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Temperatures affected on two hinged steel arch bridge

[1]Prof. Dr. bilyk sergy ivanovech (head Faculty of metal and wood structures),
[2]Student of PhD. Natheer Aied Athaab Al-Taie ,
[3]Student of Phd. Adil Jabbar Abbas
Kyiv National University of Construction and Architecture, Ukraine

Abstract - The strain energy stored inside rip and tie of steel arch. Where product thermal loading with X-X, for steel arch ,the temperature effect on steel arch cusses some elongation in the length of arch ,where effected by increase and descries of the temperature degree, for two hinged steel arch ,and causes stress concentration in structures of steel arch .

Key words: **steel arch, critical temperature, max bending stress from temperature effected.**

I. INTRODUCTION

The distinguishing characteristics of an arch are the presence of horizontal reactions at the ends, and the considerable rise of the axis at the center of span, see Figure 1. Rigid frames and tied arches are closely related to the arch. However, both of these types have characteristics which cause them to act quite differently from true arches. In the case of the rigid frame, no attempt is made to shape the axis for the purpose of minimizing dead load bending moments, thus resulting in bending stresses which are considerably larger than axial compressive stress. In the case of the tied arch rib, the horizontal reactions are internal to the superstructure, the span generally having an expansion bearing at one end. As a result the stresses are different, in several respects, for a tied arch as compared to an arch with abutments receiving horizontal thrust.

In a true arch, the dead load produces mainly axial stress, and most of the bending stress comes from live load acting over a part of the span. Live load over the entire span causes very little bending moment. True arches are generally two-hinged, three-hinged or hinge less. The two-hinged arch has pins at the end bearings, so that only horizontal and vertical components of force act on the abutment. The hinge less arc his fixed at the abutments so that moment, also, is transmitted to the abutment .The three-hinged arch has a hinge at the crown as well as the abutments ,making it statically determinate and eliminating stresses from change of temperature and rib shortening.

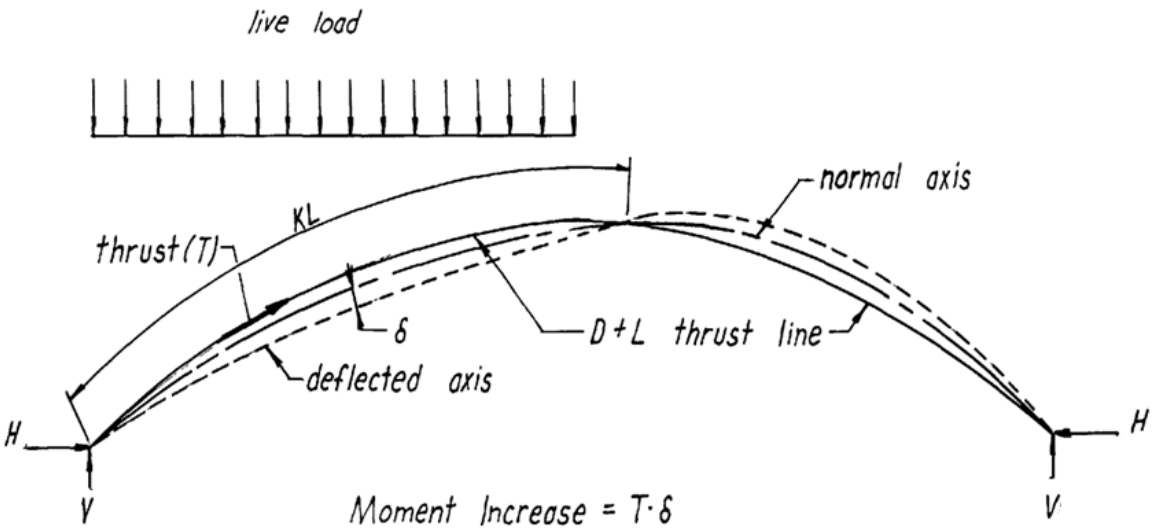

Fig .1. Arch Deflection in rip with the direction of thrust with the distribution live load

Two hinged steel arch as the name indicated is an arch hinged on two supported only like three hinged arch the reaction at the support of two hinged arch will consist of a vertical components V_L and V_R as well as horizontal

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component ***H***. the vertical component of the support reaction my be easily found out by equating the clockwise and anticlockwise moments of all the forces on the arch about any one hinged. See fig. 1 Arch Deflection and fig. 2.Two hinged steel arch how to connect from two ended.

