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Comparison of calculation of axial loads on columns by tributary area method and 3D modeling by SAP2000

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ABSTRACT

This research is an attempt to understand the distribution of axial loads on columns in one story building model under different case of slab (rigid and flexible slab) and different load condition (gravity and horizontal load), then comparing the results obtained by model with those results obtained by tributary area method. To do this, a technique utilizing finite element analysis is used in order to create computerized model with SAP2000 program. This model is built to simulate the real state of slab and columns in one story building. According to the analysis of the data obtained, we can see the big difference between the real load carried by columns and the load calculated by using the Tributary area method, so using 3-D model is the best method to calculate the real load effected on columns and design this columns according this load.

Keywords: Tributary area method, rigid slab, flexible slab, FEM analysis, stiffness

1. Introduction

Recently, the usage of computer techniques in engineering analysis and design work has become an inextricable sensation. Using computer as the tool for modeling, analysis, and design has become the established and preferred method.

Designing a building, any civil engineer has to calculate the forces in the structural elements which a building contains like slabs, beams, columns, and footings. Then civil engineer uses these forces to design building in correct case.

Column one of the structural elements can be defined as a members that carry loads chiefly in compression (Nilson 2003). Columns transmit loads from the upper floors to the lower levels and then to the soil through the foundation. Since columns are compression elements, failure of one column in critical location can cause the progressive collapse of the adjoining floors and ultimate total collapse of the entire structure (Nawy 2005). Column load transfer from beams and slabs by two methods: tributary area method and Beams reaction method. Tributary area method is one of these methods which are being used to calculate the forces carried by columns in the building, this method depends on computing the forces on columns due to the load applied on the slab by calculating the surrounded area of columns and multiply this area by the load on the slab (Madan Mehta et al 2009).

The Tributary Area method is more suitable for masonry buildings and more widely used because of its suitability for hand calculation checks, and will also produce larger reactions in the walls and columns that terminate on a transfer level (Bezkorovainy 2006).They are many software used for structure analysis and design such as:SAP2000,Staad Pro,R/C

BUILDING. Some research investigated vertical load analysis by R/C BUILDING software, the result show if we used R/C BUILDING software we can obtain the same results as the tributary area method (Bezkorovainy 2006).

(Kurc and Lulec 2011) studied different analysis approaches to find the axial loads on columns and structural walls at tall buildings, the result indicated that the column and wall axial load might vary up to 45% depending on the type of analysis and effects that were considered.

SAP2000 is a general purpose finite element program which performs the static or dynamic, linear or nonlinear analysis of structural systems. It is also a powerful design tool to design structures following AASHTO specifications, ACI and AISC building codes (Linzhong Deng and Michel Ghosn).

In this paper we will try to determine the forces carried by columns in one story building and understand how the slab will distribute this load to the columns by studying a number of different cases of models by using 3D modeling by SAP2000, and compare the results from these models with those obtained by Tributary area method.

We have two cases, the first case calculates the carried load by columns when subjected the slab by gravity load (dead and live load) under different type of slab (rigid and flexible slab).

The other case calculates the carried load by columns when subjected the slab by horizontal load under different type of slab (rigid and flexible slab).

2. Model description

The model used is one story building that can be built using one of the computer's structure analysis programs, and sets of input are given, such as load on slab, material characteristics, model size and outputs such as load carried by columns.

SAP2000 program is used to create and analyze finite element model for one story building, keeping in mind that there is compatibility between this model and the actual case, as shown in Figures 1 and 2.

In order to represent a structural model for one story building, the following assumptions are used:

1. Each model consists of a flat plate slab with (40cm thickness in actual model) carried by nine columns.
2. The dimensions of slab are (12m x 12m) divided into two spans in each direction each one equal (6m).
3. The height of columns in the building equal (3m).
4. Pin hinges are used to support of (20 * 20 cm) columns.
5. All models made by concrete.

