# EXPERIMENTAL AND THEORETICAL INVESTIGATION OF A SHALLOW FLEXIBLE ARCH

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By

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CONTENTS

## NOTATIONS

| | |
|---|---|
| $D_s$, $D_s^2$ | First and second derivatives with respect to s |
| $D_x$, $D_x^2$ | First and second derivatives with respect to x |
| $D_z$, $D_z^2$ | First and second derivatives with respect to z |
| E | Young's modulus of the arch material |
| f | Rise of the arch |
| g | A parameter, $g^2 = \frac{H_a L^2}{EI}$ |
| H | True horizontal reaction |
| $H_a$ | Assumed horizontal reaction |
| I | Moment of inertia of the cross section |
| L | Span length |
| M | Bending moment |
| $M_o$ | Bending moment under the load in a simply supported beam having the same span as that of the arch |
| $M_a$, $M_b$ | Fixed end moment for ends A and B respectively |
| n | Non-dimensional parameter, $n = \frac{f}{L}$ |
| N | Influence line for thrust force |
| q(x) | A loading function characterizing the intensity of a distributed load |
| R | Initial radius of curvature of the arch axis |
| $\rho$ | Radius of curvature of the arch axis after deformation |
| s | Arc length along the arch axis |
| $\theta$ | Angle between the horizontal and the tangent to the arch axis |
| $u_q$, $u_h$ | Non-dimensional functions |
| v | Total vertical displacement (+ve downward) |
| $v_h$ | v due to unit horizontal reaction H, with respect to the equilibrium position attained after the application of $H_a$ |
| $v_q$ | v due to external load, with respect to the equilibrium position attained after the application of $H_a$ |

| | |
|---|---|
| $w$ | Radial displacement |
| $X, Y$ | Rectangular coordinates |
| $y(x)$ | The function describing the shape of the arch axis |
| $z$ | Non-dimensional parameter, $z = \frac{x}{L}$ |

TABLES AND FIGURES

# INTRODUCTION

Elastic theory [1] has been in use for many years in the design of structures. In general, this theory neglects any change in geometry of the structure due to strain. When the elastic displacements and axial forces are small, the error involved is usually small. But, when the elastic displacements are appreciable, or when the axial force is not a small fraction of its buckling value, the error introduced may be an important factor in the design. This awareness calls for a more refined method that could reduce the error in the analysis. Deflection theory[2], the subject matter, is one such method. Since the coefficients of equilibrium equations in this theory depend on the displacements, the governing equations are not linear and hence principle of superposition is not applicable without special treatment.

Deflection theory, applied to a number of structures in the past, has shown that the behaviour of a structure can be predicted with much higher accuracy as compared to the elastic theory[3]. The theory was used in the design of the Rainbow arch bridge across the Niagara. Analysis of the arch rib showed that the quarter point deflection of 12 inches as computed by the elastic theory, increased to 21 inches by deflection theory. At the same time, it was observed that the unit stresses hiked up by 28%.

In long spanned arches, the thrust due to dead load becomes an important consideration when determining the moments with the use of deflection theory. The present work is an attempt to test the applicability of a linearized deflection theory for a fixed-fixed parabolic flexible arch. The stresses induced in a long span arch due to the deflection of the arch axis are very much significant. This fact solidifies our belief that the change in geometry cannot be neglected. Wang[4], in his Masters report, has put forward the deflection theory as applied to a parabolic arch of variable moment of inertia. It should be mentioned that Wang's work has been taken as the basis of this thesis.

If one uses iterative method of analysis, the internal forces of the arch determined by the elastic theory is used as the first approximation and are applied to calculate an approximate resulting deflected shape. Additional bending moments due to the deflection is calculated and used for the determination of the second approximate deflected position of the arch axis. If the loaded arch is stable, the deflection is finite and repetition of this procedure will yield the equilibrium position of the arch at which the forces and deflections are consistent[3].