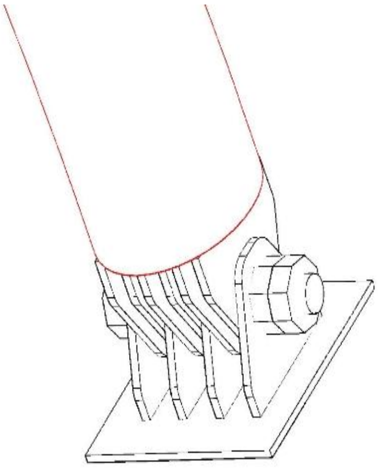

Fig .2. Pin Ended for Steel Arch from one side for hollow circle section

Mainly three types of arches are used in practice: three-hinged, two-hinged and hinge less arches[4]. In the early part of the nineteenth century, three-hinged arches were commonly used for the long span structures as the analysis of such arches could be done with confidence. However, with the development in structural analysis, for long span structures starting from late nineteenth century engineers adopted two-hinged and hinge less arches. Two-hinged arch is the statically indeterminate structure to degree one. Usually, the horizontal reaction is treated as the redundant and is evaluated by the method of least work. In this lesson, the analysis of two-hinged arches is discussed and few problems are solved to illustrate the procedure for calculating the internal forces.

The live load moment in an arch is increased by the product of the total dead plus live arch thrust by the deflection from live load, as shown in Figure 1. The major component of the total arch thrust is dead load. Thus dead load interacts with live load in arch moment magnification. Maximum positive and negative moments are increased in about the same proportion. Additional live load deflection is produced by the increase in moment, and this increase in deflection produces an additional increase in moment. This effect continues in a decreasing series. An approximate method of taking this Equation (1A) effect into account is to use a moment magnification factor, A_F

$$A_{FS} = \frac{1}{1-\frac{T}{A_{Fe}}} \quad \text{(for deflection only} \qquad (1A)$$

A_{FS} = moment magnification factor for deflection Ander service load

T = arch rib thrust at the quarter point (approximately equal to H * secant of slope of line from springing to crown)
A = arch rib area at the quarter point

$$F_e = \frac{\pi^2 . E}{(KL/r)^2} \quad \text{the Euler buckling stress}$$

L = half the length of the arch rib (approximately equal to L/2 * secant of slope of line from springing to crown)

r = radius of gyration at the quarter point

K=is a factor varying from 0.7 to 1. 16, depending on end restraint.

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II. EFFECT OF CHANGE IN TEMPERATURE IN TWO-HINGED ARCH

The heat transfer in structures of steel arch during the direct effected of the sun can increase the value of temperatures in rip cross section and tie section where lead this stage to elongation in structures with X-X and this elongation cusses **Thermal Strain** and thane product the stress concentration in joint of connection Equation (3) and deformations in all structures and happened .and An arch responds to temperature change by increasing or decreasing its rise, instead of by increasing or decreasing the span. If the arch has a hinge Equation (1B) at the crown and at the ends, no stresses are produced by a change of temperature. In the case of a two-hinged arch, positive moment is produced by a drop in temperature and negative moment by a rise in temperature. For a fixed arch, the moments reverse in the outer portions of the span .The greater the ratio of rise to span, the smaller is the temperature stress. A lesser depth of rib also results in smaller temperature stresses. The following approximate equations are based on an assumed uniform moment of inertia .by depended[7] on the AASHTO Specifications. (American Association of State Highway and Transportation Officials)

$$H_t = \frac{15EI_0\alpha t}{8yc^2} \qquad (1B)$$

$$M_x = -H_t.y \qquad .(2)$$

Where is the:

