DESIGN OPTIMIZATION (ME - 5320-001)
FALL 2015 - FINAL PROJECT

Weight Optimization of Dome Structure using MATLAB and ANSYS Integration

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Design Specification

No of Nodes - 51

No of Elements - 130

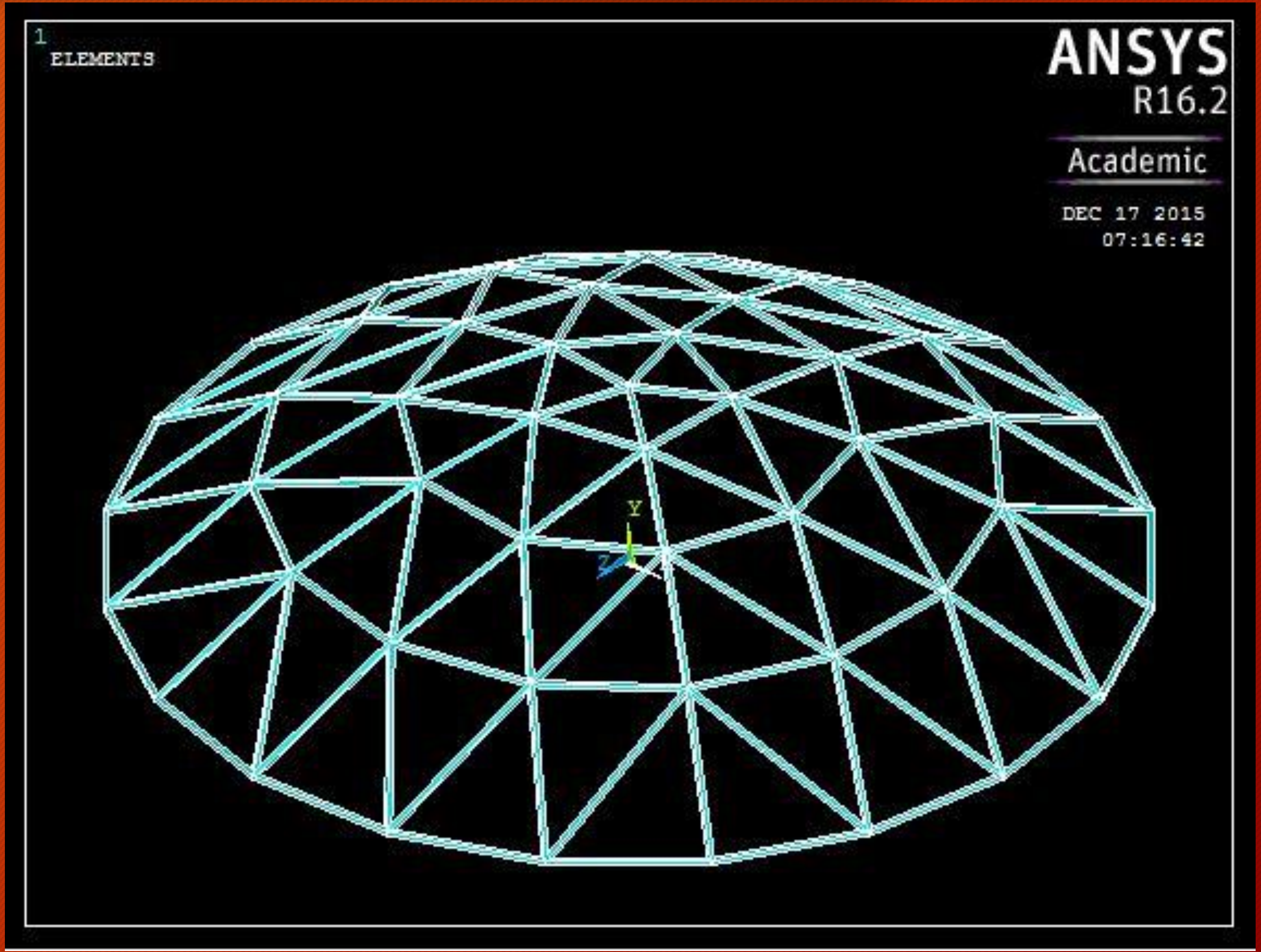
Material – Steel

Modulus of Elasticity – 2e11 pa

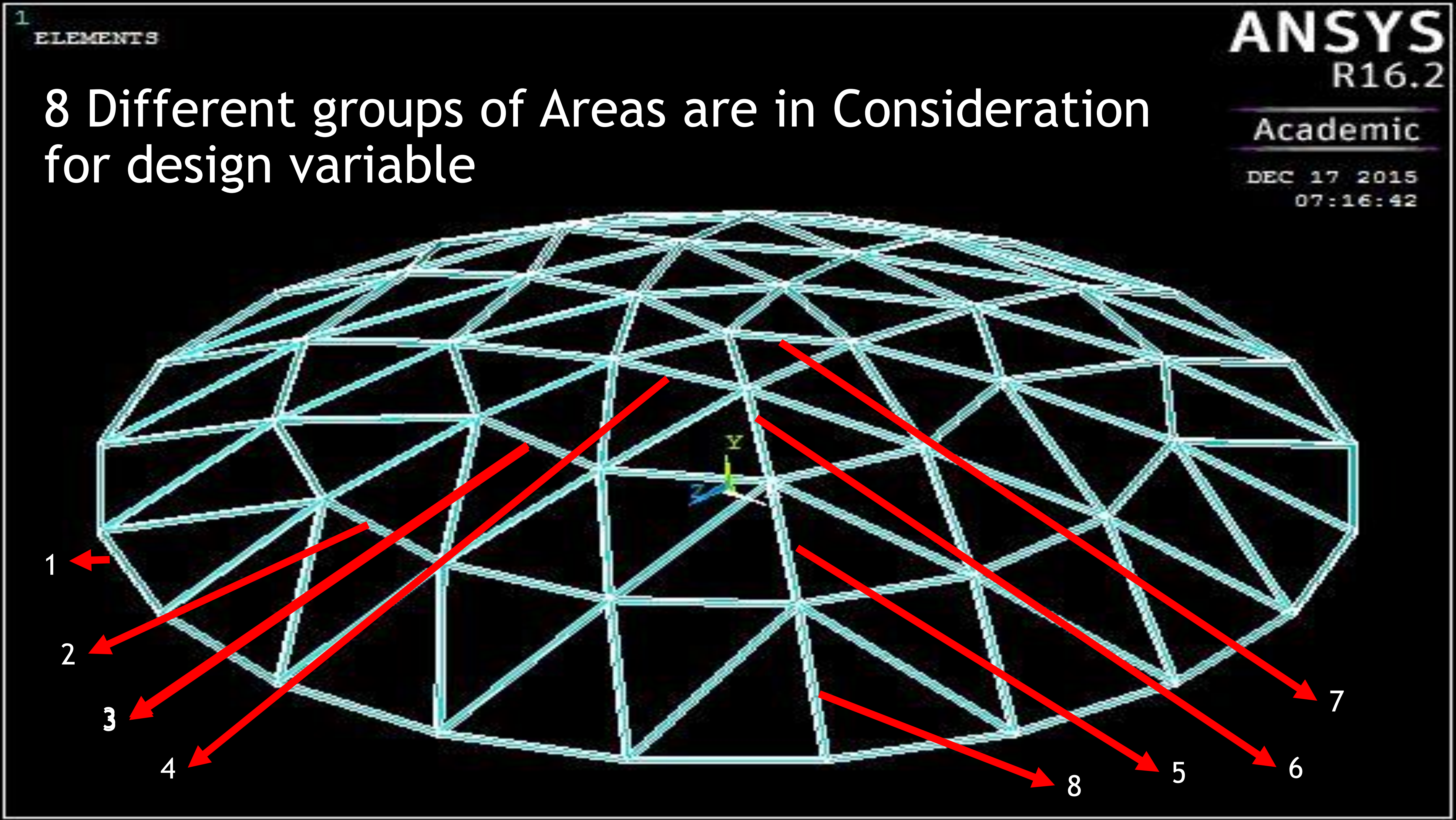
Poissons' Ratio – 0.3

Density – 7850 kg/m^3

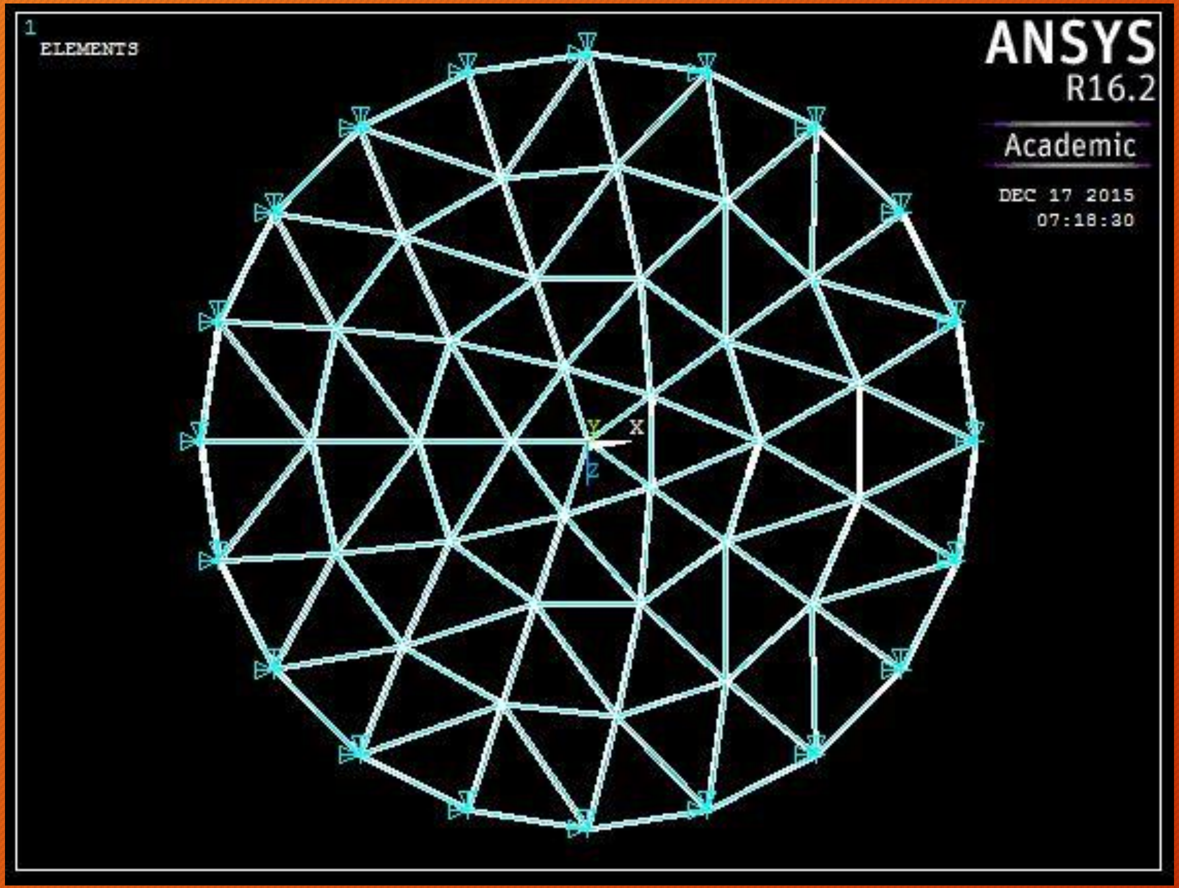
Dome base Diameter – 20 m

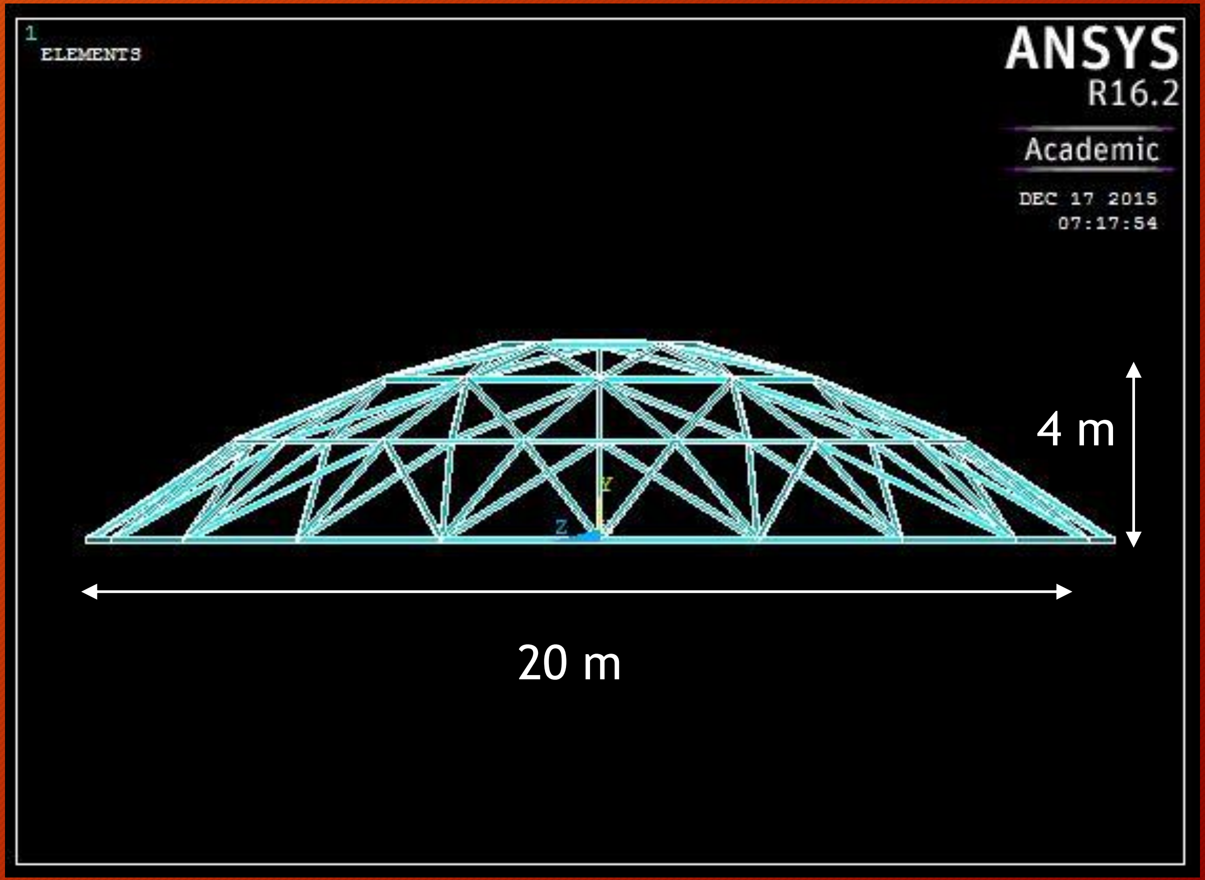


8 Different groups of Areas are in Consideration for design variable

