DESIGN OF BIOCLIMATIC STRUCTURE WITH INSULATION OF CAVITY WALL

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Abstract - *A sustainable design approach that attempts to connect with nature and maintaining the building comfort based on local climate like summer, winter, rain literally named as bioclimatic building. Increased global warming leads to increased temperatures. Peoples urge for design of temperature comfort building. Thus a bioclimatic building with insulation provided in the cavity wall of building mainly designed for stabilizing heat in interior rooms at high temperature areas that ultimately leads to reduction of cooling loads and fuel energy required for the both heating and cooling of the building.*

Keyword: Bioclimatic, Cavity Wall, Temperature, Cooling, Heating, Green House.

1. INTRODUCTION

The buildings in cities usually use mechanical air conditioning systems for thermal comfort in occupying spaces. This requires producing electrical energy to support the demand.

This is an important factor contributing to CO_2. In environment which in turn rises the temperatures, i.e. the greenhouse effect Most of the buildings in hot humid climate have been designed without considering for materials and insulation. This is an important reason why the heat influencing temperature inside the building usually includes the heat gains from outside air and the buildings envelope, especially if the roof is directly exposed to the sunlight all day. Inappropriate selection of the material can cause the external heat to escape into the building, which in turn requires more energy to cool down the building.

The proper application of insulation will reduce the transmission of heat into the building and heat gain during the hottest period of the day. This is one of the alternative ways to help in solving the energy and environmental problems.

This paper provides design for bioclimatic factor with insulation in hot-humid climate for buildings. The envelope is of the material selected to save the energy by applying the combination in proper studied wind flow areas with maximum fall of sun radiations and insulation to the envelope. A large number of properties that had the insulation installed by successive UK government-backed schemes were installed incorrectly or were unsuitable for the property. [2]Incorrectly installed cavity wall insulation causes water to seep into a properties walls, causing structural problems and damp patches that may also manifest into mould. In some cases, the damp and mould resulting from CWI can cause health problems.

1.1 Objective

Considering weather ecosystem to maximize efficiency of building. Using sunlight patterns for alignment of doors and windows for proper air flow and heat regulation .Overall energy balance by reducing fuel and electrical energy used for both heating and cooling of the building.

2. STRUCTURAL DETAILS

2.1 Design Of Circular Slab

Since the building in circular in plan a circular slab is designed considering required loads

Area of our proposed plan for construction is 1217 m^2

Type of slab is circular
Diameter of the circular slab : 12 m
Radius of the circular slab : 6 m

Design

Modification factor
According to IS 456 2000
L/D ratio for span more than 10 m is taken as 35

$$L/D = 35$$

By the condition of circular slab

$$L/D = 1/3 \times 35 = 1.333 \times 35 = 46.5$$

L/D ratio of the slab is taken as 46.5

Modification of the L/D ratio for the calculation of effective depth

$0.36\ f_{ck}\ b_{xu}$ = 0.87 fy Ast
Xu/D = 0.87 fy Ast / 0.36 f_{ck} bd
Ast / Bd = 9.572 x 10^{3}
$P_t^{(lim)}$ = Ast x 100 / Bd
= 0.957 %
Assume 75 % of $P_t^{(lim)}$
$P_t^{(lim)}$ = 0.72%
Modification for tensile reinforcement
f(s) = 0.58 x fy
= 0.58 x 415
= 240.75 N / mm ^{2}
Modification factor = 1.1

Modified L/D ratio

L /D = 46.5 X 1.1 / 52
D = 12 x 10^{3} / 52
= 230 mm
Assume clear cover = 20 mm
Diameter of the bar = 12 mm Φ
Total depth = 256 mm
Take the total depth as 300 mm
Effective depth as 274 mm
Effective depth = 300mm
Diameter = 12m
Radius = 6m

Load calculation

Assuming for 1m of slab,
= (π/4)x1x1x0.3x25000
= 5890.4 N/m^2
Parapet wall = 0.6
Water tank = nil
Total dead load = 5892 N/m^2
Live load
Curved roof with access
Provided = 1.5kN/m^2
Floor finish = 1kN/m^2
Total load, W = (5.892 + 1.5 + 1) kN/m
Factored load = 1.5 x 8.392
= 12.588 kN/m^2

Moment calculation

At centre (Mur) = 3/16 x W_v x a^2
= 84.969 x 10^3 N/m^2
At edge = 2/16 x W_v x a^2
= 56.646 x 10^3 N/m^2

Computation of effective depth

M_u = C x lever arm
$M_{u(max)}$ = $0.36f_{ck}bx_u(d-0.42x_u)$
= 3.456 (0.4384)d^2
D = 236.81mm < 274mm