H_t = Horizontal thrust from change of temperatures M_x = Moment at point x

y = ordinate to arch axis at point x

I_o = assumed uniform moment of inertia

α = temperature expansion coefficient

t = change of temperature

h = arch rise = yc Where the I= $I_o \sec\theta$

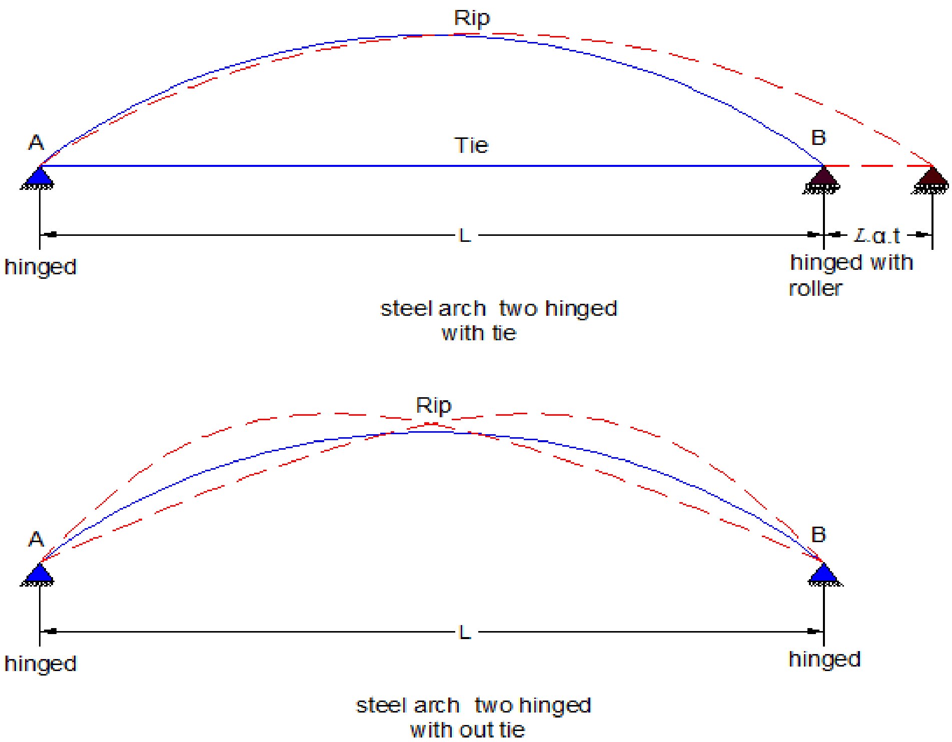

Fig.3. The deformation different between two hinged and hinged with roller under temperatures effected.

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Consider an unloaded two-hinged arch of span L . When the arch undergoes a uniform temperature change of T, then its span would increase by $L\alpha t$ if it were allowed to expand freely (Fig.3) . α is the co-efficient of thermal expansion of the arch material. Since the arch is restrained from the horizontal movement, a horizontal force is induced at the support as the temperature is increased

III. STRAIN ENERGY IN ARCH

The strain energy in arch due to bending U_b is calculated from the following expression.

$$U_b = \int_0^L \frac{M^2}{2EI} \quad .... \quad (3)$$

Where I is the moment of inertia of the arch cross section, E is the Young's modulus of the arch material. L is the length of the centerline of the arch.
and, any section of the arch (Fig 4) is subjected to shear force V, bending moment M and the axial compression N. The strain energy due to bending U_b is calculated from the above Equation (3) .

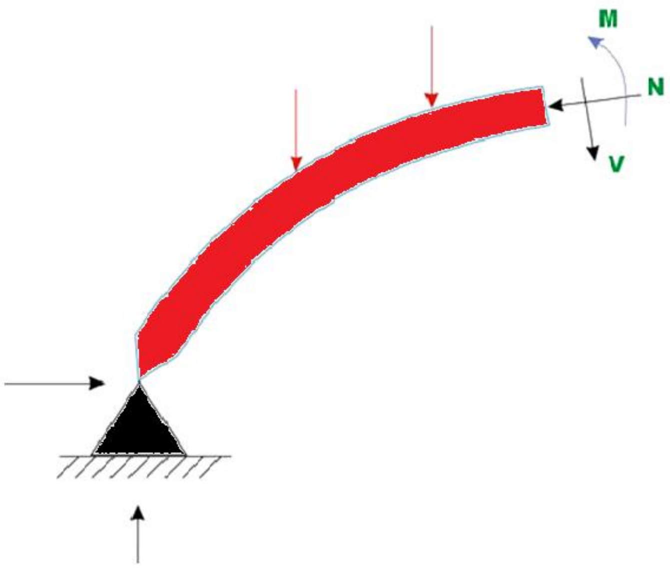

Fig .4. Analysis per one point

The strain energy due to shear is small as compared to the strain energy due to bending and is usually neglected in the analysis. And we can obtained on the strain energy by Equation (5) due to axial compression can be appreciable and is given by,

$$U_A = \int_0^L \frac{N^2}{2AE} \quad .... \quad (4)$$

The summation strain energy of the arch is given by the following,

$$U = \quad U = \int_0^L \frac{M^2}{2AE} ds + \int_0^L \frac{N^2}{2AE} ds \quad .... \quad (5)$$

