

# Manual and Software-Based Analysis and Design of Multi-Story Building Using Robot Structural Analysis Professional

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This study analyzed and designed a commercial building consisting of six floors manually using the Robot program. The analysis was conducted using the ROBOT Structural Analysis Professional 2020 and the structural elements were designed using the American Concrete Institute specifications (ACI 19-318), and (ACI 14-318) maximum resistance method. The study examined the buildings and their loads, including dead load and live load, as well as lateral loads such as earthquake load and wind load, and provided an engineering study of multi-story concrete buildings. The Robot structural program is a modern and high-accuracy program used in civil engineering and construction, designed to analyze concrete, steel, hydraulic, pneumatic, and other structures. The program employs 3D modeling techniques and finite element analysis (FEA). In general, it was concluded that the manual calculations are somewhat similar to the calculations of the software robot program in the case of live and dead loads. In the third case, which is dead and live loads, wind loads, and earthquakes, the difference was massive and noticeable, as the difference between the first and second cases was slightly within (0% to 25%). The difference between the first and third cases was significant, with a range of (33% to 89%).

**Keywords:** Manual Design, Software Design, Robot structural analysis professional, Wind loads, Seismic loads.

## 1. Introduction

The multi-story concrete building can be defined as a body consisting of a structural system capable of bearing loads without collapsing. The multi-story concrete buildings represent a solution to limit horizontal expansion, reduce the high cost of land, and preserve agricultural lands. They also help to facilitate the control of services and achieve the requirements of various operational and service activities, making them close to the city center. The dead loads

of multi-story concrete buildings are similar to those of ordinary concrete buildings and differ from them in that they are subjected to lateral loads resulting from wind movement, earthquakes, and others, resulting in an increase in lateral deflection due to the increase in slimness of the building. Furthermore, there is a significant increase in the vertical members to maintain the balance of the building and prevent rotation. The effect of wind loads on multi-story buildings is not limited to a significant increase in the surface area of the building's facade. Instead, it also increases the density of wind loads at high altitudes. Additionally, there is an increase in the moments regarding the building's foundation, unlike ordinary buildings. Therefore, the effect of these loads on these buildings is significantly controlled by the structural and design arrangements. The geometric shape of multi-story concrete buildings plays a fundamental role in resisting lateral loads (wind). Therefore, choosing the appropriate structural system that meets the basic requirements of the building with the lowest costs to resist these loads entails determining the appropriate method of structural analysis. Despite the numerous advantages of multi-story concrete buildings, some negative effects (obstacles) could exist it is divided into two sections:

- a. Natural problems include winds, earthquakes, soil, moisture, temperature, fires, and resistance to gravity.
- b. Construction problems (design errors - execution errors).

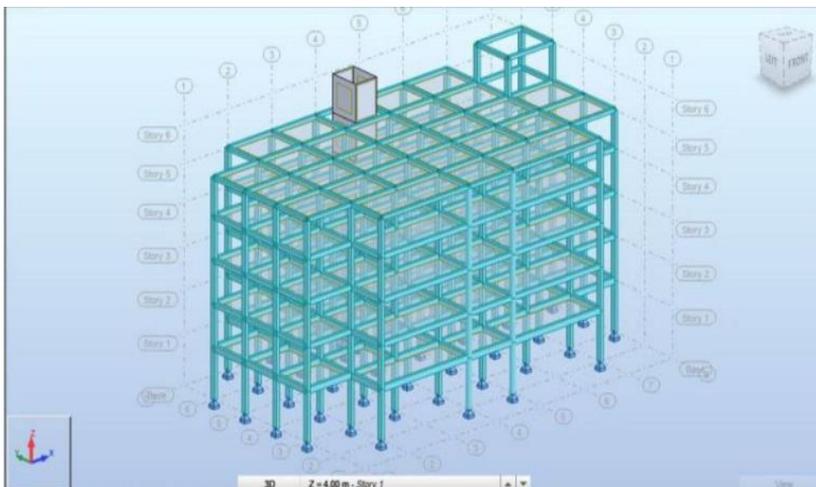


Figure 1. Design of a multi-story building using a robot program

## 2. LOADS PLACED ON THE BUILDING

2.1 Dead Loads: Dead loads consist of the permanent construction material loads compressing the roof, floor, wall, and foundation systems, including claddings, finishes and fixed equipment. Dead load is the total load of all of the components of the components of the building that generally do not change over time, such as the steel columns, concrete floors, bricks.

2.2 Live Loads: Live loads are produced by the use and occupancy of a building.

Loads include those from human occupants, furnishings, no fixed equipment, storage, and construction and maintenance activities. As required to adequately define the loading condition, loads are presented in terms of uniform area loads, concentrated loads, and uniform line loads.

