig.(3.4): View shows material properties menu.

### 3.2 Define frame sections

|                             |         |
|-----------------------------|---------|
| Short column + ground floor | 250*450 |
| 1 st + 2 st                 | 250*400 |
| Edg beam                    | 250*500 |

### 3.3 Define slab thickness

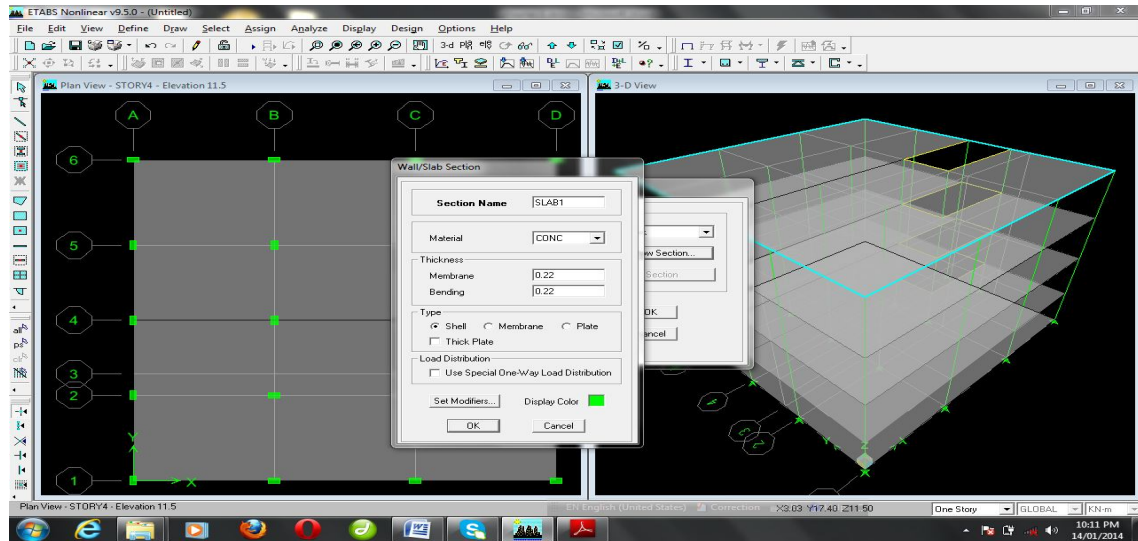


Fig.(3.5): View shows define slab thickness menu.

### 3.4 Define static load

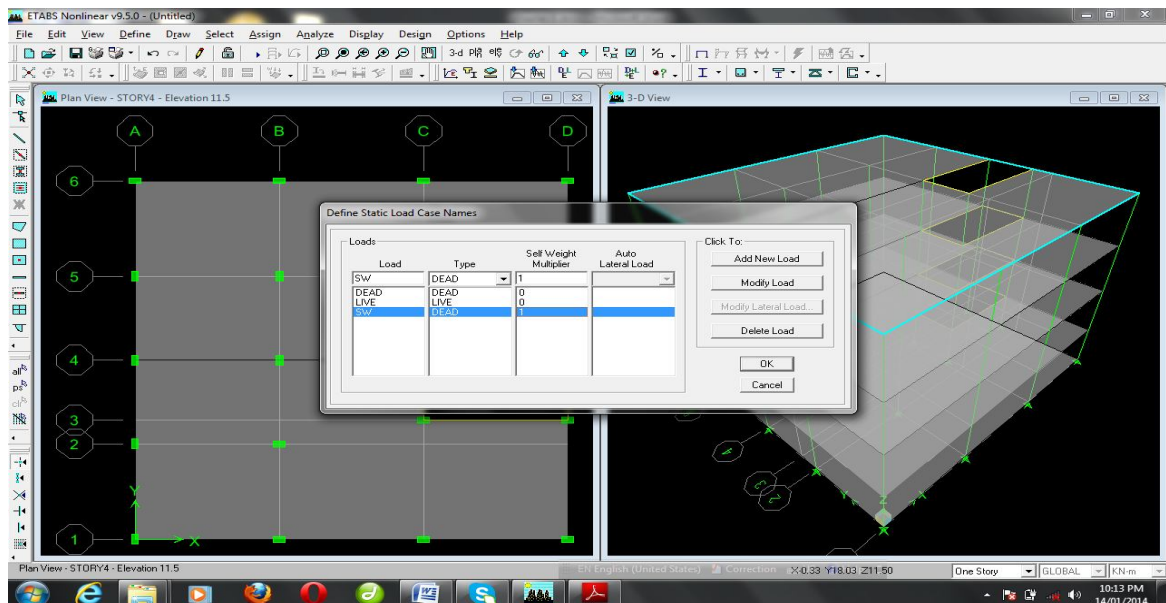


Fig.(3.6): View shows define static load menu .