The type of cross section for rip effected on the thermal strain[8] and can limited from controlled on the thermal expansion of the steel arch and tie (for two hinged) as show in (Fig3).The design of shape of internal stiffener inside cross section of rip and depth of section Effected on the thermal strain and on the Elongation of steel arch with X-X the below graphic in (Fig. 5.A), Respect between length of bridge and depth of section for rip by use (feet) where per one meter equal (1M= 3.28 feet) where in this graphic (Fig.5.B) max length for tie of steel arch **1200** feet equal **365m** and max depth **16** feet equal **4.87m** Rip depth for solid section According to the American standard for steel

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arch two hinged equal The fallowing $\frac{L}{D} = 44 + 0.6\sqrt{L}$ where the L length of span and d depth of rip section .The show below type cross section of pipe for steel arch two hinged where the number 1 section with out internal stiffener and in section 2 with strip stiffener and 3 with trapezoidal section where in the figure below all section the same area cross section but different the moment of inertia

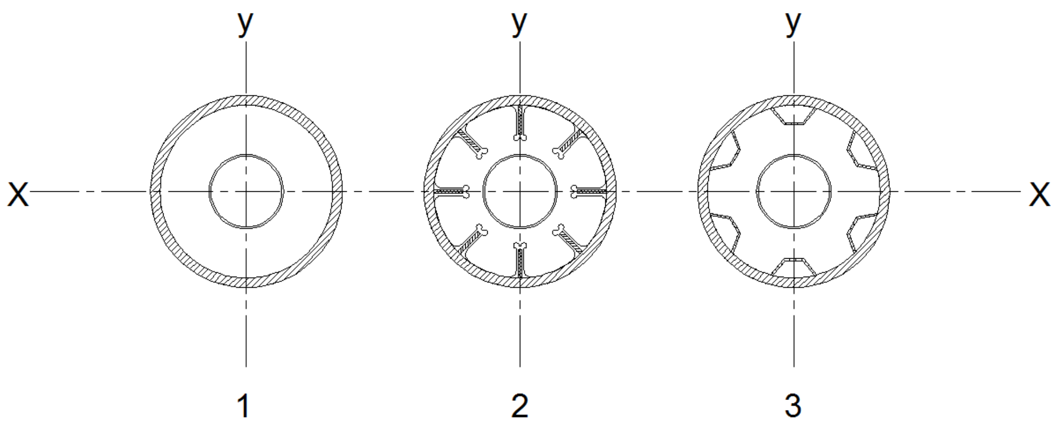

Fig .5.A Type of inside cross hollow circle section with the different shape stiffeners

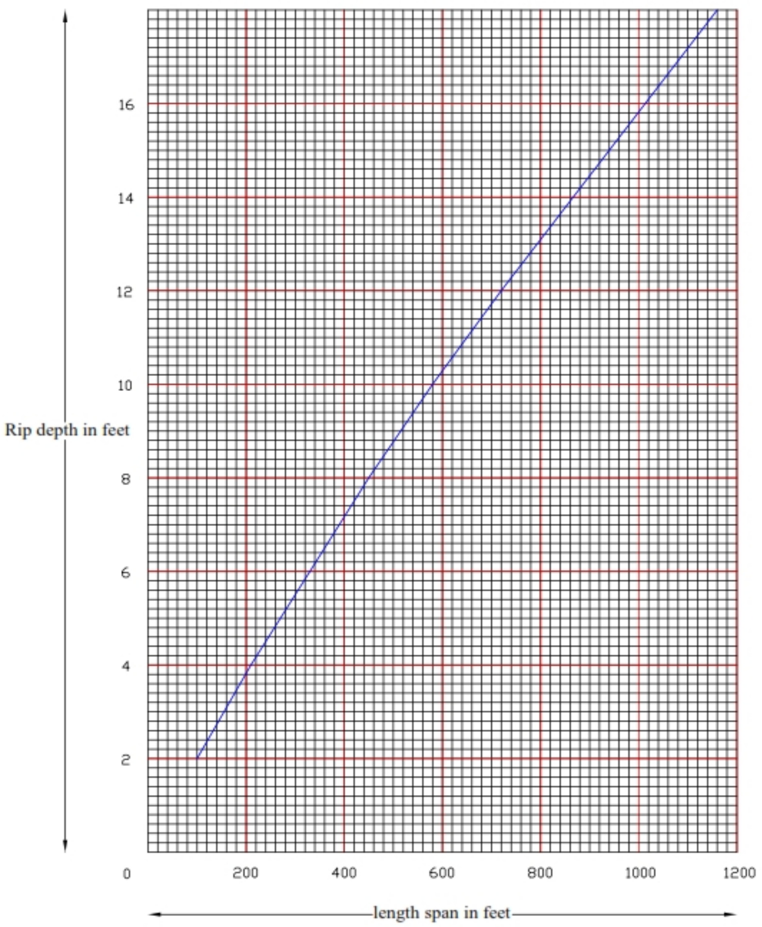

Fig .5.B value span to depth ratio two hinged, solid web, constant depth, steel arch for steel arch (Rip)

