Analysis and Design of Multistorey Building G+4

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Abstract: A multi-storey is a building that has multiple floors above the ground. It can be a residential or commercial building. In this project the analysis and design of multi-storey building G+4. In general, the analysis of multi-storey is elaborate and rigorous because those are statically indeterminate structures. Shears and moments due to different loading conditions are determined by many methods such as portal method, moment distribution method and matrix method.

The present project deals with the analysis of a G+4 building. The dead load & live loads are applied and the design for beams, columns, the footing is obtained manually. The Analysis part of the structure is done using Kani’s Method and the values are taken for design.

Keywords: Multi-storey, Load Bearing Masonry Buildings.

INTRODUCTION

The procedure for analysis and design of a given building will depend on the type of building, its complexity, the number of stories etc. First, the architectural drawings of the building are studied, structural system is finalized sizes of structural members are decided and brought to the knowledge of the concerned architect. The procedure for structural design will involve some steps which will depend on the type of building and also its complexity and the time available for structural design. Often, the work is required to start soon, so the steps in design are to be arranged in such a way the foundation drawings can be taken up in hand within a reasonable period of time.

Further, before starting the structural design, the following information of data are required:
(i) A set of architectural drawings;
(ii) Soil Investigation report (SIR) of soil data;
(iii) Location of the place or type of building in order to decide loadings;
(iv) Data for lifts, water tank capacities on top, special roof features or loadings, etc. Choice of an appropriate structural system for a given building is vital for its economy and safety. There are two type of building systems:-
(a) Load Bearing Masonry Buildings.
(b) Framed Buildings.

(a) Load Bearing Masonry Buildings

Small buildings like houses with small spans of beams, slabs generally constructed as load bearing brick walls with reinforced concrete slab beams. This system is suitable for building up to four or fewer stories. (As shown in fig. below). In such buildings crushing strength of bricks shall be 100 kg/cm² minimum for four stories. This system is adequate for vertical loads it also serves to resists horizontal loads like wind & earthquake by box action. Further, to ensure its action against earthquake, it is necessary to provide RCC Bands in horizontal & vertical reinforcement in brick wall as per IS: 4326-1967(Indian Standards Code of Practice for Earthquake Resistant Construction of Buildings.). In some Buildings, 115mm thick brick walls are provided since these walls are incapable of supporting vertical loads, beams have to be provided along their lengths to support adjoining slab & the weight of 115mm thick brick wall of the upper storey. These beams are to rest on 230 mm thick brick walls or reinforced concrete columns if required. The design of Load Bearing Masonry Buildings are done as per IS 1905-1980 (Indian Standards Code of Practice for Structural Safety of Buildings: Masonry Walls (Second Revision). Load bearing brick wall.

(b) Framed Buildings

In these types of buildings, reinforced concrete frames are provided in both principal directions to resist vertical loads and the vertical loads are transmitted to vertical framing system i.e., columns and Foundations. This type of system is effective in resisting both vertical & horizontal loads. The brick walls are to be regarded as non-load bearing filler walls.
only. This system is suitable for the multi-storied building which is also effective in resisting horizontal loads due to the earthquake. In this system the floor slabs, generally 100-150 mm thick with spans ranging from 3.0 m to 7.0 m. In certain earthquake prone areas, even single or double storey buildings are made framed structures for safety reasons. Also the single storey buildings of large storey heights (5.0m or more), like electric substation etc. are made the framed structure as brick walls of large heights are slender and load carrying capacity of such walls reduces due to slenderness.

1.1 BASIC CODES FOR DESIGN
The design should be carried so as to conform to the following Indian code for reinforced concrete design, published by the Bureau of Indian Standards, New Delhi:

**Purpose of Codes**

National building codes have been formulated in different countries to lay down guidelines for the design and construction of the structure. The codes have evolved from the collective wisdom of expert structural engineers, gained over the years. These codes are periodically revised to bring them in line with current research, and often, current trends. Firstly, they ensure adequate structural safety, by specifying a certain essential minimum requirement for design. Secondly, they render the task of the designer relatively simple; often, the result of sophisticated analyses is made available in the form of a simple formula or chart. Thirdly, the codes ensure a measure of consistency among different designers. Finally, they have some legal validity in that they protect the structural designer from any liability due to structural failures that are caused by inadequate supervision and/or faulty material and construction.