2.3 Wind loads

In the list of loads we can see wind load is present both in vertical and horizontal loads. This is because wind load causes uplift of the roof by creating a negative(suction) pressure on the top of the roof wind produces non static loads on a structure at highly variable magnitudes, the variation in pressures at different locations on a building is complex to the point that pressures may become too analytically intensive for precise consideration in design.

2.4 Floor load

Floor load is calculated based on the load on the slabs. Assignment of floor load is done by creating a load case for floor load.

2.5 Earthquake loads (earthquake)

Is a rapid opposite movement of the earth It usually exceeds one minute in duration. horizontal and vertical forces Applied to buildings, horizontal forces lead to movement Foundations of the direction of the Earth's movement, and separating the foundations of buildings from their other upper parts, Structural elements: -

a) SLABS

They are flat structural elements that are placed horizontally in the structure and serve to transfer loads to the supports It is either to the bridges or to the columns directly or to the bearing walls and its thickness is small compared to its space. a) Classification of slabs according to the direction of load distribution.

b) ONE WAY SLABS

2.5.1 Solid slabs

The slab is called one-way if it is the ratio of the long to the short length ( $L/S > 2$ ). When it rests on two opposite supports only. In this type of slabs, loads are transmitted in one direction, and this type is determined by the length-to-width ratio.

2.5.2 Two-way slabs:

A slab is called two-way if the ratio of the long length to the short length is equal. In this type of slabs, loads are transmitted in both directions, and the ratio between length to width is less than or equal to 2.

Table 1. Manual Design results of slab (Ground Floor)

No. of slab	Direction	H (mm)	Vu <sub>max</sub> (kN)	Mu <sub>max</sub> (kN.m)	As (mm <sup>2</sup> )	Spacing (mm)
S1	Long	200	8.116	10.63	360	300
	Short	200	11.462	16.845	360	300
S2	Long	200	10.52	15.35	360	300
	Short	200	20.65	12.84	360	300
S3	Long	200	9.785	9.917	360	300
	Short	200	16.85	15.95	360	300
S4	Long	200	6.684	10.299	360	300
	Short	200	15.86	15.868	360	300
S5	One way slab	200	30.86	16.14	360	300
		200	30.86	25.1	389	290

c) BEAMS

Beams are horizontal structural elements that are able to bear transverse loads perpendicular to their longitudinal axis as a result of the loads coming from the slabs and walls as well as the self-weight from which bending moments arise.

Table 2. Manual Design results of beams (Ground Floor)

No. of beam	Type of load	As (mm <sup>2</sup> )	Reinforcement
B1	Triangle load	803.6	4φ16
	Trapezoid load	1205.4	6φ16
B2	Triangle load	803.6	4φ16
	Trapezoid load	1205.4	6φ16
B3	Triangle load	803.6	4φ16
	Trapezoid load	1205.4	6φ16
B4	Triangle load	803.6	4φ16
	Trapezoid load	1205.4	6φ16
B5	Long	2000	10φ16
	Short	600.7	3φ16

d) COLUMNS

They are the structural members that transfer loads through bridges to the foundations, and they are elements that bear axial compressive forces or compressive forces with torques about one axis or about two axes.

Table 3: Manual Design of Column Longitudinal Reinforcement

Story	External	Internal	Corner
1	6φ16	10φ16	6φ16
2	6φ16	8φ16	6φ16
3	6φ16	6φ16	6φ16
4	6φ16	6φ16	5φ16

5	6 $\phi$ 16	6 $\phi$ 16	6 $\phi$ 16
6	6 $\phi$ 16	6 $\phi$ 16	4 $\phi$ 16

#### d) DESIGN OF FOUNDATIONS

The purpose of the foundations is to transfer loads on columns or load-bearing walls in buildings to the soil below them, and the design of foundations often requires special care and precautions unlike other structural elements (such as beams and slabs), since any error in their design can be easily corrected except for errors In the

design of the foundations, where this leads to the collapse of part or all of the structure once it is completed directly, and that is why it is highly recommended to take caution and make the necessary reservations for both the design and implementation of the foundations, and also it is not like designing all the structural elements that are above the surface of the earth.

Table 4. Manual Design of Reinforcing of raft foundations

Pu (KN)	X` (m)	Y` (m)	A <sub>s</sub> bottom steel (mm)	Spacing (mm)	A <sub>s</sub> top Steel (mm)	Spacing (mm)
2228	<b>10.72</b>	<b>9.2</b>	<b>5518</b>	<b><math>\phi</math>30@100</b>	<b>7312</b>	<b><math>\phi</math>30@130</b>

#### e) THE STAIRS

Stairs are a means of communication between one floor and the other. Or a set of stairs consisting of an inclined plane intended for easy access from one floor to another. Stairs are placed in a place designated for them in the building. known idiomatically as the stair well

#### f) SHEAR WALLS

It is a vertical concrete structural member and it is originally a column. If its depth is more than five times its width, we consider it a shear wall. Its purpose is to resist vertical loads (gravitational loads) resulting from live loads and dead loads, its self-weight and resistance to horizontal loads resulting from winds and earthquakes.