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Where the L= length span in feet
d=Rip depth in feet

$$\frac{L}{D} = 44 + 0.6\sqrt{L}$$

Nots. Per 1 feet = 12 inches =30.48 CM

IV. HORIZONTAL EXPANSION

We do the horizontal expansion prevented by the hinges = $L\alpha t$

If *Ht* is the horizontal thrust due to rise in temperature, exerted by the hinged, the B.M. on in element of the arch at high y from the support.

$$M = H_t . y \quad ... \text{ (A)}$$

The thrust horizontal increse due to bending moment as show below.

$$\int_0^L \frac{M.y.ds}{EI} ....(B)$$

Now equating (A)and (B)

$$L\alpha t = \int_0^L \frac{M.y.ds}{EI}$$

$$= \int_0^L \frac{H_t.y.y.ds}{EI}. \qquad \text{where } \mathrm{M} = \mathrm{H_t}.y$$

$$= \int_0^L \frac{H_t.y^2.ds}{EI}. \qquad (\text{substituting } \mathrm{I} = \mathrm{I_0}\sec\theta..and..ds = dx\cos\theta)$$

$$H_t = \frac{L\alpha t}{\frac{y^2.dx}{EI_0}} = \frac{L\alpha t}{\frac{1}{EI_0}\int_0^l y^2.dx} = \frac{E.I_0.L.\alpha.t}{\int_0^l y^2.dx}$$

Now we can obtained on maximum bending stress for rip by fiend the value $\int_0^l y^2.dx$

Where $$R = \frac{L^2}{8y_c} + \frac{y_c}{2} \qquad .... \text{ (6)}$$

β= Angle, which OX makes with center line OC,
x,y = coordinates of the point ,with reference to the point D, which is the middle of the span AB of the arch .see (Fig 6)

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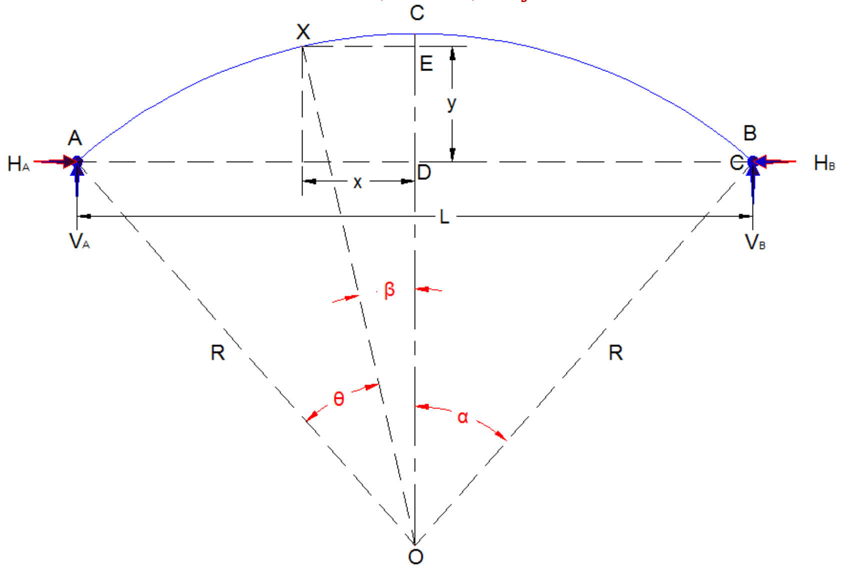

Fig. 6. Parametric of steel arch

V. PROCEDURE DETERMAIN MAX BENDING STRESS DUE TO TEMPERATURES EFFECTED IN THIS EXAMPLE

A two hinged circular arch of span 129.57m and center of rise 21.34 m has 254cm deep rip . Determine the maximum bending stress in the arch when it is subjected to a rise of temperature of 30°C and modules of elasticity $E = 2.1 * 10^6$ and $\alpha = 12 * 10^{-6}$ per °c for the arch materials .see fig (6)

ANS.