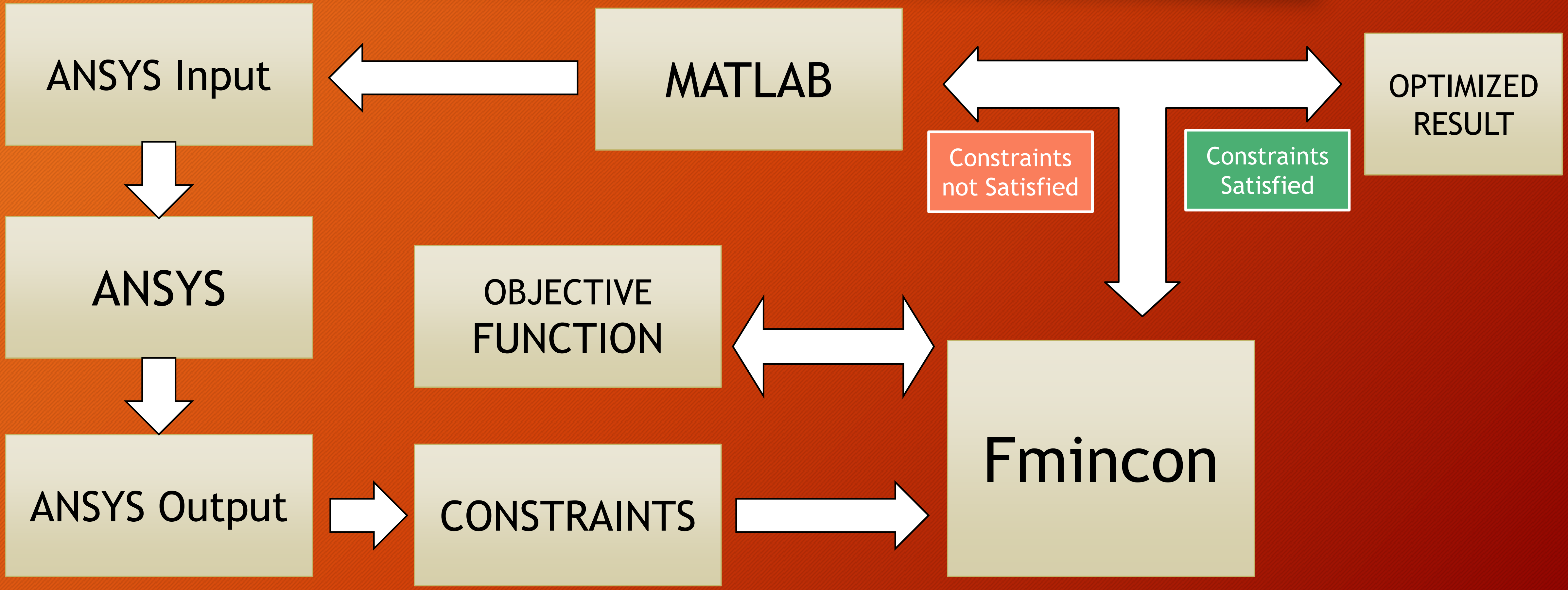


Design Model





Project Flow Chart



PROJECT OBJECTIVE (Fmincon)

- **Objective Function**

- Find a vector of integer values I (Eqn. 1) representing the sequence numbers of standard sections in a given section table

$$I^T = [I_1, I_2, \ldots, I_{N_d}]$$

- To generate a vector of cross-sectional areas A for N m members of the dome (Eqn. 2)

$$A^T = [A_1, A_2, \ldots, A_{N_m}]$$

- Such that A minimizes the objective function

$$W = \sum_{m=1}^{N_m} \rho_m L_m A_m$$

- Where W refers to the weight of the dome; A_m L_m ρ_m , are cross-sectional area, length and unit weight of the m-th dome member, respectively.