(i) **IS 456: 2000 – Plain and Reinforced Concrete – Code of Practice (Fourth Revision)**
(ii) **Loading Standards**

These loads to be considered for structural design are specified in the following loading standards:

**IS 875 (Part 1-5): 1987 – Code of practice for design loads (other than earthquake) for buildings and structures (second revision)**

- Part 1: Dead loads
- Part 2: Imposed (live) loads
- Part 3: Wind loads
- Part 4: Snow loads
- Part 5: Special loads and load combinations

**Design Handbooks**
The Bureau of Indian standards has also published the following handbooks, which serve as a useful supplement to the 1978 version of the codes. Although the handbooks need to be updated to bring them in line with the recently revised (2000 version) of the Code, many of the provisions continue to be valid (especially with regard to structural design provisions).

- **SP 16: 1980 – Design Aids (for Reinforced Concrete) to IS 456: 1978**
- **SP 34: 1987 – Handbooks on Concrete Reinforced and Detailing.**

**General Design Consideration of IS: 456-2000.**
The general design and construction of reinforced concrete buildings shall be governed by the provisions of IS 456–2000

### 1.2 AIM OF DESIGN
The aim of design is achievement of an acceptable probability that structures being designed shall, with an appropriate degree of safety –

### 1.3 METHOD OF DESIGN

- **Structure and structural elements shall normally be designed by Limit State Method.**
- **Where the Limit State Method cannot be conveniently adopted, Working Stress Method may be used.**

### MINIMUM GRADE OF CONCRETE
The minimum grade of concrete for plain & reinforced concrete shall be as per table below:

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Plain Concrete</th>
<th>Reinforced Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Minimum</td>
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<tr>
<td></td>
<td>Grade of Concrete</td>
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<td>Concrete</td>
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<td></td>
<td>kg/m³</td>
<td>kg/m³</td>
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<tr>
<td>i)</td>
<td>M15</td>
<td>M20</td>
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<tr>
<td>ii)</td>
<td>M20</td>
<td>M25</td>
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<tr>
<td>iii)</td>
<td>M25</td>
<td>M30</td>
</tr>
<tr>
<td>iv)</td>
<td>M30</td>
<td>M35</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Concrete cured in moist condition and is tested at the age of 28 days. 2. These grades are suitable for general purposes.

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BUILDING DESIGN

2.1 G+4 BUILDING DESIGN

2.1.1 DESIGN OF SLAB:

I: kitchen room size: 4.83m×4.83m f.e 415, M20, Clear cover =20mm

Assuming the depth of the slab as 120mm effective depth = 120-20-10 =100 mm

Load calculation:

Dead Load = 0.1X25 = 2.5kn/m²

Live Load = 3kn/m²

Floor Finish = 1kn/m²

Total load = 6.5kn/m²

Factored total load = 6.5*1.5 = 9.75kn/m²

ly/lx = 4.83/4.83 = 1<2

Design as two way slab.

Two adjacent edges discontinuous

αx for = 1 = 0.047 (For –Ve moment)

αy for = 1 = 0.035 (For +Ve moment)

Mx = αxwlx²

For –ve moment in x direction

Mx= -0.047x9.75x4.83 = -10.69KNm

The +ve moment in x direction

Mx = 0.035x9.75x4.83 = 7.96KNm.