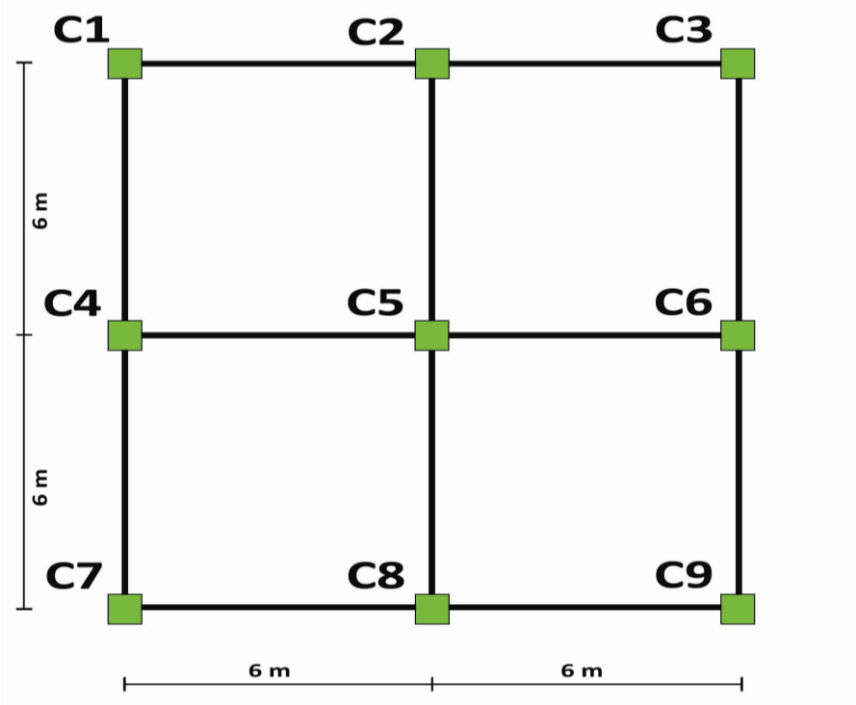

Figure 1: 2D one story building model

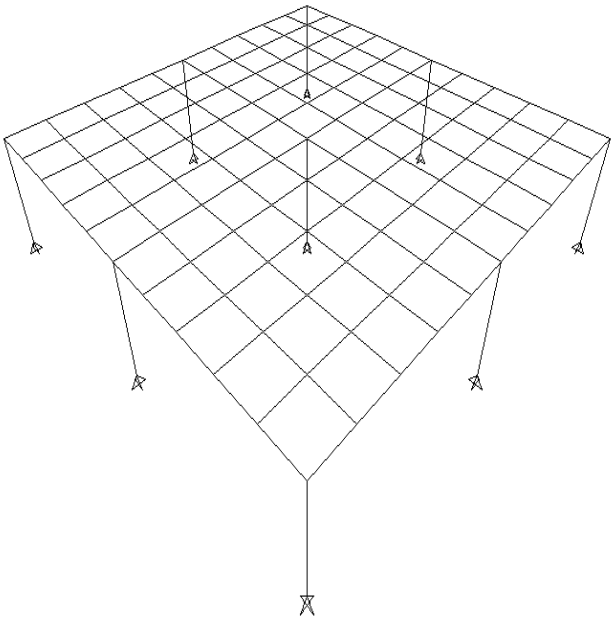

Figure 2:3D model for one story building

2.1 Case 1:- One story building model under gravity load

In this case we are going to analyze one story building model under gravity load, and find out how the slab distributes the load into columns under different types of slab. The Load hand calculation in this case the following assumptions are used:

1. The own weight of slab = 0.4 * 2.5 = 1t/m^2
2. The supper imposed load = 0.3 t/m^2
3. The live load = 0.25 t/m^2

According to this assumption, the ultimate load is (w_u) = 1.2 * (1+0.3) + 1.6 * 0.25 = 2 t/m^2

By Tributary area method, the load carried by columns is

1. Center column (C5): P = 6 * 6 * 2 = 72 t.
2. Edge column (C2, C4, C6, C8): P = 6 * 3 * 2 = 36 t.
3. Corner column (C1, C3, C7, C9): P = 3 * 3 * 2 = 18 t.