Table 5. Manual Design of Reinforcing shear walls

Story	L (m)	Pu (kN)	Vu (kN)	Mu (kN.m)	No. of horizontal	No. of vertical
Bedroom	2.5	5823.05	2166.65	34046.17	16@22	18@22

### 3. RESULTS AND DISCUSSION

The design of buildings to resist earthquakes, with regard to tall buildings and important concrete installations such as bridges and dams, is located in the seismic-bearing region, except for some areas that are located on the edges of known seismic zones in the world, especially in northern Iraq, some regions of Morocco and Algeria, and the continental geological border areas in the Red Sea and the Gulf of Aqaba, which requires The engineer must take seismic loads into consideration when designing structures in these areas, especially tall buildings and important concrete structures such as bridges and dams.

An earthquake (earthquake) is a rapid opposite movement of the earth that usually exceeds  
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one minute in duration. Horizontal and vertical forces are applied to the buildings, and the horizontal forces lead to the movement of the foundations with the direction of the earth's movement, and the separation of the foundations of the buildings from their other upper parts, and the large upper parts of the buildings cancel out the effect of what is the area The external floor to manufacture the image from the floor area generated by this image.

Earthquake recording devices know the schematic recording that is used to establish an attic in the assembly stations, and as a result, the vibration subsides and the oscillation decreases, and these lines express the recording time and the shape. The arrival of seismic waves from the source of the earthquake, and it is noted that the seismic graph gives us a true perception of the length of the earthquake period and its intensity and vibration amplitude.

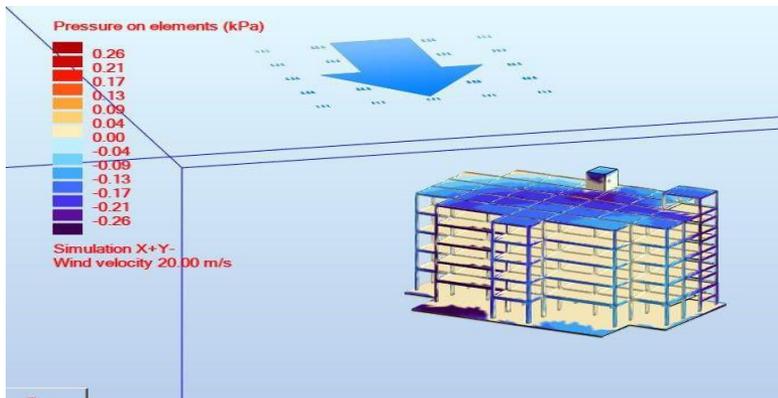


Figure 2. The effect of wind on the building

Story	Reinforcement
1	21 Ø16
2	15 Ø16
3	15 Ø16
4	15 Ø16
5	15 Ø16
6	15 Ø16
Story	External
1	15 Ø16
2	15 Ø16
3	15 Ø16
4	10 Ø16
5	4 Ø16
6	4 Ø16

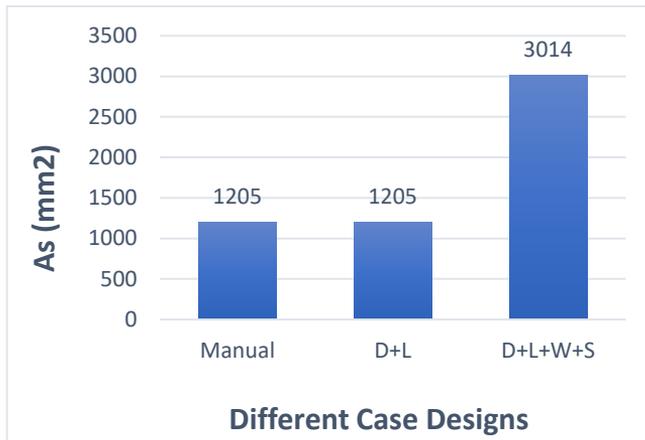


Figure 3. Comparison between the results of the Manual & D+L & D+L+W+S for Columns

