DESIGN OPTIMIZTION (ME–5320-001)

FALL 2015 FINAL

PROJECT REPORT

Weight Optimization of Dome Structure using MATLAB and ANSYS Integration

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CONTENT

1. Introduction

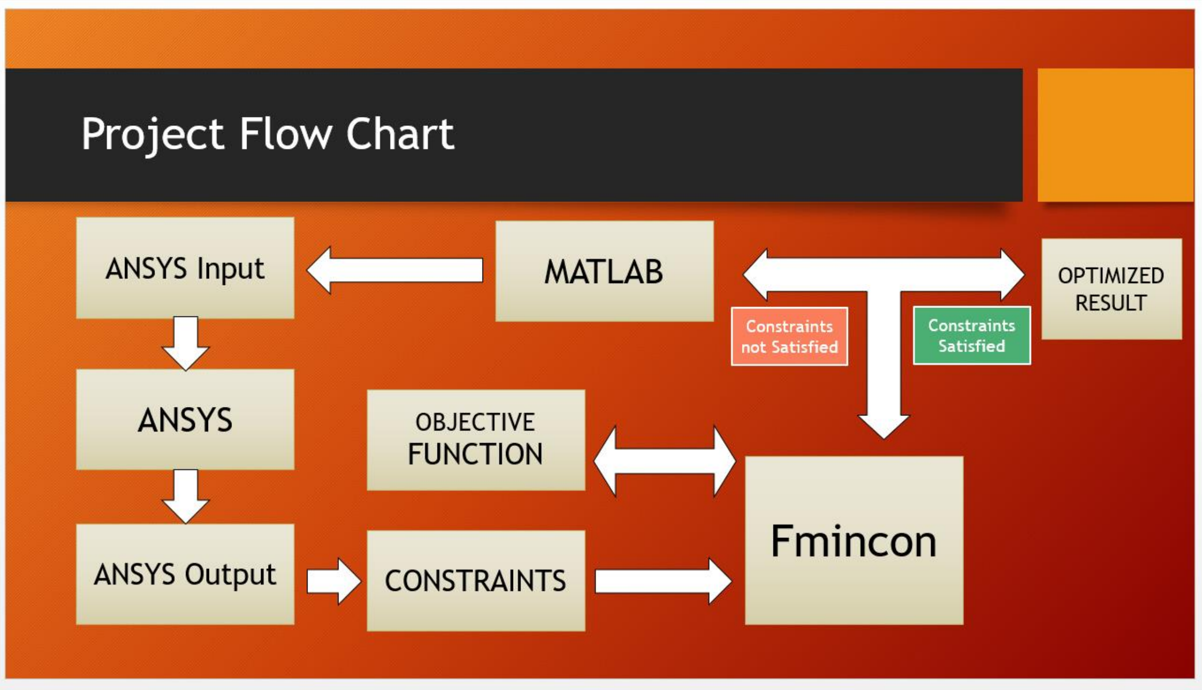
Those field from claiming structural streamlining is a moderately new range undergoing fast transforms on techniques and centre. Until as of late there might have been a extreme lop-sidedness between gigantic sum of expositive expression on the subject What's more lack of requisitions should useful configuration issues. There is at present no deficiency about new publications, Be that as there need aid likewise energizing requisitions of the systems for structural optimizations in the common engineering, machine outline Furthermore other building fields. Similarly as an after effect of the developing pace of applications, exploration under structural streamlining routines may be progressively determined by real-life issues.

Structural streamlining At principal rose need pulled in An broad consideration Around designers. because of engineering reasons. Hence, the structural creator figures himself/herself done An confined territory the place just discrete values would accessible when it goes to settle on a choice what areas he/she need should select to the parts of a steel or strengthened solid span. Consequently, those discrete structural streamlining calculations formed so far using those scientific modifying strategies need not discovered broad provisions done useful configuration about structures. Characteristically this need headed those researches to look for finer calculations for the result about discrete ideal outline issues.

2. Design Problem of Steel Domes

Steel Dome structure of 130 elements and 51 node considered in this problem. To solve this problem we are going to study method of design optimization using MATLAB and ANSYS.

A Matlab function called Fmincon is used as the optimization technique and ANSYS is used to calculate the Element stresses and Nodal displacements due to structure under loading.



2.1.Objective Function

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

$$I^T = [\, I_1,\ I_2\,, \dots.,\, I_{N_d}\,] \qquad (1)$$

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

$$A^T = [\, A_1,\ A_2\,, \dots.,\, A_{N_m}\,] \qquad (2)$$

Such that A minimizes the objective function

$$W = \sum_{m=1}^{N_m} \rho_m\, L_m A_m \qquad (3)$$

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.