2.2 Case 2:- One story building model under horizontal load

In this case we will use one story building model under horizontal load, and see how the slab distributes the load into columns under many types of slab. In this case the following assumptions are used:

1. The horizontal load = 3t/m, see Figure 3.
2. The gravity load will be neglected, to show the effects of horizontal load only.
3. The own weight of slab will be neglected.

By Tributary area method the horizontal loads carried by columns are:

1. Center column (C5): P = 6 * 6 * (3 /12) = 9 t.
2. Edge column (C2, C4, C6, C8): P = 6 * 3 * (3 /12) = 4.5 t.
3. Corner column (C1, C3, C7, C9): P = 3 * 3 * (3 /12) = 2.25 t.

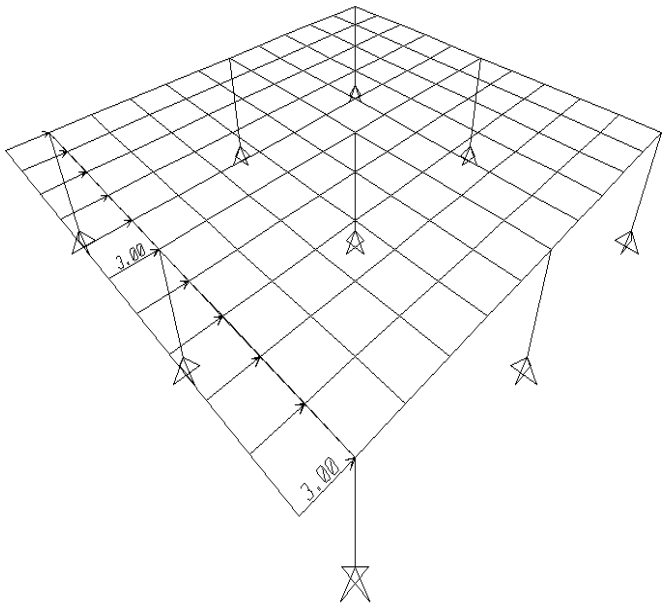

Figure 3: 3D Model for under horizontal load

3. Results and discussion

By using SAP2000 software to analyze one story building model to find axial load carried by columns under different parameters: horizontal load, gravity load, rigid slab, flexible slab and semi rigid slab.

3.1 Analysis of rigid slab under vertical load

In this type, we assume that the slab has a large stiffness comparing with the stiffness of columns, that occurs in case the slab has a large thickness and columns have a small dimensions as shown in Figure 4.

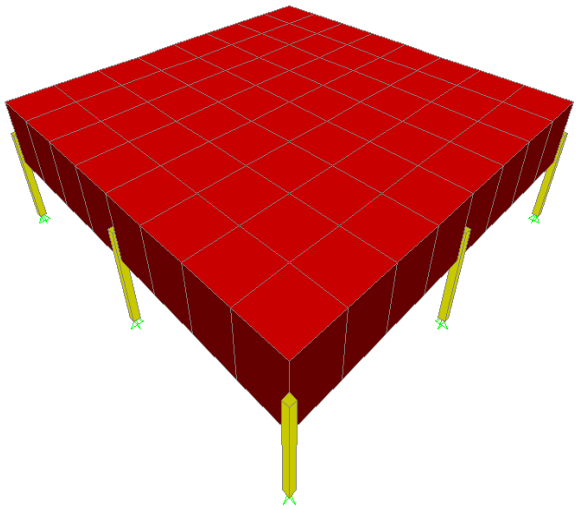

Figure 4: 3D model for rigid slab

By using SAP2000 program, we have analyzed this model and have got the results listed in Table 1.