To avoid over deflection, we can proceed to design with effective ratio from L/D

D = 274mm
84.969 x 10^3 x 10^3= $0.87f_yA_{st}(d-0.42x_u)$
C = T
$0.36f_{ck}bx_u$ = $0.87f_yA_{st}$
x_u/d = $(0.87f_y A_{st})/ (0.36f_{ck}bx_u)$
x_u/d = 1.83 x 10^{-4} x A_{st}
A_{st} = 12096mm^2
A_{st} (centre) = 925mm^2
Provide 12mm ϕ bar
Spacing of 12mm ϕ bar
= [(π/4) x 12^2 x 1000]/925
= 122.26mm ≈ 150mm
Provide c/c distance of 150mm
Spacing (s) = (Area of single bar x 1000)/ A_{st} provided
A_{st} provided = [(π/4) x 12^2 x 1000]/150
= 753mm^2
Available d of the ring = 300-20-12-12-(8/2)
D (ring) = 252mm
A_{st} for circumferential reinforcement at end moment
$(Mu\theta)_e$ = T x lever arm
x_u/d =(0.87 x 415 x A_{st})/ (0.36 x 20 x 1000 x 252)
x_u/d = 1.989 x 10^{-4} A_{st}
A_{st} = 727.17mm^2
Spacing for ring
Reinforcement = [(π/4) x 8^2 x 1000]/727
= 100mm
Circumferential reinforcement is anchorage reinforcement
L = 47 pi
= 47 x 8
= 376mm

No. of rings = L_d/s
= 376/100
= 3.76 ≈ 4rings
Provide 4 no. of 8mm ϕ rings with 100mm c/c

2.2 DESIGN OF RING BEAM

Load calculation

Load of slab = 12.5 kN/m^2 x 12
= 150kN
Uniformly distributed load per meter
W/Πd = 150/πx12
= 3.97kN/m

Moments and shear force

Negative BM at supports = 0.0148 WR
= 0.0148 X 150 X 6
= 13.32 kNm

Positive BM at c/c support = 0.0075 WR
= 0.0075 x 150 x 6
= 6.75 kNm
Torsional moment = 0.0015 WR
= 0.0015 x 150 x 6
= 1.35 kNm

Shear force at support

V = Total load/(2xno. of colums)
= 150 / (2x6)
= 12.5kN
Shear force at section of maximum torsion
V = 12.5 - [(3.97 x 6 x π x 25.5) / 180]
= 12.5 - (1908.2/180)
= 12.5 - 10.6
= 2kN

Design of support section

M = 13.32 kNm
V = 12.5 kNm
Effective depth = √M/Qb
=√(13.32 x 10^6)/(0.89 x200)
D = 250mm
Overall depth = 300mm
A_{st} = (13.32 x 10^6)/(150 x 0.88x 250)
= 400mm^2
Provide 2 bars of 20mm diameter
τ_v = V/bd
= (12.5 x 10^3) / (250 x 200)
= 0.25 N/mm^2
τ_c = 0.67 (IS 456:2000)
$\tau_c > \tau_v$
Shear reinforcement not required

Design of center span

M = 6.75 kNm
A_{st} = (6.75 x 10^6)/(150 x 0.89 x 250)
A_{st} = 250mm^2
Minimum quantity of steel
A_s = (0.85bd)/f_y
= (0.85 x 200 x 250)/415
= 300mm^2
Provide 2 bars of 20mm dia

Design section subjected to torsion shear

T = 1.35kNm
V = 2 kN
M = 0 kNm
D = 250mm
B = 200mm
M_S = T[1+(D/b)]/1.7
= 1.35[(1+1.25)/1.7]
M_S = 2kNm
M_e = M + M_t
= 2kNm
A_{st} = (2 x 10^6)/(150 x 0.89 x 250)
= 100mm^2
Minimum reinforcement required 300mm^2
Provide 2 bars of 20mm dia
V_e = V + 1.6V/b
= 2 + 1.6 (2/0.2)
= 2 + 16
= 18kN
τ_{ve} = (18 x 10^3)/ (200 x 250)
= 0.36 N/mm^2
100A_{st}/bd =(100 x 300) / (200 x 250)
= 0.6;
τ_c = 0.28 ;
$\tau_c < \tau_{ve}$

Shear reinforcement

10mm dia two legged stirrups
Side cover = 25mm
b_1 = 150mm
d_1 = 200mm
A_{sv} = 150mm^2
S_v = $A_{sv}.\sigma_{sv}/(\tau_{ve} - \tau_c)b$
=(150 x 150)/ (0.36 - 0.28)200
= 700mm
Adopt 10mm of two legged stirrups at 500mm centers