My = a y2 = -0.047x9.75x4.82

My = -10.69KNm

The +ve moment in y direction

My = 0.035x9.75x4.83x4.83 = 7.96KNm

Checking for depth

Taking max moment & checking depth

\[ Mu = 0.138 \times f_{ckbd}^2 \]

\[ 10.69\times10^6 = 0.138\times20\times1000\times d^2 \]

\[ d = 62.23\text{mm}\times100\text{mm safe} \]

Calculation of Ast:

Along shorter span:

\[ Mu = 0.87 \]

Taking –Ve moment

\[ Ast = 10.69\times10^6 = 0.87\times415\times Ast \]

\[ Ast = 316.916\text{mm} \]

Spacing of bars 10mm ø bars is

\[ = 247.825\text{mm} \quad = \quad 240\text{mm} \]

Hence proved 10mm ø bars @ 240mm c/c spacing @ edge strip

Provide 10mm ø bars @ 300mm c/c spacing at @ middle strip.

2.1.3. DESIGN OF LIVING ROOM

Living room size: 7.56m×4.83m f.e 415, M20, Clear cover =20mm

Assuming the depth of the slab as 120mm effective depth = 120-20-10 =100 mm

Load calculation:

Dead Load = 0.1X25 = 2.5kn/m²

Live Load = 3kn/m²

Floor Finish = 1kn/m²

Total load = 6.5kn/m²

Factored total load = 6.5*1.5 = 9.75kn/m²

ly/lx = 4.83/2.53 = 1.9<2

Design as two way slab.

One short edge continuous

αx for = 1 = 0.053 (For –Ve moment)

αy for = 1 = 0.032 (For –Ve moment)

Mx = αxwlx²

For –ve moment in x direction

Mx= -0.050x9.75x4.83 = -12.05KNm

αx for =1.5 =0.53 (For –Ve moment)

αy for =1.5 =0.32 (For –Ve moment)

Mx= αxwlx²

For –ve moment in x direction

Mx= -0.041x9.75x4.83 = -12.05KNm

αx for =1.5 =0.53 (For –Ve moment)

αy for =1.5 =0.32 (For –Ve moment)

Mx= αxwlx²

For –ve moment in x direction

Mx= -0.041x9.75x4.83 = 9.32KNm

My = -0.041x9.75x4.83x4.83 = 9.32KNm

For -Ve moment in y direction

\[ My = -0.032x9.75x4.83x4.83 \]

Checking for depth

Taking max moment & checking depth

\[ Mu = 0.138\times f_{ckbd}^2 \]

\[ 4.11\times10^6 = 0.138\times20\times1000\times d^2 \]

\[ d = 66.075\text{mm} <100\text{mm hence safe} \]
Calculation of Ast:
Along shorter span:
\[ \text{Mu} = 0.87 \ \text{Ast Taking –Ve moment} \]
\[ 12.05 \times 10^6 = 0.87 \times 415 \times \text{Ast} \]
\[ \text{Ast} = 360.745 \text{mm}^2 \]
Spacing of bars 10mm ø bars is
\[ = 217.715 \text{mm} = 300 \text{mm} \]
Hence proved 10mm ø bars @ 200mm c/c spacing @ edge strip Taking +Ve moment
\[ 9.32 \times 10^6 = 36105 \text{mm}^2 \]
\[ \text{Ast} = 286.98 \text{mm} S \]
Provide 10mm ø bars @ 280mm c/c spacing at @ middle strip
Hence safe

**ALONG LONGER SPAN**

Calculation of Ast:
Along longer span:
\[ \text{Mu} = 0.87 \ \text{Ast Taking –Ve moment} \]
\[ 7.27 \times 10^6 = 0.87 \times 415 \times \text{Ast} \]
\[ \text{Ast} = 210.55 \text{mm}^2 \]
Spacing of bars 10mm ø bars is
\[ = 373.02 \text{mm} > 300 \text{mm} \]
Hence proved 10mm ø bars @ 300mm c/c spacing at @ middle strip
Taking +Ve moment
\[ 5.45 \times 10^6 = 36105 \text{mm}^2 \]
\[ \text{Ast} = 52.64 \text{mm}^2 \]
Spacing of 10mm ø bars
\[ = 280 \text{mm} \]
Provide 10mm ø bars @ 300mm c/c spacing at @ middle strip