Table 1: Transfer rigid slab axial loading under gravity load

Column Cases	Axial Loads (Ton)
Center column (C5)	37
Edge column(C2,C4,C6.C8)	33
Corner column(C1,C3,C7,C9)	30

3.2 Analysis of flexible slab under vertical load

In this type, we suppose that the slab has a small stiffness comparing with the stiffness of columns that occurs in case slab has a small thickness and the columns have large dimensions as shown in Figure 5.

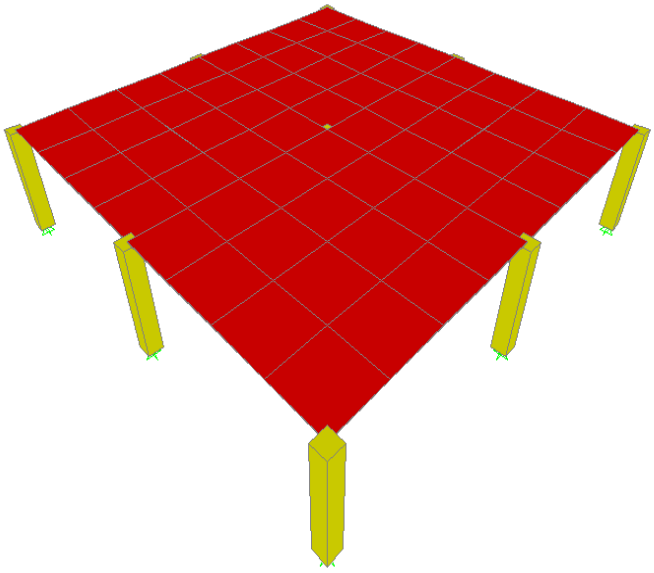

Figure 5: 3D model for flexible slab

By using SAP2000 program, we have analyzed this model and have got the results listed in Table 2.

Table 2: Transfer flexible slab axial loading under gravity load

Column Cases	Axial Loads (Ton)
Center column (C5)	88
Edge column(C2,C4,C6.C8)	35
Corner column(C1,C3,C7,C9)	15

3.3 Analysis of semi rigid slab under vertical load

In this type the model is built to simulate the real state of one story building with slab thickness equal (40cm) and dimension of columns (20 * 20 cm) as shown in Figure 6.

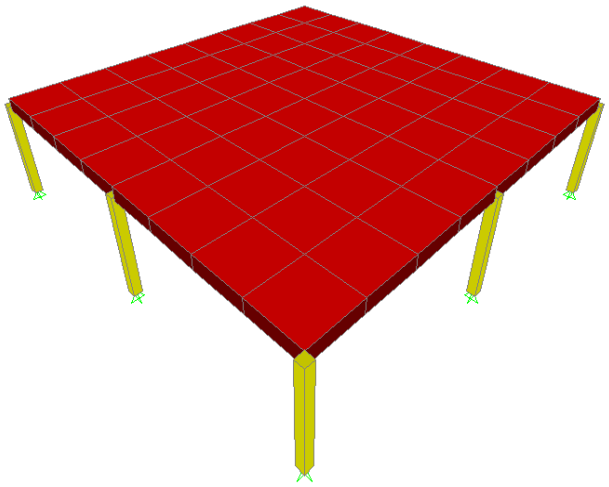

Figure 6: 3D model for semi-rigid slab

By using SAP2000 program, we have analyzed this model and have obtained the results listed in Table 3

Table 3: Transfer semi rigid slab axial loading under gravity load

Column Cases	Axial Load (Ton)
Center column (C5)	96
Edge column(C2,C4,C6.C8)	36
Corner column(C1,C3,C7,C9)	12

If we compare the results shown in Table 4 and Figure 7 which have been obtained from case (1), we can note the following:-

1. In rigid slab model, load distributed to the columns in approximately equal values.
2. In flexible slab model, load on columns small difference the values calculated by tributary area methods.
3. A big difference between values obtained from semi-rigid slab model which simulate the real state, and those obtained from tributary area method.