The derived governing differential equation is nonlinear, because one of the coefficients is the horizontal reaction which is a functional of deflection. To remove the difficulty, a linearization technique is employed. This linearization enabled the applicability of the principle of superposition under a preassigned horizontal thrust H. The resultant internal forces were expressed as a combination of effects due to transverse load on a beam and that due to the horizontal reaction and curvature of the arch. Shooting method was used to determine the influence lines of sectional forces for a set of carefully selected flexibility parameters. Using these influence lines, relationship between the variation of a stress at any section of the arch to the variation of assumed horizontal reaction can be obtained. At the same time, the relationship between the corresponding computed horizontal reaction and the assumed horizontal reaction forces are obtained. By the use of the second relationship, the correct horizontal reaction force component can be calculated and used to find the correct value of the force of interest from the first relationship.

## Derivation of the Governing Differential Equation

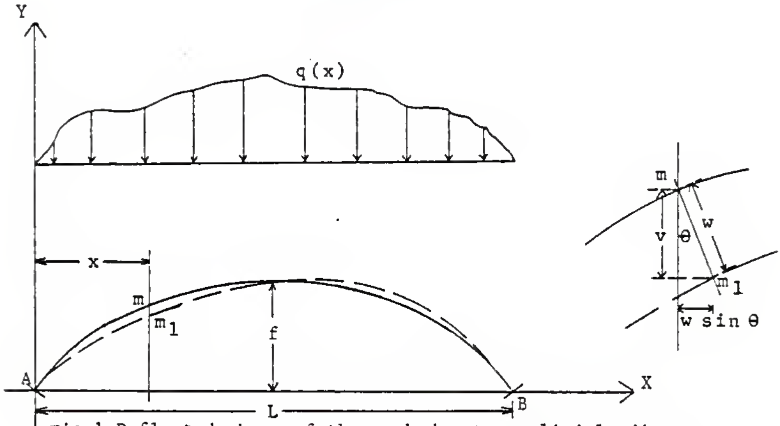



Fig.1 Deflected shape of the arch due to applied loading

In the derivation of the equation, the following assumptions are being made.

1. Stresses and strains are within proportional limits.
2. The influence of the horizontal component of the deflection is small and can be neglected.
3. The change in slope of the axis of the arch due to the applied load, at any point, is so small that the differential length can be assumed as $ds = dx \text{ Sec } \theta$ .
4. The load is assumed to act directly on the arch axis.
5. The radius of curvature is large compared to the thickness of the arch rib so that the straight beam formula is applicable.
6. The arch axis is assumed to be inextensible, thus neglecting the axial effects due to deformation.
7. The effects due to shearing strain is small.

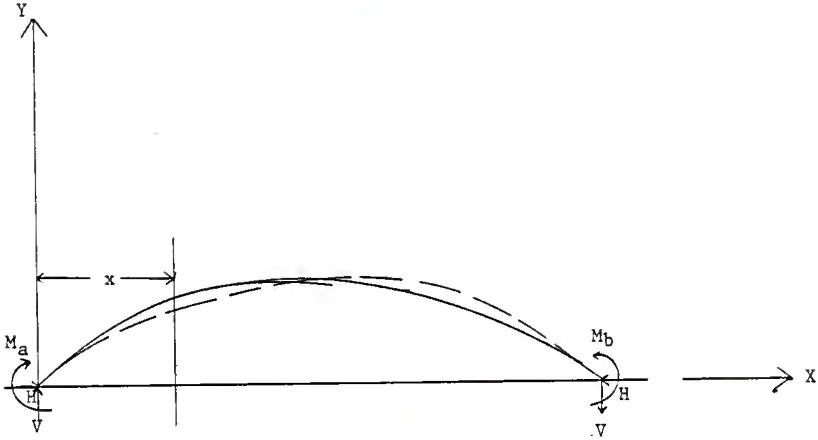


Fig.2 Reaction forces due to applied load

Based on the assumptions made, the bending moment at any point m, distant x from the left end of the fixed-fixed arch can be written as,

$$M_x = M_o - H(y - v) + (M_b - M_a)\frac{x}{L} + M_a \qquad (1)$$

Equation ( 1 ) can be rewritten as,

$$M_x = M_o - H(y - v) + M_a\left(1 - \frac{x}{L}\right) + M_b\frac{x}{L} \qquad (2)$$

We can express the relation between change in curvature and magnitude of bending moment M by the equation,

$$EI\left(\frac{1}{\rho} - \frac{1}{R}\right) = -M \qquad (3)$$

M is taken positive when it produces a decrease in the initial curvature of the arch axis. Note that, in the above case the moment is increasing the curvature.