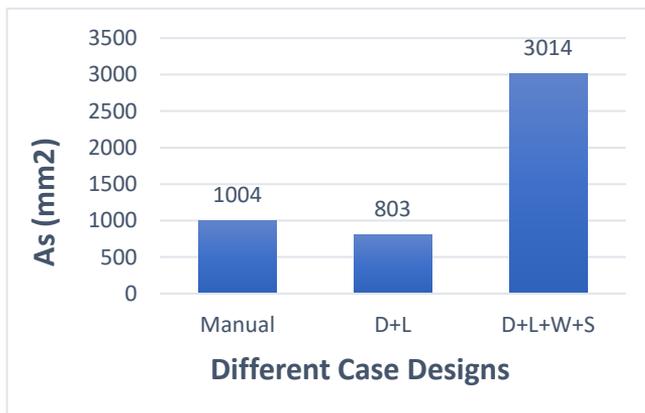


Figure 4. Comparison between the results of the Manual & D+L & D+L+W+S for Beams

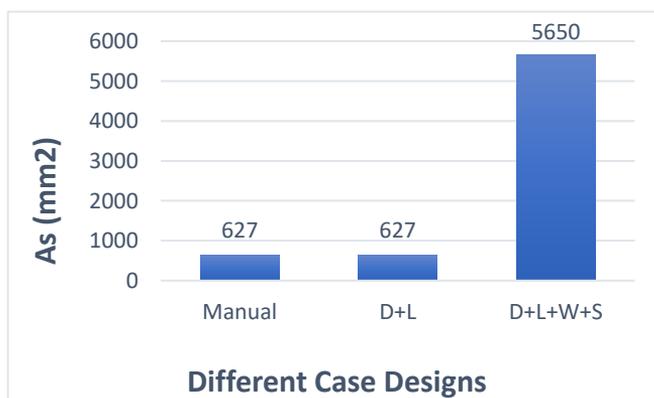


Figure 5. Comparison between the results of the Manual & D+L & D+L+W+S for stairs

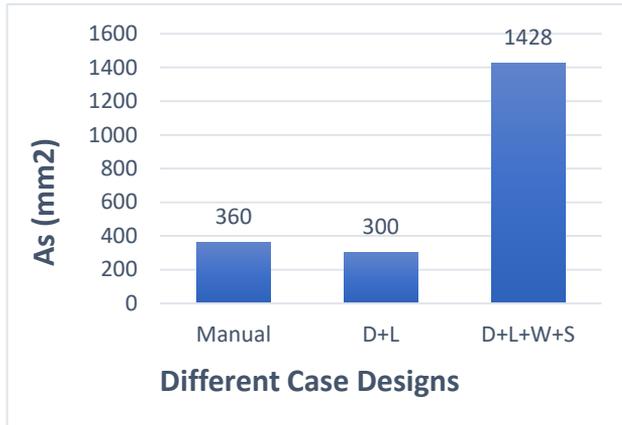


Figure 6. Comparison between the results of the Manual & D + L & D + L + W + S for Slab

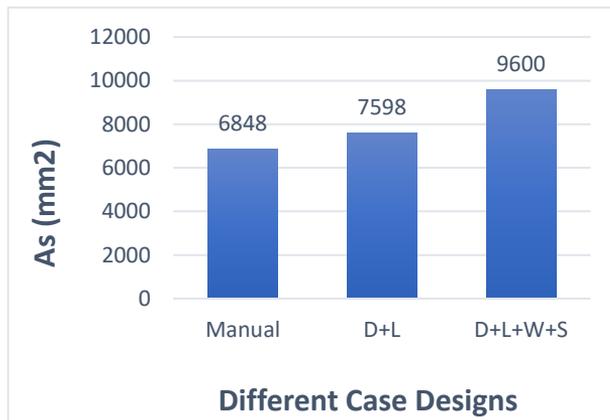


Figure 7. Comparison between the results of the Manual & D+L & D+L+W+S for Shear Wall

In general, it was concluded that the manual calculations are somewhat similar to the calculations of the robot program in the case of live and dead loads. In the third case, which is dead and live loads, wind loads, and earthquakes, the difference was vast and noticeable, as the difference between the first and second cases was slightly within (0% to 25%). The difference between the first and third cases was significant, with a range of (33% to 89%).

#### 4. CONCLUSION

Through this wandering in this research and identifying its data and aspects, and then coming out with a summary of this research through the results of below:

- 1- Understanding the architectural plans has a major role in finding appropriate structural solutions for the type of use in the building.
- 2- The ability to solve manually is necessary for the structural designer to confirm the solution of the calculated programs and understand how they work.

- 3- Identify the structural elements, and how to deal with them. And with its mechanism of action in order to be designed as a good amulet that achieves safety and Structural strength.
- 4- Computer programs deal with dynamic and static loads in some detail, and analysis and design are carried out according to the required codes and different loading conditions, so the results of the program are of high accuracy.
- 5- In general, it was concluded that the manual calculations are somewhat similar to the calculations of the robot program in the case two of live and dead loads
- 6- In the third case, which is dead and live loads, wind loads, and earthquakes, the difference was vast and noticeable, as the difference between the first and second cases was slightly within (0% to 25%).
- 7- The difference between the first and third cases was significant, with a range of (33% to 89%).

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