Table 4: Axial loads carried by columns under gravity load and different cases of slabs

Column cases	Tributary area (Ton)	Rigid slab (Ton)	Flexible slab (Ton)	Semi-rigid slab (Real state) (Ton)	Error (%) between tributary area and real state
Center column (C5)	72	37	88	96	25
Edge column(C2,C4,C6.C8)	36	33	35	36	0
Corner column(C1,C3,C7,C9)	18	30	15	12	33

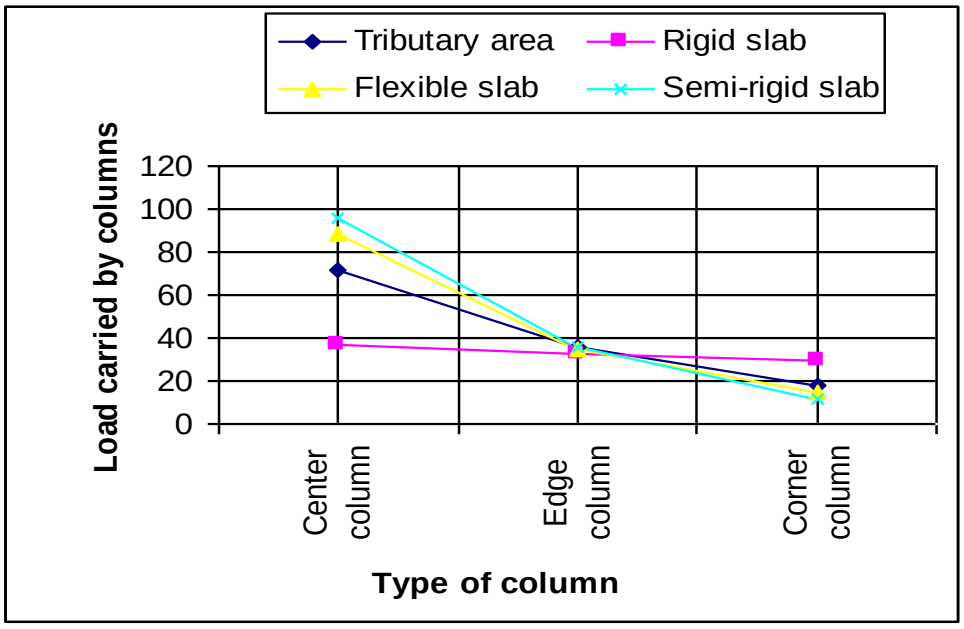

Figure 7: Axial load carried by columns under gravity load and different types of calculation

3.4 Analysis of rigid slab under horizontal load

In this type we assume that the slab have a large stiffness comparing with the stiffness of columns, that occurs if we assume the slab have a large thickness and the columns have a small dimensions. By using SAP2000 program we analyzed this model and obtained the results listed in Table 5.

Table 5: Transfer rigid slab axial loading under horizontal load

Column Cases	Axial Loads (Ton)
Center column (C5)	4
Edge column(C2,C4,C6.C8)	4
Corner column(C1,C3,C7,C9)	4

3.5 Analysis of flexible slab under horizontal load

In this type we assume that the slab have a small stiffness comparing with the stiffness of columns, that occurs if we assume the slab have a small thickness and the columns have a large dimensions. By using SAP2000 program we analyzed this model and obtained the following results listed in Table 6.

Table 6: Transfer flexible slab axial loading under horizontal load

Column Cases	Axial Loads (Ton)
Center column (C5)	9.65
Edge column(C2,C4,C6.C8)	4.5
Corner column(C1,C3,C7,C9)	2.16

3.6 Analysis of semi rigid slab under horizontal load

Model in this type is built to simulate the real state of one story building with slab thickness equal (40cm) and dimension of columns (20 * 20 cm). By using SAP2000 program we analyzed this model and obtained the results listed in Table 7.