**Chapter-3 KANI’S METHOD ANALYSIS FOR G+4 BUILDING**

3.1. SIZE OF BEAM

\[ \text{B} = \frac{I}{3} \] 
\[ \text{D} = \frac{1}{12} \cdot \frac{5030}{12} = 419 \text{mm} \times 420 \text{mm} \]

\[ \text{BxD} = 420 \times 280 \text{mm} \]

\[ \text{I} = \frac{\text{B}^3}{12} \times \frac{280 \times 420}{12} = 1.7 \times 10^8 \text{mm}^4 \]

3.2. SIZE OF COLUMN

\[ \text{BxH} = 300 \times 400 \]

\[ \text{I} = \frac{\text{B}^3}{12} \times \frac{300 \times 400}{12} = 1.6 \times 10^9 \text{mm}^4 \]

3.3. CALCULATION OF SLAB LOAD ON BEAMS:

**AB LOAD = 9.75 KN/M²**

\[ \text{l}_x = 4.83 \text{m} \ 	ext{ly} = 4.83 \text{m} \]

\[ 3 \left( \frac{\text{ly}}{3} \right)^2 \times \frac{\text{w}_{x}}{6} \]

\[ \{ 3 \left( \frac{4.83}{3} \right)^2 \times \frac{9.75 \times 4.83}{6} = 15.96 \text{kn/m} \}

Weight of parapet wall
\[ = 19 \times 1.3 \times 0.125 = 3.08 \text{kn/m} \]

**BC Load = 9.75kN/mm²**

\[ \text{l}_x = 2.53 \text{m} \ 	ext{ly} = 4.83 \text{m} \]

\[ 3 \left( \frac{\text{lx}}{3} \right)^2 \times \frac{\text{w}_{x}}{3} \]

\[ \{ 3 \left( \frac{2.53}{3} \right)^2 \times \frac{9.75 \times 2.53}{3} = 22.4 \text{kn/m} \}

Weight of parapet wall
\[ = 19 \times 1.3 \times 0.125 = 3.08 \text{kn/m} \]

**CD Load = 9.75kN/mm²**

\[ \text{l}_x = 4.83 \text{m} \ 	ext{ly} = 5.03 \text{m} \]

\[ 3 \left( \frac{\text{lx}}{3} \right)^2 \times \frac{\text{w}_{x}}{6} \]

\[ \{ 3 \left( \frac{4.83}{3} \right)^2 \times \frac{9.75 \times 4.83}{6} = 16.3 \text{kn/m} \}

Weight of wall
\[ = 19 \times 1.3 \times 0.125 = 3.08 \text{kn/m} \]

**Fixed end Moments:**

\[ \text{MAB} = - \frac{w_{12}^2}{12} = -36.49 \text{kNm} \]

\[ \text{MBA} = + \frac{w_{12}^2}{12} = 36.49 \text{kNm} \]

\[ \text{MBC} = - \frac{w_{12}^2}{12} = -13.61 \text{kNm} \]

\[ \text{MCB} = + \frac{w_{12}^2}{12} = 13.61 \text{kNm} \]

\[ \text{MCD} = - \frac{w_{12}^2}{12} = -40.86 \text{kNm} \]

\[ \text{MDC} = + \frac{w_{12}^2}{12} = +40.86 \text{kNm} \]

\[ \text{MAB} = - \frac{w_{12}^2}{12} = -58.38 \text{kNm} \]

\[ \text{MBA} = + \frac{w_{12}^2}{12} = +58.38 \text{kNm} \]

\[ \text{MBC} = - \frac{w_{12}^2}{12} = -58.38 \text{kNm} \]

\[ \text{MCB} = + \frac{w_{12}^2}{12} = +58.38 \text{kNm} \]
3.4. DESIGN OF BEAMS
3.4.1. FOR BEAM AB

\[ M_{ab} = M'_{ab} + 2M_{ab} + M_{ba} = -36.49 + 2 \times 7.80 - 2.01 = -22.9 \text{kNm} \]

\[ M_{ba} = M'_{ba} + 2M_{ba} + M_{ab} = 36.49 + (2 \times -2.01) + 7.80 = 40.27 \text{kNm} \]