2.3 Design of Coloumn

L = 3m
F_{ck} = 20N/mm^2
F_y = 415N/mm^2

Load calculation

Load of slab
Self wt =θ/360 x π x (R^2-h^2) x h x γ
=60°/360xπx(6^2-1.5^2)x0.3x25
= 110kN
Floor finish = 1/6
= 0.1666kN
Tank + water = 0.1635
Parapet wall = 0.1kN
Live load = 1.5/6
= 0.25kN
Total load
From slab = 111kN
Load from ring beam
Self wt =θ/360 x π x (R^2-r^2) x h x γ
=60°/360xπx(6^2-5.9^2)x0.3x 5
= 4kN
Total load = 111+4
= 115kN

Axial load = 115kN
Factored axial load = 115 x 1.5
= 173kN
Diameter = 300mm
Slenderness ratio = L/D
= 3000/300
= 10 < 12
Hence, short column is designed

Minimum eccentricity

e_{min} = L/500 + D/30
= 3000/500 + 300/30
= 15mm < 20mm
0.05D = 0.05 x 300
= 15mm < 20mm

Main reinforcement

P_u = $1.05[0.4\, f_{ck}A_g + (0.67f_y - 0.4\, f_{ck})A_{sc}]$
164762 = 565487 + 270 A_{sc}
A_s = 1484mm²
A_{sc} = 1500mm²
A_{sc} min = 0.8% of cross sectional area
= $(0.8 \times \pi \times 300^2)/4$
= 565mm²
No. of bars = A_{st}/ a_{st}
= 1500/314
4.7 ≈ 5bars
Provide 6 bars of 20mm ϕ
A_{sc} = 1570mm²

Helical reinforcement

Cover = 50mm for spirals
Core dia = [300 - (2 x 50)]
= 200mm
Area of core A_c = [(P x 200²)/4 - 1570]
A_c = $(\pi x 200^2)/4 - 1570$
= 29845mm²
Volume of core V_c = 29845 x 10³ mm³
Gross area of section A_g = $(\pi x 300^2)/4$
= 70685mm²
Using 8mm diameter helical spirals
V_{us} =[πx(300-100 - 8)x50x1000]/p
= (30159.288 x 10³)/p mm³/m
$V_{us}/ V_c < 0.36\, [(A_g/ A_c) - 1][f_{ck}/f_y]$
P = 50mm
P < core dia / 6
= 200/6
= 33.6mm
P > 25mm
= 3 x helical diameter
3 x 8 = 24mm
8 mm diameter @ pitch 30mm helical

2.4 Design of Footing

SIZE OF THE FOOTING

Self weight of the column= π×0.025×3×25
= $\pi \times (0.3\backslash 2)^2 \times 3 \times 2$= 5.30
W1 = 5.30kN
Slab weight W2 = 111kN
Beam weight W3 = 4kN
Axial load = W1+W2
= W3 = 120kN

Self weight of the footing(10%) = 120(10\100)
= 12kN
Total load = 120+12=132×1.5
= 198kN
Af = 0.66
Df = $\sqrt{4} \times 0.66\backslash\pi = 0.9 \cong 1m$
Upward soil pressure
Pu = $(120{\times}4\backslash\pi \times (1)^2)$ = 153 kN/m²
= 0.6(R²+r²+Rr\Rr)
= 320mm
Upward load = 117 kN

BENDING MOMENT

Mu = 117(0.32-0.15)
= 20kNm
Breath of footing at column face
= 235mm
Depth of the footing = d
= $\sqrt{Mu\backslash 0.138fckb}$
= 180 mm
Effective depth = 270mm
Overall depth = 350mm

REINFORCEMENT

Mu = (0.87fyAst×d) [1- Astfy\b×d×fck]
Ast = 305mm²
Provide 8mm dia bar at 100mm
Ast = 300mm²

CHECK FOR SHEAR

Shear = $153(1^2\text{-}1.35^2)(\pi\backslash 4)$
= 100kN
(100\p×1.35) = 30kN
[100Ast\bd) = [100×300\10²×270]
= 0.111
Refer table 19 IS 456-2000
Kstc) = (1×0.28)
= 0.28N\mm²>0.11 N\mm²

4. CONCLUSION

We conclude that the building is designed with the cavity wall filled with poly urethane material along with proper arrangement of the structural, nonstructural elements and ventilation provided by the open to sky of 3m diameter . Using sunlight patterns for alignment of doors and windows for proper air flow and heat regulation .This design reduces the heat transmission from outside through the insulated cavity wall and thereby reducing the usage of the cooling loads and future bills accordingly.

Maximum bending moments are calculated for all types of load and each sections are designed to resist each moments. The slab is designed considering the end conditions and proper access provided according to the IS code book of live loads for residential building .circular columns and ring beam is designed according to the load derived from the circular slab. Thus a bioclimatic structure is designed involving all the environmental effects on building and aligned based on ventilation and lighting with insulation of cavity wall provided with poly urethane foam .

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