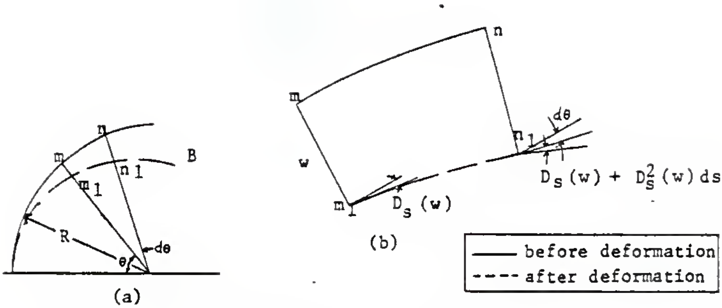



Fig.3 Change in curvature of arch axis

The change in curvature of the arch axis during bending will be found from a consideration of the deformation of a small element mn included between two radii with an angle dθ between them.

The initial length and curvature of the small element mn are,

$$ds = R\, d\theta \quad \text{and} \quad \frac{1}{R} = D_s\ (\theta) \qquad (4)$$

The curvature of the arch axis after bending is,

$$\frac{1}{\rho} = \frac{(d\theta + \triangle d\theta)}{(ds + \triangle ds)} \qquad (5)$$

where, $d\theta + \triangle d\theta$ = Angle between normal cross sections at $m_1$ and $n_1$.

$ds + \triangle ds$ = Length of element $m_1 n_1$

The angle between the tangent to the centerline at $m_1$ and the perpendicular to the radius mo is $D_s\ (w)$. The corresponding angle at cross section $n_1$ is $D_s(w) + D_s^{\ 2}\ (w)\ ds$

Hence, $d\theta = D_s\ (w) + D_s^{\ 2}\ (w)\ ds - D_s(w)$

$$= D_s^{\ 2}\ (w)\ ds \qquad (6)$$

As the angle $D_s(w)$ is very small, we could oeglect the same while calculating the length of $m_1 n_1$.

$$\text{Length of } mn = R\, d\theta$$

$$\text{Length of } m_1 n_1 = (R - w)\, d\theta$$

Hence
$$ds = (R - w)\, d\theta - R\, d\theta$$

$$ds = - w\, d\theta$$

But from ( 4 ),

$$d\theta = \frac{1}{R}\, ds$$

Therefore,

$$ds = - w \frac{1}{R}\, ds$$

Hence ( 5 ) can be rewritten as,

$$\frac{1}{\rho} = \frac{[\, D_s(\theta) + D_s^{2}(w)\, ds ]}{[\, ds - \frac{w}{R}\, ds\, ]}$$

$$= \frac{ds\, [\, D_s(\theta) + \{D_s^{2}(w)\}\, ]}{ds\, [1 - \frac{w}{R}\, ]}$$

$$= \frac{(1/R) + D_s^{2}(w)}{1 - \frac{w}{R}} \qquad (\ 7\ )$$

For $r < 1$,

$$\frac{1}{1-r} = 1 + r + r^2 + \ldots\ldots\ldots$$

Thus for $w \ll R$, one has,

$$\frac{1}{1-(w/R)} = 1 + (w/R) + (w/R)^2 + \ldots\ldots.$$

Neglecting small terms of higher order,

$$\frac{1}{\rho} = (1 + (\frac{w}{R}))\ \frac{1}{R} + D_s^{\ 2}\ (w)$$

Substituting for $\frac{1}{\rho}$ in ( 3 ),

$$EI\ [\frac{1}{R}\ (\ 1 + (\frac{w}{R})\ ) + D_s^{\ 2}\ (w) - \frac{1}{R}\ ] = -M$$