The first we can use segment small element (S) of the arch at the angle β with the center line OC,
From the geometry of the figure (6) above we can find that.

$$y = R\cos\beta - R\cos\alpha = R(\cos\beta - \cos\alpha)$$

$$\therefore \int yds = \int_{-\alpha}^{\alpha} R^2(\cos\beta - \cos\alpha)^2 R d\beta$$

$$= \int_0^{\alpha} 2R^2(\cos\beta - \cos\alpha)^2 d\beta$$

$$= R^3\int_0^{\alpha}\left[(1+\cos 2\beta) + 2\cos^2\alpha - 4\cos\alpha\cos\beta\right]d\beta$$

$$= R^3\left[\beta + \frac{\sin 2\beta}{2} + 2\beta\cos^2\alpha - 4\cos\alpha\cos\beta \quad {}_0^{\alpha}\right]d\beta$$

$$= R^3\left[\alpha + \frac{\sin 2\alpha}{2} + 2\alpha\cos^2\alpha - 4\cos\alpha\cos\alpha\right]$$

$$= R^3\left[\alpha - \frac{3}{2} + \sin 2\alpha + \alpha(1+\cos 2\alpha)\right]$$

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$$= R^3[2\alpha - 1.5\sin 2\alpha + \alpha\cos 2\alpha]$$

Now from geometry of the arch we see that.

$$R = \frac{L^2}{8y_c} + \frac{y_c}{2}$$ See equation .... (6)

$$R = \frac{129.57^2}{8*21.34} + \frac{21.34}{2} = 109m$$

$$\sin\alpha = \frac{L}{R} = \frac{129.57}{2*109} = 0.594$$

$$\alpha = 36.44 = \frac{36.44}{180}*3.1416 = 0.6360 \ \ radian$$

$$2\alpha = 0.6360*2 = 1.272 \ \ radian$$

Sin 2α=sin 2*36.44= sin 72.88 =0.955

cos 2α=cos 2*36.44= cos 72.88 = 0.2943

Now we apply in equation (6)

$$= R^3[2\alpha - 1.5\sin 2\alpha + \alpha\cos 2\alpha]$$

$$= R^3[1.272 - 1.5*0.955 + 0.6360*0.2943] = 0.02667R^3$$

$$\therefore \int y^2 ds = 0.02667R^3$$

Now we use the relation to obtained , $H_t = \dfrac{L\alpha t}{\dfrac{1}{EI_0}\int_0^L y^2.dx}$

$$\frac{129.57*100*12*10^{-6}*30}{\dfrac{1}{2.1*10^6*I}*0.02667*(109*100)^3} = 0.0002833I$$

The max moment at the crown

$$M_C = H_t * y_C = 0.0002833I*(21.34*100) = 0.6046I$$

we know that the modules rip section ,

$$Z = \frac{I}{\frac{d}{2}} = \frac{I}{\frac{254}{2}} = \frac{I}{127}$$

By the relation Max bending stress $\sigma = \dfrac{M_C}{Z} = \dfrac{0.6046I}{\dfrac{I}{127}} = 76.78\dfrac{KG}{CM^2}$

Change in the length steel arch with X-X = $L\alpha t$ = 4.66 Cm the true value

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VI. CONCLUSION

The thermal strain effected by type of area cross section for arch Rip as clear in Fig .5.A the 2-max bending stress in the steel arch can obtained from max temperatures thrust for two hinged parabolic as show in Fig.6. parametric of steel arch special procedure by use integration equations with define the(α)temperature expansion coefficient 3-where if we use low cross section in Eq.4 (the rip section for steel arch or tie section this can causes fatigue in structures for low time without avoided this stage . and the strength of materials can avoid the Elongation of structures for low span in some time BY use high strength materials such as GERMANY standard DIN St52-3, or American standard ASTM A588 , A514.

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AUTHOR BIOGRAPHY

[1]**Bilyk Sergy Ivanovech,** Professor, Doctor of science, Head of the Department of metal and wood structures, Kyiv National University of Construction and Architecture, Ukraine.

[2]**Natheer Aied Athaab Al-Taie,** PhD Student, Department of Civil Engineering, Kyiv National University of Construction and Architecture, Ukraine.

[3]**Adil Jabbar Abbas ,** PhD Student, Department of Civil Engineering, Kyiv National University of Construction and Architecture, Ukraine.