### 3.5 Define load combinations

#### Com.1

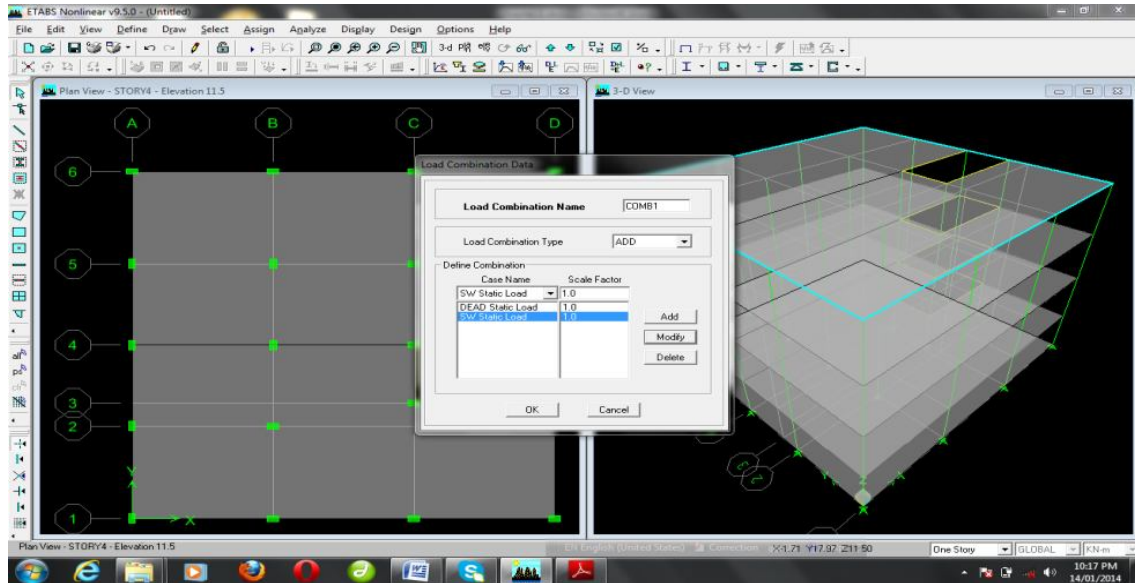


Fig.(3.7): View shows define load combination one menu .

#### Com.2

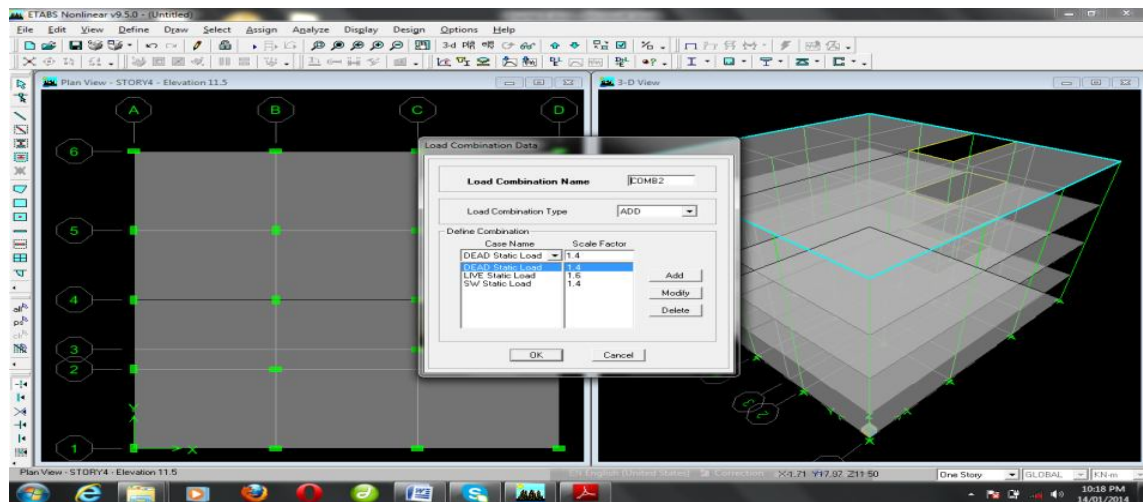


Fig.(3.8): View shows define load combination two menu .