$$EI\ [\ (\frac{w}{R^2}) + (D_s^{\ 2}\ (w))\ ] = -M$$

Equation ( 2 ) will therefore become,

$$-EI\ [\frac{w}{R^2} + D_s^{\ 2}\ (w)\ ] = M_o - H\ (\ y - v\ ) + M_a\ (\ 1 - \frac{x}{L}\ ) + M_b\ \frac{x}{L}$$

As the radius of curvature is large compared to the radial displacement $w$,

$$-EI\ D_s^{\ 2}\ (w) = M_o - H\ (\ y - v\ ) + M_a\ (\ 1 - \frac{x}{L}\ ) + M_b\ \frac{x}{L} \qquad (\ 8\ )$$

The vertical displacement of the arch axis is,

$$v = w\ \text{COS}\ \theta$$

or,
$$w = v\ \text{SEC}\ \theta$$

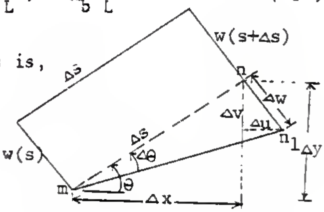



Fig ( 3c) Elemental displacement

With reference to the sketch shown alongside,

$$D_s(w) \simeq D_x(v)$$

and, $D_s^2(w) = D_s\{D_x(v)\}$

$$= \cos\theta \, D_x\{D_x(v)\}$$

$$= \cos\theta \, D_x^2(v)$$

As moment of inertia of the arch is constant, ( 8 ) can therefore be written as,

$$- EI \cos\theta \, D_x^2(v) = M_o - H\,y + H\,v + M_a\left(1 - \frac{x}{L}\right) + M_b\left(\frac{x}{L}\right)$$

Defining $G(x) = \cos\theta$,

$$G(x)\, D_x^2(v) = - \frac{H}{EI}v + \frac{H}{EI}y + f(x)$$

where, $f(x) = - \frac{1}{EI}\left[ M_o(x) + M_a\left(1 - \frac{x}{L}\right) + M_b\left(\frac{x}{L}\right)\right]$

or,

$$G(x)\, D_x^2(v) = - \frac{1}{L^2}\left(\frac{HL^2}{EI}\right) v + \frac{H}{EI}y + f(x) \qquad (9)$$

The first term on the right hand side of equation ( 9 ) is the moment due to deflection and horizontal thrust ; the second term is the moment due to the action of the arch profile ; and last term is the end moment.

( 9 ) can be rewritten as,

$$G(x)\, D_x^2(v) + \frac{1}{L^2}\left(\frac{HL^2}{EI}\right) v = \frac{H}{EI}y + f(x)$$

Differentiating twice and rearranging,

$$G(x)\, D_x^{4}\,(v) + 2\, G'(x)\, D_x^{3}\,(v) + \left[G''(x) + \frac{1}{L^2}\left(\frac{HL^2}{EI}\right)\right] D_x^{2}\,(v)$$

$$= \frac{H}{EI}\, y'' + \frac{q(x)}{EI} \qquad (10)$$

For a fixed ended arch, the vertical deflection and slope at the two ends are zero. Hence,

$$\begin{aligned} v\,(0) &= v\,(L) = 0 \\ v'\,(0) &= v'\,(L) = 0 \end{aligned} \qquad (10a)$$

To solve the fourth order differential equation ( 10 ), one more constraint condition is required, as H is also an unknown. The condition that the sum of horizontal displacements, through the span length L, is zero will give us this additional condition.

$$\int v'\, y'\, dx = 0 \qquad (10b)$$

This consists of horizontal displacements due to both external load and horizontal force

i.e. $\int v_q'\, y'\, dx + \int H v_h'\, y'\, dx = 0$

Linearization of the differential equation

The fourth order differential equation ( 10 ) has unknown coefficients. Also as H is a functional of v, this poses to be a nonlinear problem. Solving this nonlinear problem directly is going to be a tedious job. In order to simplify this, a linearization technique is adopted, thus avoiding the multiplication of H with the functional of v, by assuming a parameter,

$$g^2 = \frac{H_a L^2}{EI} \qquad (10c)$$

Substitution of this into eqn.( 10 ) yields a fourth order linear differential equation, with one unknown value g.