2.2. Design Constraints

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

$$g_m = \frac{\sigma_m}{(\sigma_m)_{all}} - 1 \leq 0 \quad m = 1, \dots.., N_m \qquad (4)$$

$$\delta_m = \frac{d_{j,k}}{(d_{j,k})_{all}} - 1 \leq 0 \;\; j = 1, \ldots\ldots, N_j \tag{5}$$

In Eqns. (4-6), the functions m_g *and* $\delta_{j,k}$ are referred to as constraints being bounds on stresses and displacements, respectively; σ_m and $(\sigma_m)_{all}$ are the

Computed and allowable axial stresses for the *m*-the member, respectively N_j is the total number of joints; and finally $d_{j,k}$, and $(d_{j,k})_{all}$, are the displacements computed in the *k*-th direction of the *j*-th joint and its permissible value, respectively. In the present study, these limitations are implemented according to ASD-AISC code provisions.

The allowable tensile stresses for tension members are calculated as in Eqn. (6):

$$(\sigma_t)_{all} = 0.60F_y$$
$$(\sigma_t)_{all} = 0.50F_u \tag{6}$$

Where F_y and F_u stand for the yield and ultimate tensile strengths, and the smaller of the two formulas is considered to be the upper level of axial stress for a tension member. The allowable stress limits for compression members are calculated depending on two possible failure modes of the members known as elastic and inelastic buckling, Eqns. (9-11).

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

$$(\sigma_c)_{all} = \frac{\left[1 - \frac{(K_m L_m / r_m)^2}{2C_c^2}\right] F_y}{\frac{5}{3} + \frac{3(K_m L_m / r_m)}{8C_c} - \frac{(K_m L_m / r_m)^3}{8C_c^3}}, \lambda_m < C_c \text{ (inelastic buckling)}$$

$$(\sigma_c)_{all} = \frac{12\pi^2 E}{23(K_m L_m / r_m)^2}, \lambda_m \geq C_c$$

In Eqns. (9-11), E is the modulus of elasticity, and C_c is referred to as the critical slenderness ratio parameter. For a member with $\lambda_m < C_c$, it is assumed that the member buckles inelastically, and its allowable compression stress is computed according to Eqn. (10). Otherwise ($\lambda_m < C_c$), elastic buckling of the member takes place, in which case the allowable compression stress is computed as to Eqn. (11).

3. Design Loads

For those outline from claiming structural systems, it will be accepted that those structures need aid uncovered should Different gravity (e. G., dead, snow) What's more parallel (e. G. , wind, earthquake) loads Throughout their administration life. The structures must be proportioned will securely suit these loads or their joined impacts without whatever failure, splitting or unreasonable deformity. Amongst an assortment about different loadings, the A large portion basic load situations that must be strictly viewed as in the configuration for arch structures show up will make dead, snow, wind and in addition temperature prompted loads. In the study, the least values for these loads need aid registered as stated by the procurements of ASCE 7-98, which will be demonstrated in the accompanying subsections..

3.1. 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.

3.2. Snow Load

In ASCE 7-98, snow loads are categorized into three groups as ground snow loads, flatroof snow loads and sloped-roof snow loads. Because of the arched shape geometry of a dome structure, the sloped-roof snow load values are adopted here and the design snow load $f\,p$ is computed using the following equation in ASCE 7-98:

$$p_f = 0.7 C_s C_e C_t I_{p_g} \tag{12}$$

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, and P_g is the ground snow load.

3.3. Wind Load

ASCE 7-98 recommends three different approaches for calculation of wind loads referred to as (i) simplified procedure, (ii) analytical procedure and (iii) wind tunnel procedure. In the present study, wind loads acting on dome structures are computed in accordance with the analytical procedure. In this approach, the velocity pressure is first computed using the following equation in the specification

$$q_h = 0.613 K_z K_{zt} K_d V^2 I \tag{13}$$

where q_h (in N/m^2) is the velocity pressure evaluated at mean roof height, K_z is the velocity exposure coefficient, K_{zt} is the topographic factor, K_d is the wind directionality factor, V (in m/s) is the basic wind speed, and I is the importance factor.