#### 4- Draw structural members

#### 5- Assign

##### 5.1 *support restraints*

Assign →→ joint / point →→ restraints (support)

[Select - One story – Base]

##### 5.2 *Assign the load*

Assign →→ shell / Area loads →→ uniform

[ select slab ]

Load case name                      units

Dead = 7                                   $kN/m^2$

Live = 2

##### 5.3 *Mesh*

Assign →→ shell / Area

[Select all]

- Area object mesh options
  - Auto mesh object structure element

##### 5.4 *Auto line constraint*

Assign →→ Auto line constraint →→ ok

[ select all ]

#### 6- Analyze

Check model →→ No warning messages →→ ok

Run Analysis

### 3.3 Analysis Output Results

In this investigation, the analysis of columns in ground floor is carried out by using combinations one and two for loadings coupled by choosing the critical case for column (Column 15) Com<sub>2</sub>

Combination [1]  $\equiv$  1.0 DL

Combination [2]  $\equiv$  1.4 DL + 1.6 LL

**Table (3.4):** the analysis output for short columns of combination one.

| story  | column | Load | Loc   | p       | V2    | V3     | t      | M2     | M3     |
|--------|--------|------|-------|---------|-------|--------|--------|--------|--------|
| Story1 | C1     | Com1 | 0.000 | -263.9  | 6.66  | -8.3   | -0.033 | -7.202 | 6.485  |
|        |        |      | 1.500 | -256.1  | 6.66  | -8.3   | -0.033 | 5.255  | -3.506 |
|        |        |      | 3.000 | -248.1  | 6.66  | -8.3   | -0.033 | 17.712 | -13.49 |
| Story1 | C2     | Com1 | 0.000 | -559.1  | 15.82 | 1.54   | -0.006 | 2.356  | 15.503 |
|        |        |      | 1.500 | 551.1   | 15.82 | 1.54   | -0.006 | 0.047  | -8.227 |
|        |        |      | 3.000 | -543.2  | 15.82 | 1.54   | -0.006 | -2.262 | -31.96 |
| Story1 | C3     | Com1 | 0.000 | -557.7  | 15.79 | -1.77  | -0.005 | -0.829 | 15.51  |
|        |        |      | 1.500 | -549.8  | 15.79 | -1.77  | -0.005 | 1.818  | -8.18  |
|        |        |      | 3.000 | -541.8  | 15.79 | -1.77  | -0.005 | 4.466  | -31.87 |
| Story1 | C4     | Com1 | 0.000 | -266.3  | 6.57  | 7.94   | 0.017  | 8.614  | 6.48   |
|        |        |      | 1.500 | -258.3  | 6.57  | 7.94   | 0.017  | -3.298 | -3.38  |
|        |        |      | 3.000 | -250.4  | 6.57  | 7.94   | 0.017  | -15.21 | -13.24 |
| Story1 | C5     | Com1 | 0.000 | -1180.7 | -3.02 | 2.52   | -0.010 | 3.35   | -2.96  |
|        |        |      | 1.500 | -1172.8 | -3.02 | 2.52   | -0.010 | -0.44  | 1.57   |
|        |        |      | 3.000 | -1164.8 | -3.02 | 2.52   | -0.010 | -4.23  | 6.11   |
| Story1 | C6     | Com1 | 0.000 | -531.3  | -1.66 | -16.32 | -0.010 | -14.92 | -1.66  |
|        |        |      | 1.500 | -523.4  | -1.66 | -16.32 | -0.010 | 9.564  | 0.83   |
|        |        |      | 3.000 | -515.5  | -1.66 | -16.32 | -0.010 | 34.05  | 3.32   |
| Story1 | C7     | Com1 | 0.000 | -671.3  | -8.68 | -2.56  | -0.011 | -1.539 | -8.51  |
|        |        |      | 1.500 | -664.1  | -8.68 | -2.56  | -0.011 | 1.976  | 3.43   |
|        |        |      | 3.000 | -656.8  | -8.68 | -2.56  | -0.011 | 5.49   | 15.37  |
| Story1 | C8     | Com1 | 0.000 | -254.6  | -5.33 | -11.00 | -0.004 | -9.73  | -5.26  |
|        |        |      | 1.500 | -247.4  | -5.33 | -11.00 | -0.004 | 5.39   | 2.07   |
|        |        |      | 3.000 | -240.1  | -5.33 | -11.00 | -0.004 | 20.52  | 9.39   |