DESIGN CONSTRAINTS (Fmincon)

- The structural behavioural and performance limitations of pin-jointed geodesic steel domes can be formulated as follows:

STRESSES CONSTRAINT

$$g_m = \frac{\sigma_m}{(\sigma_m)_{all}} - 1 \leq 0 \;\; m = 1, \ldots\ldots, N_m$$ (Yield Stress - 250 MPa)

(Tensile Stress = 0.6X Yield Stress)

DISPLACEMENT CONSTRAINT

$$\delta_m = \frac{d_{j,k}}{(d_{j,k})_{all}} - 1 \leq 0 \;\; j = 1, \ldots\ldots, N_j$$ (Allowable Deflection – 2.5 cm)

Design Loads

1. Dead Load

The dead load includes the weight of the members, joints, cladding and other components of domes acting with gravity on the foundations below.

2. Snow Load

The Snow load is the downward force on a building's roof by the weight of accumulated snow and ice.

3. Wind Load

The force on a structure arising from the impact of wind on it.

Dead Load

- A sandwich type Aluminium cladding material is used to cover the dome surface, resulting in a uniform dead load pressure of 200 N/m2, including the frame elements used for the girts

As per the ASCE -798 (Minimum design load for building and other Structures, American Society of Civil Engineering)

For Steel Structures with Aluminum Cladding - 0.15 to 0.3 KN/m^2 uniform load over the entire area.

Snow Load

- The design snow load is computed by using the following parameter values in Equation: $C_s = 1.0$, $C_e = 0.9$, $C_t = 1.0$, I = 1.1 and

  p_g= 1.1975kN/m^2

Where

- C_c is the roof slope factor, C_e is the exposure coefficient
- C_t is the temperature factor, *I* is the importance factor
- P_g is the ground snow load.

- The snow load is given by $p_f = 0.7C_sC_eC_tIp_g$
- Results in a uniform design snow pressure of

  p_f = 830 N/m^2 (17.325 lb/ft^2)

Wind Load

- the design wind pressure is computed considering a combined effect of internal and external pressures acting on the roof, as follows:

$$p_w = q_h G C_p - q_h \left(G C_{pi} \right)$$

Where

p_w is the design wind pressure,

G is the gust effect factor (taken as 0.85),

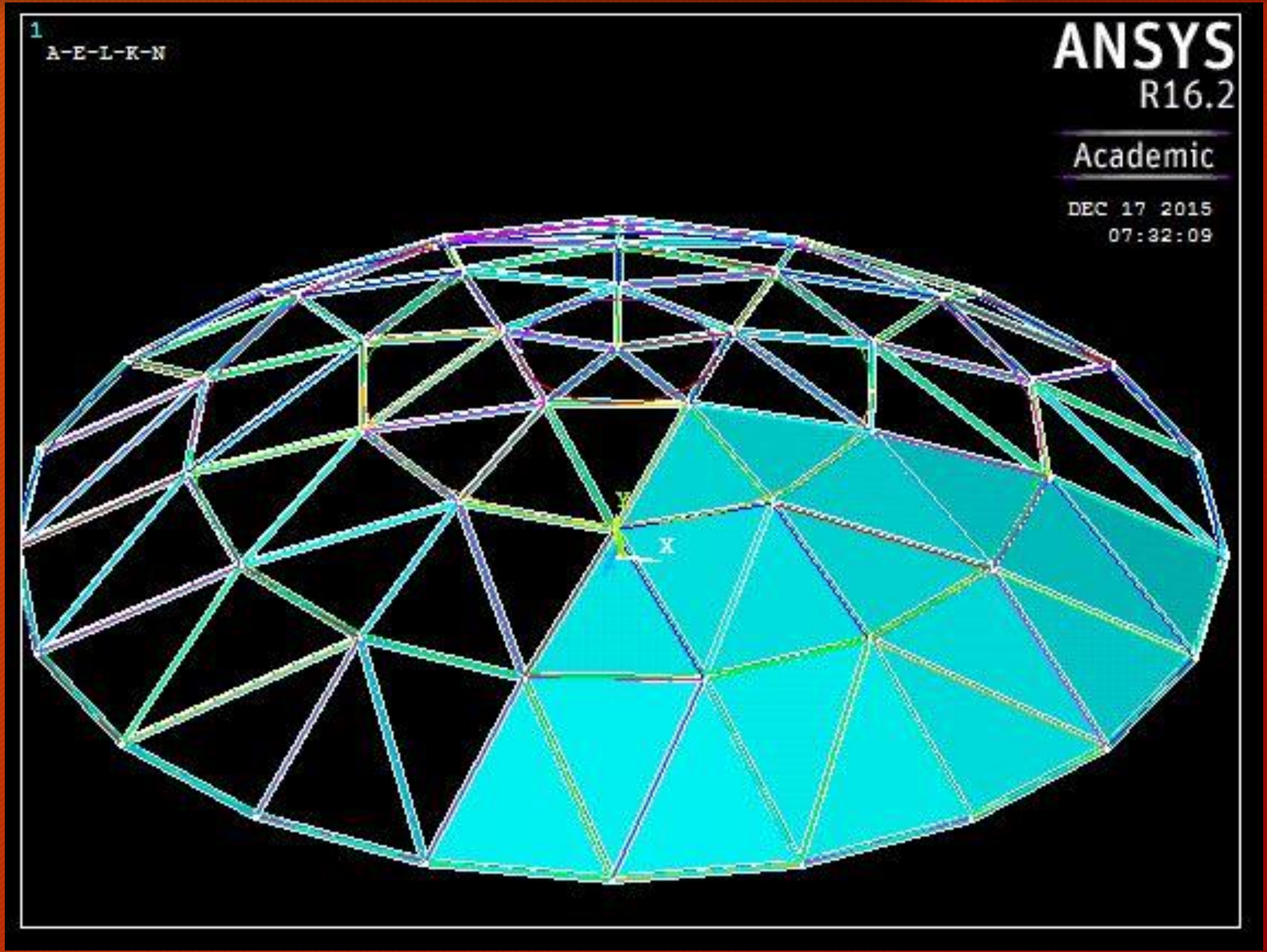
C_p is the external pressure coefficient, and

(GC_p) is the internal pressure coefficient.

Design wind load is calculated by assuming wind speed of 40m/s (or 90mph).

Wind Load

- Wind load is Assumed to be acting on 20% of the entire dome area
- Area considered is show in the Figure
- Uniform Wind pressure of 200N/m^2 is considered to be acting on shown area in z-direction parallel to the ground.
- Assumptions per the ASCE-798 code (American Society of Civil Engineering)



Results
Optimum Design of 130 member Dome

Variable (Area)	Optimized Area (cm^2)
1	1.00
2	8.413
3	5.741
4	3.573
5	2.983
6	2.838
7	2.765
8	3.376
Weight Optimized	1166.1kg (1.16Tons)

As seen from the result the Element with area one which is fixed at both node has the minimum area.

Smallest Area at the TOP

Largest Area at Vertical Bottom

Conclusion

- The optimum design of steel domes is investigated by Integration of MATLAB and ANSYS, which have emerged promising tools for successfully handling discrete programming problems encountered in structural optimization.

- The performance of the MATLAB and ANSYS technique in finding optimum solutions to the problems of interest is numerically scrutinized in conjunction with a 130-member steel dome design example. Results by this method are practically satisfactory. Hence Technique of MATLAB and ANSYS give us one of the better way to solve the design optimization problem.