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

$$p_w = q_h G C_p - q_h \left(G C_{pi} \right) \tag{14}$$

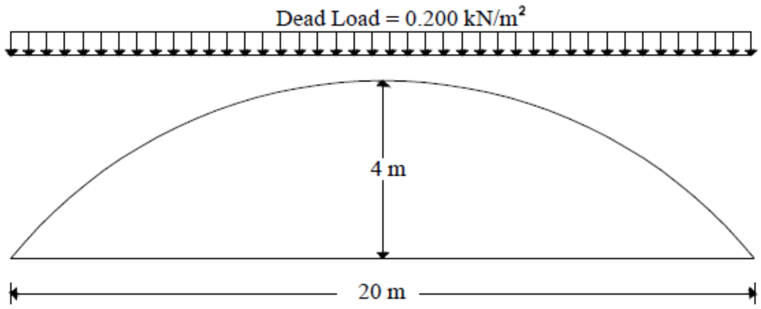
Where p_w is the design wind pressure, G is the gust effect factor (taken as 0.85), C_p is the external pressure coefficient, and $(G C_p)$ is the internal pressure coefficient. The first term in Eqn. (15) considers the effect of external pressure, whereas the second term accounts for the effect of internal pressure.

4. Design and Analysis

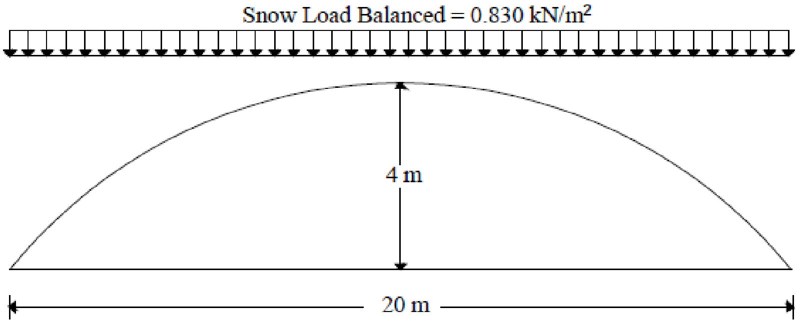
Figure 1 shows plan, elevation and 3-D views of a Steel steel dome with a base diameter of 20 m (65.6 ft) and a total height of 4 m (13.1 ft). The structure consists of 51 joints and 130 members that are grouped into 8 independent size design variables. The size variables are to be selected from a database of 37 pipe (circular hollow) sections issued in ASD-AISC standard section tables. The stress and stability limitations of the members are calculated according to the provisions of ASD-AISC, as explained in Section 2. The displacements of all nodes are limited to 5.55 cm (2.18 in) in any direction. The following material properties of the steel are used: modulus of elasticity (E) = 29000ksi (203893.6MPa) and yield stress (F_y) = 36ksi (253.1MPa).

The design loads and combined loads effects are applied on the dome as explicated in Section 3. A sandwich type aluminum 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 (Figure 2a). The design snow load is computed by using the following parameter values in Equation (12): $C_s = 1.0$, $C_e = 0.9$, $C_t = 1.0$, I = 1.1 and p_g= 1.1975kN/m^2 (25.0lb/ft^2), which results in a uniform design snow pressure of p_f = 830 N/m^2 (17.325 lb/ft^2) as displayed in Figure 2(b).

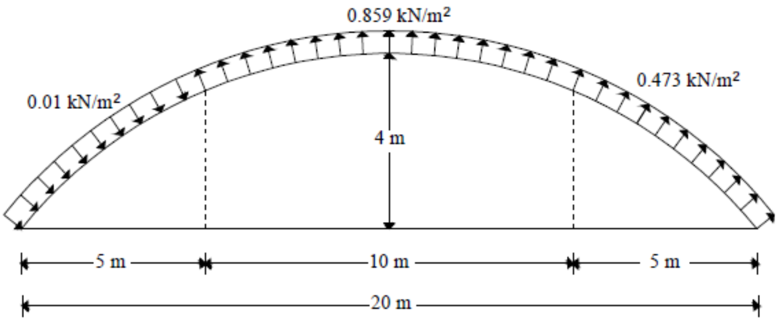
V = 40 m/s (90mph), and the other quantities in Equation (13) are set to the following parameter values: $K_z = 1.07$, $K_d = 0.85$, K_{zt}= 1.087 zt K , I = 1.15 , and V = 40 m/s (90mph), resulting in a velocity pressure of q_h= 1.115 kN/m^2 (23.285 lb/ft^2). The wind pressure is assumed to be 0.200 kN/m^2 is assumed to be applicable on small dome area.



a) Dead load



b) Snow load



c) Wind external pressure

Figure 2. Loads acting on 130-member Steel steel dome **a.** dead load, **b.** snow load, **c.** wind external pressure, **d.** wind negative internal pressure and **e.** wind positive internal pressure.

6. Results

Variable (Area)	**Optimized Area (cm^2)**
1	**1.003**
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)**

7. Conclusions

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 optimum design process is implemented in conformity with design requirements and specifications prescribed for these systems in actual design practice.

Accordingly, the functional and structural requirements of the dome structures, such as allowable stress levels, acceptable deflections, service loads, etc., are enforced according to chosen codes of practice, namely ASD-AISC and ASCE 7-98.

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.