|        |     |      |       |          |        |        |        |        |        |
|--------|-----|------|-------|----------|--------|--------|--------|--------|--------|
| Story1 | C9  | Com1 | 0.000 | -404.24  | 13.49  | -14.46 | -0.022 | -13.06 | 13.18  |
|        |     |      | 1.500 | -396.96  | 13.49  | -14.46 | -0.022 | 6.827  | -5.366 |
|        |     |      | 3.000 | -389.69  | 13.49  | -14.46 | -0.022 | 26.70  | -23.90 |
| Story1 | C10 | Com1 | 0.000 | -990.82  | 19.57  | -3.21  | -0.008 | -2.142 | 19.185 |
|        |     |      | 1.500 | -983.55  | 19.57  | -3.21  | -0.008 | 2.268  | -7.721 |
|        |     |      | 3.000 | -976.27  | 19.57  | -3.21  | -0.008 | 6.678  | -34.62 |
| Story1 | C11 | Com1 | 0.000 | -1227.84 | 4.16   | -1.04  | -0.008 | -0.023 | 4.111  |
|        |     |      | 1.500 | -1219.90 | 4.16   | -1.04  | -0.008 | 1.536  | -2.126 |
|        |     |      | 3.000 | -1211.9  | 4.16   | -1.04  | -0.008 | 3.096  | -8.363 |
| Story1 | C12 | Com1 | 0.000 | -567.3   | -16.77 | -1.60  | -0.014 | -0.516 | -16.40 |
|        |     |      | 1.500 | -559.4   | -16.77 | -1.60  | -0.014 | 1.878  | 8.756  |
|        |     |      | 3.000 | -551.4   | -16.77 | -1.60  | -0.014 | 4.271  | 33.913 |
| Story1 | C13 | Com1 | 0.000 | -694.5   | -24.53 | 1.71   | -0.017 | 2.682  | -24.03 |
|        |     |      | 1.500 | -686.6   | -24.53 | 1.71   | -0.017 | 0.124  | 12.76  |
|        |     |      | 3.000 | -678.6   | -24.53 | 1.71   | -0.017 | -2.434 | 49.55  |
| Story1 | C14 | Com1 | 0.000 | -342.0   | -12.02 | -10.1  | 0.002  | -8.82  | -11.81 |
|        |     |      | 1.500 | -334.1   | -12.02 | -10.1  | 0.002  | 6.404  | 6.229  |
|        |     |      | 3.000 | -326.2   | -12.02 | -10.1  | 0.002  | 21.628 | 24.26  |
| Story1 | C15 | Com1 | 0.000 | -1185    | 2.55   | -3.26  | -0.006 | -3.102 | 1.946  |
|        |     |      | 1.500 | -1177    | 2.55   | -3.26  | -0.006 | 1.178  | -1.87  |
|        |     |      | 3.000 | -1169    | 2.55   | -3.26  | -0.006 | 6.67   | -5.69  |
| Story1 | C16 | Com1 | 0.000 | -510.2   | -18.24 | -2.00  | -0.014 | -1.840 | -18.43 |
|        |     |      | 1.500 | -502.3   | -18.24 | -2.00  | -0.014 | 1.157  | 8.934  |
|        |     |      | 3.000 | 494.3    | -18.24 | -2.00  | -0.014 | 4.154  | 36.29  |
| Story1 | C17 | Com1 | 0.000 | -1037    | 2.45   | -0.04  | -0.008 | 0.018  | 1.829  |
|        |     |      | 1.500 | -1029    | 2.45   | -0.04  | -0.008 | 0.076  | -1.84  |
|        |     |      | 3.000 | -1021    | 2.45   | -0.04  | -0.008 | 0.134  | -5.53  |
| Story1 | C18 | Com1 | 0.000 | -443.9   | -15.89 | -0.24  | -0.015 | -0.123 | -16.14 |
|        |     |      | 1.500 | -436.1   | -15.89 | -0.24  | -0.015 | 0.233  | 7.69   |
|        |     |      | 3.000 | -428.1   | -15.89 | -0.24  | -0.015 | .589   | 31.52  |
| Story1 | C19 | Com1 | 0.000 | -503.9   | -18.36 | 1.47   | -0.015 | 1.54   | -18.59 |
|        |     |      | 1.500 | -496.1   | -18.36 | 1.47   | -0.015 | -0.67  | 8.951  |
|        |     |      | 3.000 | -488.1   | -18.36 | 1.47   | -0.015 | -2.88  | 36.49  |
| Story1 | C20 | Com1 | 0.000 | -262.1   | -9.19  | -5.99  | 0.001  | -5.71  | -9.62  |
|        |     |      | 1.500 | -254.2   | -9.19  | -5.99  | 0.001  | 3.28   | 4.17   |
|        |     |      | 3.000 | -246.3   | -9.19  | -5.99  | 0.001  | 12.25  | 17.95  |