Since, for any proper value of g assigned, the equation is transformed into a linear form, the superposition principle is applicable. Therefore, the vertical deflection v can be split up as,

$$v = v_q + H\,v_h \qquad (10d)$$

where, $v_q$ = total vert. disp. due to ext. load
$v_h$ = total vert. disp. due to unit hor. reaction H

Equation ( 10 ) therefore becomes,

$$G(x)\,D_x^4(v_q + v_h H) + 2\,G'(x)\,D_x^3(v_q + v_h H) + [G''(x) + \frac{g^2}{L^2}]\,D_x^2(v_q + v_h H)$$

$$= \frac{H}{EI}\,y'' + \frac{q(x)}{EI} \qquad (10e)$$

This allows to find the solution in two simpler cases :

$$G(x)\,D_x^4(v_q) + 2\,G'(x)\,D_x^3(v_q) + [\,G''(x) + \frac{g^2}{L^2}\,]\,D_x^2(v_q) = \frac{q(x)}{EI} \qquad \ldots\ldots\ldots (11)$$

and

$$G(x)\,D_x^4(v_h) + 2\,G'(x)\,D_x^3(v_h) + [\,G''(x) + \frac{g^2}{L^2}\,]\,D_x^2(v_h) = \frac{y''}{EI} \qquad \ldots\ldots\ldots (12)$$

The boundary conditions are,

$$v_q(0) = v'_q(0) = v_q(L) = v'_q(L) = 0$$

and $$v_h(0) = v'_h(0) = v_h(L) = v'_h(L) = 0$$

Differential equation for a parabolic arch

In case of a parabolic arch, profile is characterized by,

$$y = \frac{4f}{L} \left( x - \frac{x^2}{L} \right) \qquad (12a)$$

Its first and second derivatives with respect to x are,

$$y' = \frac{4f}{L} \left( 1 - \frac{2x}{L} \right) = \tan\theta \qquad (12b)$$

and $$y'' = -\frac{8f}{L^2}, \quad \text{respectively.} \qquad (12c)$$

As defined earlier,

$$G(x) = \cos\theta = \frac{1}{(1 + y'^2)} \qquad (12d)$$

Differentiating this successively, we can get G'(x) and G"(x)

For simplicity, some of the nondimensional terms are defined as follows.

$$z = \frac{x}{L}$$

$$n = \frac{f}{L}$$

$$u_q = \frac{v_q}{L} \qquad (13)$$

$$Q(z) = \frac{q(x)\, L^3}{EI}$$

$$u_h = \frac{v_h}{L}$$

The differential equations ( 11 ) and ( 12 ) can therefore be written as,

$$G(z)\, D_z^4 (u_q) + 2\, G'(z)\, D_z^3 (u_q) + ( G''(z) + g^2 )\, D_z^2 (u_q) = Q(z) \quad \ldots\ldots\ldots \qquad (14)$$

and its boundary conditions are,

$$u_q(0) = u_q(L) = u_q'(0) = u'_q(L) = 0$$

$$G(z)\, D_z^{4}(u_h) + 2\, G'(z)\, D_z^{3}(u_h) + (G''(z) + g^2)\, D_z^{2}(u_h)$$
$$= -\,8\, n\, r \qquad \ldots\ldots\ldots \qquad (15)$$