Final moment = 20.9 + 40.27 = 30.58 \text{kNm}

\[ \frac{\pi l^2}{8} = \frac{18.77 \times 4.83}{8} = 54.73 \text{kNm} \]

\[ \text{Moment} = 54.73 - 30.58 = 24.15 \text{kNm} \]

\[ \mu_{\text{limit}} = 0.138 f_{ck} b d^2 = 0.138 \times 20 \times 280 \times 384 \times 10^6 = 113.95 \times 10^6 \text{KNm} \]

Calculation of Ast

\[ A_{st} = \frac{f_{ck} b d^2}{2 f_y} \left[ 1 - \sqrt{1 - \frac{4.59 b f_{ck} d^2}{20 b_2}} \right] = 180.47 \text{mm}^2 \]

Spacing of 16mm \( \phi \) bars.

\[ \frac{\pi l^2}{8} = 626.68 \text{mm} \]

No of bars = \[ \frac{626.68}{2.12}\times 12 = 1.59 \] = 2 bars/m

Provide 12 mm \( \phi \) bars

@ 300 mm c/c spacing.

Provide 8mm \( \phi \) 2 legged stirrups

Shear force = \[ \frac{w l^2}{2} \times 12.44 = 190.77 \text{kNm} \]

Spacing Sv = \[ \frac{0.87 f_{y} A_{st}}{s f} = \frac{0.87 \times 415 \times 2 \times 80 \times 8 \times 300 \times 217.7 \times 10^6}{2} = 500 \text{mm} \]

Provide 8mm \( \phi \) 2 legged stirrups @ 300 mm c/c spacing.

COLUMN DESIGN FOR G+4 BUILDING

AXIAL COLUMNS:
COLUMN 3:

\[ P_u = 23715 \text{kN} \]

\[ P_o = 0.4 f_{ck} A_c + 0.67 f_y A_{ac} \]

**DESIGN OF FOOTING FOR G+4 BUILDING**

Column load = 237.15kN

Column size = 300x400

Column Ast = 16mm \( \phi \) bars

Soil bearing capacity = 100kN/mm2

Base of footing @ 1 m below ground level

r = 20kN/

\[ f_{ck} = 20 \text{N/mm2} \]

\[ f_y = 415 \text{N/mm2} \]

Approximate area of footing = column load/s.b.c

= 237.17/100 = 2.37mm2

Total weight on Earth = 20x1x2.37 = 47.43kN

Total weight on column including Earth is = 237.15 + 47.43 = 284.58kN

Area of footing = 284.58/100 = 2.84 \( \sqrt{2.84} = 1.68 \text{m} = 1.7 \text{m} \)

Size of footing = 1.7mx1.7m

**Bending Moment:**

A critical section is at the face of the column.

Net pressure = \[ \frac{237.15 \times 1.5}{1.7 \times 1.7} = 123.08 \text{kN/mm2} \]

B.m = 123.08x1.7x0.7/2 = 51.26kNm

**Effective depth:**

\[ M = 0.138 f_{ck} b d^2 \]

\[ 23 \times 10^6 = 0.138 \times 20 \times 1700 \times d^2 \]

\[ D = 104.52 \text{mm} \]
Provide 200mm depth for taking shear into consideration
(104.52x2=210=260mm)
D=260mm
d=260-40=220mm

Calculation of Ast:

\[
Ast = \frac{f_{ck}}{2f_y} \left[1 - \sqrt{1 - \frac{4.59x_{mu}x_{bd}}{20x1700x220}}\right]x1700x220
\]

=670.22mm²

Spacing of 10mm ø bars

\[
\pi \frac{4}{10} x 2 = 117.184 \text{ mm}
\]

No of bars = 670.2224x10² ≈ 8.53 = 9 number of bars

Check:

One way shear:

A critical section is at a distance d from the face of the column.