**Table (3.5):** the analysis output for short columns of combination two.

| story  | column | Load | Loc   | p      | V2     | V3     | t      | M2     | M3     |
|--------|--------|------|-------|--------|--------|--------|--------|--------|--------|
| Story1 | C1     | Com2 | 0.000 | -294.1 | 7.49   | -9.38  | -0.041 | -8.16  | 7.29   |
|        |        |      | 1.500 | -286.1 | 7.49   | -9.38  | -0.041 | 5.91   | -4.001 |
|        |        |      | 3.000 | -278.5 | 7.49   | -9.38  | -0.041 | 19.98  | -15.23 |
| Story1 | C2     | Com2 | 0.000 | -638.6 | 17.88  | 1.76   | -0.010 | 2.656  | 17.47  |
|        |        |      | 1.500 | -620.6 | 17.88  | 1.76   | -0.010 | 0.016  | -9.34  |
|        |        |      | 3.000 | -612.7 | 17.88  | 1.76   | -0.010 | -2.624 | -36.16 |
| Story1 | C3     | Com2 | 0.000 | -627.4 | 17.67  | -1.98  | -0.010 | -0.948 | 17.51  |
|        |        |      | 1.500 | -619.5 | 17.67  | -1.98  | -0.010 | 2.019  | -9.29  |
|        |        |      | 3.000 | -611.5 | 17.67  | -1.98  | -0.010 | 4.985  | -36.09 |
| Story1 | C4     | Com2 | 0.000 | -296.9 | 7.44   | 9.02   | -0.016 | 9.750  | 7.314  |
|        |        |      | 1.500 | -288.9 | 7.44   | 9.02   | -0.016 | -3.779 | -3.84  |
|        |        |      | 3.000 | -281.3 | 7.44   | 9.02   | -0.016 | -17.30 | -14.98 |
| Story1 | C5     | Com2 | 0.000 | -1332  | -3.53  | 2.92   | -0.014 | 3.84   | -3.507 |
|        |        |      | 1.500 | -1324  | -3.53  | 2.92   | -0.014 | -0.542 | 1.787  |
|        |        |      | 3.000 | -1316  | -3.53  | 2.92   | -0.014 | -4.925 | 7.082  |
| Story1 | C6     | Com2 | 0.000 | -597.2 | -1.95  | -18.45 | -0.015 | -16.87 | -2.005 |
|        |        |      | 1.500 | -589.3 | -1.95  | -18.45 | -0.015 | 10.80  | 0.914  |
|        |        |      | 3.000 | -581.3 | -1.95  | -18.45 | -0.015 | 38.47  | 3.833  |
| Story1 | C7     | Com2 | 0.000 | -730.5 | -10.11 | -2.10  | -0.016 | -0.966 | -9.955 |
|        |        |      | 1.500 | -723.2 | -10.11 | -2.10  | -0.016 | 1.919  | 3.946  |
|        |        |      | 3.000 | -715.9 | -10.11 | -2.10  | -0.016 | 4.804  | 17.847 |
| Story1 | C8     | Com2 | 0.000 | -279.3 | -6.17  | -12.30 | -0.007 | -10.85 | -6.142 |
|        |        |      | 1.500 | -272.7 | -6.17  | -12.30 | -0.007 | 6.052  | 2.337  |
|        |        |      | 3.000 | -264.8 | -6.17  | -12.30 | -0.007 | 22.96  | 10.817 |
| Story1 | C9     | Com2 | 0.000 | -449.6 | 15.20  | -16.24 | -0.029 | -14.65 | 14.799 |
|        |        |      | 1.500 | -442.4 | 15.20  | -16.24 | -0.029 | 7.685  | -6.108 |
|        |        |      | 3.000 | -435.7 | 15.20  | -16.24 | -0.029 | 29.11  | -27.01 |
| Story1 | C10    | Com2 | 0.000 | -1043  | 21.16  | -1.92  | -0.013 | -0.746 | 20.69  |
|        |        |      | 1.500 | -1035  | 21.16  | -1.92  | -0.013 | 1.890  | -8.395 |
|        |        |      | 3.000 | -1028  | 21.16  | -1.92  | -0.013 | 4.526  | -37.48 |
| Story1 | C11    | Com2 | 0.000 | -1227  | 4.07   | -1.03  | -0.013 | 0.138  | 3.995  |
|        |        |      | 1.500 | -1219  | 4.07   | -1.03  | -0.013 | 1.684  | -2.105 |
|        |        |      | 3.000 | -1211  | 4.07   | -1.03  | -0.013 | 3.230  | -8.214 |
| Story1 | C12    | Com2 | 0.000 | -563.6 | -16.78 | -1.65  | -0.020 | -0.392 | -16.44 |
|        |        |      | 1.500 | -555.8 | -16.78 | -1.65  | -0.020 | 2.083  | 8.731  |
|        |        |      | 3.000 | -547.9 | -16.78 | -1.65  | -0.020 | 4.558  | 33.89  |
| Story1 | C13    | Com2 | 0.000 | -740.8 | -26.34 | 2.95   | -0.022 | 4.067  | -25.88 |
|        |        |      | 1.500 | -752.9 | -26.34 | 2.95   | -0.022 | -0.365 | 13.66  |
|        |        |      | 3.000 | -724.9 | -26.34 | 2.95   | -0.022 | -4.796 | 53.17  |