Table 7: Transfer semi rigid slab axial loading under horizontal load

Column Cases	Axial Loads (Ton)
Center column (C5)	4
Edge column(C2,C4,C6.C8)	4
Corner column(C1,C3,C7,C9)	3.9

If we compare the results shown in Table 8 and Figure 8 which obtained from case (2), we can note the following:-

1. In rigid slab model load distributed to the columns in equal values.
2. In flexible slab model load on columns approximately equal the values calculated by tributary area methods.
3. The big difference between values obtained from semi-rigid slab model which simulate the real state, and those obtained from tributary area method.

4. The semi-rigid slab and the rigid slab have the same behavior under horizontal load.

Table 8: Axial load carried by columns under horizontal load and different cases of slab

Column cases	Tributary area (Ton)	Rigid slab (Ton)	Flexible slab (Ton)	Semi-rigid slab (Real state) (Ton)	Error (%) between tributary area and real state
Center column (C5)	9	4	9.65	4	55
Edge column(C2,C4,C6.C8)	4.5	4	4.5	4	11
Corner column(C1,C3,C7,C9)	2.25	4	2.16	3.9	42

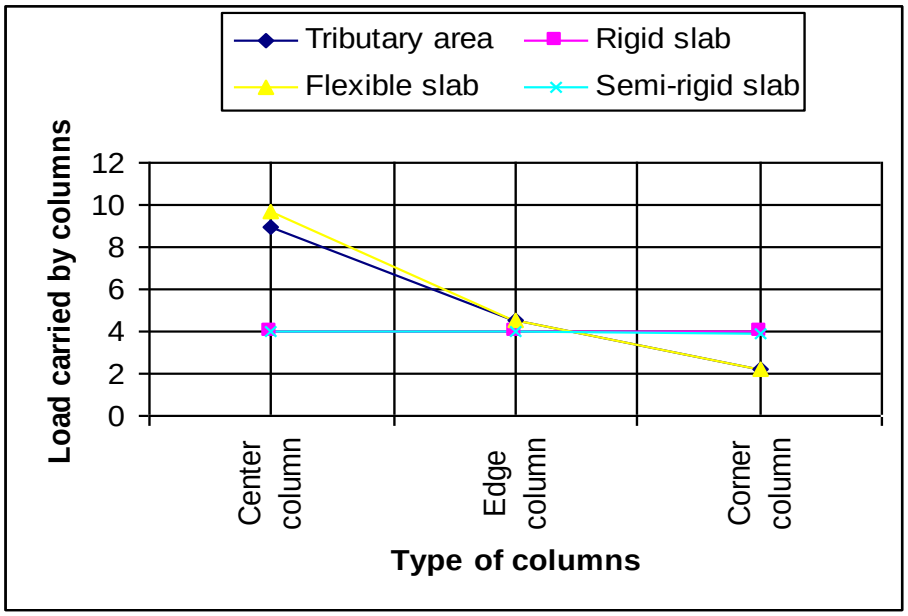

Figure 8: Axial load carried by columns under horizontal load and different types of calculation

4. Conclusion

According to the analysis of the data obtained under different parameters: gravity load, horizontal load, rigid slab, flexible slab, semi rigid slab, we can conclude that

1. Axial loads carried by columns under horizontal load and flexible slab condition approximately equal the values of axial loads obtained by tributary area method
2. The different percentage of errors between the real axial load carried by columns under horizontal and vertical loading by using SAP2000 analysis and the axial load obtained by tributary area method
3. The using 3-D model is the accurate estimation method to calculate the real load effected on columns under different cases of load and design these columns according this load.
4. Tributary area method is not always a suitable method to find axial loads on columns.

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