Tv=Vu/bd

Vu=123.08x1.7x0.48 =100.43kN
Tv= bd

Tc =% of steel , Pt =Astx100/bd

For M20 and 0.2% STEEL

Tc ≈ 0.2 KN/mm²

kx. = 1.2x0.24 ≈ 0.288N/mm²
Tv<kSafe against one way shear

Two way shear:

Considering two- way shear @ A distance of d/2 from the face of the column.

Periphery of column = (300+d+400+d)x2

Tv=Vu/bd

Vu=Net pressure + [BXL-(b+d)(l+d)] =123.08+[1.7x1.7-

(0.3+0.22)x0.4+0.22)]

Vu=125Kn B=(0.3+0.22)x2+(0.4+0.22)x2 = 2.8m

Tv=125x10²/2280x220=0.24n/mm²

The limiting stress in concrete ,Tc = Ks\times0.25\sqrt{fck}

Ks = 0.50 +f_b =0.50+0.30 = 1.25>1

Ks = 1

Tc = 1x0.25x\sqrt{20} = 1.1N/mm²
Tv<KTc

Hence safe against two way shear

Transfer of load from column to footing:

\[
0.45fck \sqrt{\frac{A1}{A2}} \text{ From page 65 IS 456}
\]

A1=0.4+4D = 0.4+4x0.26 = 0.8+4D = 0.4+4x0.26
A2=0.3x0.4
=0.121.440.12

=3.45>2

\[
\sqrt{\frac{A1}{A2}} = 2
\]

0.45x20x2 = 18 n/mm²

Actual bearing capacity = column load/ area of column
=237.15x10²/300x400=1.97 N/mm²

> Actual bearing capacity

> safe against bearing

STAIRCASE DESIGN FOR G+4 BUILDING

5.1. DOG – LEGGED STAIR-CASE

Height b/w floor = 3m

Live load = 3kN/mm² , Floor finish = 1kN/mm²

M20, Fe 415 grade steel

Width of flight = 3m

Let riser be 200mm

Number of rises = 1.5/0.2 = 7.5≈8 Numbers

Number of threads = 8-1 = 7m

Let Thread = 400mm

Going = 7x0.4 = 2.8m

Span in m = G + X + Y = 2.8+0.75+0.75 = 4.3m

Over length of stair = 4.3 + 1.5 + 0.25 = 6.05m

D = 1/20 = 0.05

Tv=125x10³/2280x220=0.24n/mm²

The limiting stress in concrete ,Tc = Ks\times0.25\sqrt{fck}

Ks = 0.50 +f_b =0.50+0.30 = 1.25>1

Ks = 1

Tc = 1x0.25x\sqrt{20} = 1.1N/mm²
Tv<KTc

Hence safe against two way shear

LOADS ON LANDING:

Self weight = 0.4x25 = 10kN/mm²

Floor load = 3kN/mm²

Floor finish = 1kN/mm²

Total load = 6kN/mm²

Factored load = 17.68x1.5 = 26.52kN/mm²

DISTRIBUTION STEEL

Ast = 0.12BD = 0.12x1500x300 = 540mm²

Using 16mmΦ bars

Number of bars =1406.68x4/\pi x162 = 12.64 ≈ 13 bars
Using 12 mm Φ bars

\[
\text{Spacing} = \frac{1000 \times 12^2 \times \pi}{540} = 209 \approx 200\text{mm}
\]

**CONCLUSION**

❖ In this report, a design of multi-story Building G+4 is presented.
❖ The durability of a building depends mainly on proper construction and proper use of construction materials.

**REFERENCES**

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