and the corresponding boundary conditions are,

$$u_h(0) = u_h(L) = u_h'(0) = u'_h(L) = 0 \qquad (15a)$$

where,

$$G(z) = \frac{1}{[\,1 + \{4\, n\, (1 - 2\, z)\}^2\,]^{0.5}}$$

$$G'(z) = \frac{32\, n^2\, (1 - 2\, z)}{[\,1 + \{4\, n\, (1 - 2\, z)\}^2\,]^{0.5}}$$

$$G''(z) = \frac{64\, n^2}{[\,1 + \{4\, n\, (1 - 2\, z)\}^2\,]^{1.5}} \left[\, \frac{3\,(4\, n\, (1 - 2\, z))^2}{[\,1 + \{4\, n\, (1 - 2\, z)\}^2\,]^2} - 1 \,\right]$$

$$r = \frac{L^2}{EI}$$

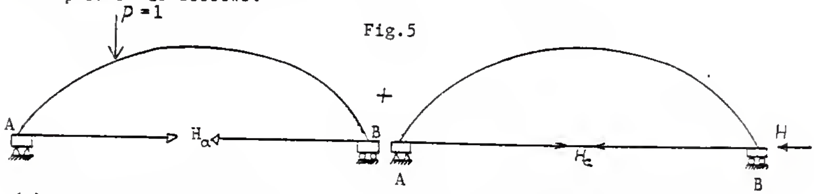
Knowing the boundary values for the solution of a differential equation, an approximate solution at any section can be determined using the Runge-Kutta method of integration.

## Numerical solution of the differential equation

The solution for the deflection of a flexible fixed ended arch under the application of a unit force is discussed in this section.

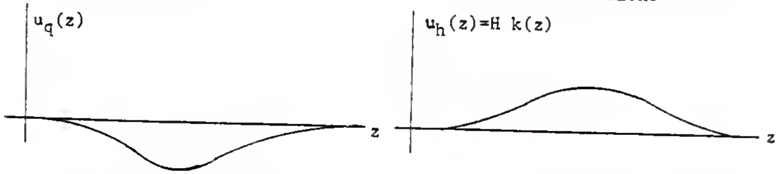
An arch with a preassigned horizontal reaction force $H_a$ can be visualized as a prestressed elastic arch as shown below. Our interest is in finding the deflection under a unit vertical force applied at $z = z_o$. The decomposition of the deflection functions can be expressed as follows.

Fig.5




(a) Arch subjected to unit moving load

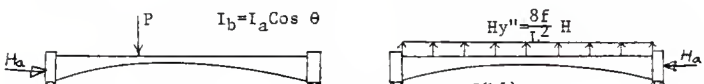
(b) Arch subjected to horizontal force H alone



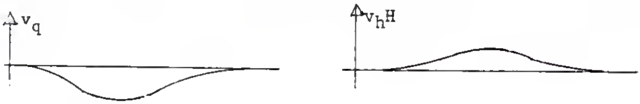

(c) Vertical displacement of the arch axis due to unit load

(d) Vertical displacement of the arch axis due to hor. force H

The mathematical model, presented above, can also be seen as a beam with varying moment of inertia $I_b = I_a \cos\theta$, where $I_a$ is the MI of the arch.




5(a1) 5(b1)




5(c1) 5(d1)

The value of H can be obtained by making the relative displacement between A and B equal to zero, as given by eqn ( 10b ).

In order to use Runge-Kutta method of integration the fourth order differential equations of ( 14 ) and ( 15 ) can be transformed into two equivalent systems of four first order differential equations as follows.