|        |     |      |       |        |        |        |        |        |        |
|--------|-----|------|-------|--------|--------|--------|--------|--------|--------|
| Story1 | C14 | Com2 | 0.000 | -573.7 | -13.65 | -11.46 | 0.002  | -9.922 | -13.56 |
|        |     |      | 1.500 | -566.2 | -13.65 | -11.46 | 0.002  | 7.272  | 7.015  |
|        |     |      | 3.000 | -558.8 | -13.65 | -11.46 | 0.002  | 24.47  | 27.49  |
| Story1 | C15 | Com2 | 0.000 | -1430  | -4.53  | 2.92   | -0.015 | 27.2   | -27.5  |
|        |     |      | 1.500 | -1422  | -4.53  | 2.92   | -0.015 | 27     | 19.1   |
|        |     |      | 3.000 | -1415  | -4.53  | 2.92   | -0.015 | 26.9   | 13.6   |
| Story1 | C16 | Com2 | 0.000 | -573.9 | -20.61 | -2.28  | -0.019 | -2.133 | -20.81 |
|        |     |      | 1.500 | -566.4 | -20.61 | -2.28  | -0.019 | 1.287  | 10.09  |
|        |     |      | 3.000 | -558.8 | -20.61 | -2.28  | -0.019 | 4.606  | 41.01  |
| Story1 | C17 | Com2 | 0.000 | -1102  | 2.62   | -1.12  | -0.012 | -1.080 | 1.924  |
|        |     |      | 1.500 | -1094  | 2.62   | -1.12  | -0.012 | 0.603  | -2.01  |
|        |     |      | 3.000 | -1086  | 2.62   | -1.12  | -0.012 | 2.286  | -5.94  |
| Story1 | C18 | Com2 | 0.000 | -503.2 | -16.99 | -0.74  | -0.019 | 1.47   | -18.80 |
|        |     |      | 1.500 | -495.8 | -16.99 | -0.74  | -0.019 | -0.66  | 8.925  |
|        |     |      | 3.000 | -487.4 | -16.99 | -0.74  | -0.019 | -2.79  | 36.65  |
| Story1 | C19 | Com2 | 0.000 | -471.5 | -16.99 | -0.74  | -0.019 | -0.628 | -17.76 |
|        |     |      | 1.500 | -463.8 | -16.99 | -0.74  | -0.019 | 0.480  | -8.18  |
|        |     |      | 3.000 | -455.1 | -16.99 | -0.74  | -0.019 | 1.589  | 33.66  |
| Story1 | C20 | Com2 | 0.000 | -261.8 | -9.23  | -6.04  | -0.005 | -5.771 | -9.77  |
|        |     |      | 1.500 | -253.9 | -9.23  | -6.04  | -0.005 | 3.287  | 4.08   |
|        |     |      | 3.000 | -245.9 | -9.23  | -6.04  | -0.005 | 12.344 | 17.94  |