1. **Effects due to a unit external load**

Letting $[u_q, u'_q, u''_q, u'''_q] = [\theta_1, \theta_2, \theta_3, \theta_4] = \theta$

Equation (14) yields the following system.

$$D_z(\theta_1) = \theta_2$$

$$D_z(\theta_2) = \theta_3$$

$$D_z(\theta_3) = \theta_4$$

$$G\,\{D_z(\theta_4)\} = -\,[(G'' + g^2)\,\theta_3 + 2\,G'\,\theta_4 - Q\,] \qquad (16)$$

$\underline{BC}$ $\theta_1(0) = \theta_2(0) = \theta_1(1) = \theta_2(1) = 0$

Choosing the loading location $z = z_o$ as the shooting point, the following sets of initial values of $\theta$ for two homogeneous solutions are assumed.

$$\theta^1\,(0) = \begin{Bmatrix}0\\0\\1\\0\end{Bmatrix}, \quad \theta^2\,(0) = \begin{Bmatrix}0\\0\\0\\1\end{Bmatrix}, \quad \theta^3\,(1) = \begin{Bmatrix}0\\0\\1\\0\end{Bmatrix}, \quad \theta^4\,(1) = \begin{Bmatrix}0\\0\\0\\1\end{Bmatrix} \qquad (16a)$$

By integrating from the two ends, the solutions for equation ( 14 ) can be expressed as the superposition of the two homogeneous solutions.

For $z < z_o$, $\qquad \theta\,(z) = C_1\,\theta^{1\,L} + C_2\,\theta^{2\,L} \qquad (17)$

For $z > z_o$, $\qquad \theta\,(z) = C_3\,\theta^{3\,R} + C_4\,\theta^{4\,R} \qquad (18)$

L and R in the superscript indicate left or right of the section under consideration.

The constants $C_1$, $C_2$, $C_3$, $C_4$ are determined from the condition that, at the loading point, deflection, slope, moment and shear difference obtained by integration from the two ends should match with the load.

Hence at the loading point $z = z_o$, each component of the solution vectors should satisfy the following conditions of continuity.

$$\theta_1^L = \theta_1^R$$
$$\theta_2^L = \theta_2^R$$
$$\theta_3^L = \theta_3^R \qquad (18a)$$

The fourth condition for determination of the solution is to use the equilibrium condition $F_y = 0$,

$$-(G'\ \theta_3^L + G\ \theta_4^L) + (G'\ \theta_3^R + G\ \theta_4^R) = 1$$

at the loading point.

Substituting the obtained coefficients into equations (17) and (18), we can get the solution for equation ( 14 ).

## 2. Effects due to unit horizontal arch reaction

In order to find the required horizontal reaction force H, the deflection of the structure under the application of a unit horizontal force is used for calculating the deflection of the structure.

Letting $[\ u_h\ ,\ u_h'\ ,\ u_h''\ ,\ u_h'''\ ] = [\ k_1\ ,\ k_2\ ,\ k_3\ ,\ k_4\ ] = k$

Equation ( 15 ) yields the following system of first order differential equations.

$$D_z(k_1) = k_2$$
$$D_z(k_2) = k_3$$
$$D_z(k_3) = k_4$$
$$G\,\{D_z(k_4)\} = -\,[(G'' + g)\; k_3 + 2\,G'\,k_4 + 8\,n\,r\,] \qquad (19)$$

and the boundary conditions at the ends are,

$$k_1\,(0) = k_2\,(0) = k_2\,(1) = k_4\,(1) = 0$$

Usíng the conditions of deformation for a symmetrical structure under the application of symmetric loading, the boundary conditions can be written as,

$$k_1\,(0) = k_2\,(0) = k_3\,(1/2) = k_4(1/2) = 0$$

The solution can now be obtained as a superposition of two homogeneous solutions and a particular integral.

The initial values of $k^{(i)}$ are assumed as,

$$k^{(1)}\,(0) = \begin{matrix} 0 \\ 0 \\ 1 \\ 0 \end{matrix} \quad , \quad k^{(2)}\,(0) = \begin{matrix} 0 \\ 0 \\ 0 \\ 1 \end{matrix} \quad , \quad P(0) = \begin{matrix} 0 \\ 0 \\ 0 \\ 0 \end{matrix}$$

$P(z)$ is for the particular integral of the solution using homogeneous boundary conditions and, $k^{(1)}\,(z)$ and $k^{(2)}(z)$ are solutions of the homogeneous differential equation. Integrating from left end to the crown of the arch, the solution for equation ( 15 ) can be expressed as,

$$k\,(\,z\,) = P\,(\,z\,) + D_1\,k^{(1)}\,(\,z\,) + D_2\,k^{(2)}\,(\,z\,) \qquad (19a)$$

Slope and shear at the center of the arch are,

$$\begin{aligned} k_2\,(1/2) &= P_2\,(1/2) + D_1\,k_2^{(1)}\,(1/2) + D_2\,k_2^{(2)}\,(1/2) \\ k_4\,(1/2) &= P_4\,(1/2) + D_1\,k_4^{(1)}\,(1/2) + D_2\,k_4^{(2)}\,(1/2) \end{aligned} \qquad (19b)$$

Solving for $D_1$ and $D_2$ equations (19b) and substituting them into (19a) yields the solution of the deflection of arch under the application of a unit horizontal force.

Calculation of influence line coefficients

The solutions for equations ( 16 ) and ( 19 ) are obtained by assuming the value of g, which is given by,

$$g^2 = \frac{H_a L^2}{EI}$$

The unknown horizontal arch reaction H can be determined by making use of the additional constraint condition,

$$\int_0^L v' \, y' \, dx = 0$$

As defined earlier,

$$v = v_q + H \, v_h$$

$$v' = v'_q + H \, v'_h$$

But,

$$v_q = u_q \, L$$

$$v_h = u_h \, L$$

Therefore,

$$v' = ( u_q' + H \, u_h' ) \, L$$

Also,

$$y' = \frac{4f}{L} \left[1 - \frac{2x}{L}\right]$$

$$= [4f \, (1 - 2 \, z)] \, \frac{1}{L}$$

$$= \frac{1}{L} \, y'( z )$$

Hence,

$$\int_0^L ( u_q' + H \, u_h' ) \, y'( z ) \, dz = 0$$

The horizontal force can be obtained by,

$$H = \frac{\int_0^L u_q' \, y' \, dz}{\int_0^L u_h' \, y' \, dz}$$

The non-dimensional function for v and its derivatives can be expressed as,

$$u_i = \theta_i + H k_i$$

for, $i = 1, 2, 3, 4$

The influence lines for the moment M, vertical shearing force V and thrust TH induced in the arch due to a moving unit load can therefore be written as,

$$M(z, \tilde{z}, g) = - G(z)\, u_3 (z, \tilde{z}, g)$$

$$V(z, \tilde{z}, g) = D_z (v) = - [G(z)\, u_4 (z, \tilde{z}, g) + G'(z)\, u_3 (z, \tilde{z}, g)]$$

$$N(z, \tilde{z}, g) = H(z, g) \operatorname{Cos}(\theta(z)) + V(z, \tilde{z}, g) \operatorname{SIN} \{\theta(z)\}$$

Thus, for any assumed value of g, the influence line for internal force component at the section of interest can be obtained.

Procedure for stress analysis

The stresses at any section of the arch due to the given set of loading can be determined as follows.

Using a set of influence line for M ( z , $\bar{z}$ , g ), a set of M for a given loading condition corresponding to the selected values of g are determined.

Under the same loading conditions, the values for horizontal reaction and the thrust force at the section are calculated corresponding to the g values selected.

Therefore a set of points for functions M(g), N(g) and H(g) over a selected $g_1$, $g_2$, ... , $g_n$ are obtsined.

$$\text{Let} \quad g^* = \frac{H_a L^2}{EI}$$

The correct vslue of g, say $g_o$, is obtained such that $H_{calculated}$ and $H_{assumed}$ agree with each other. The sectional moment of interest M, under any given loading condition, can be calculated by using H(g) such that,

$$g^*(g_o) = g_o$$

and is shown in Fig (1) of Appendix 1.

Numerical analysis

The computer program written in FORTRAN, by Wang[4], was converted to BASIC language and made to work on the mini-computer TRS 80 Model II. The program was suitably modified to find the numerical solution for the loaded model shown below.

A dead load of 5 lbs at each of the loading points, as in the experiment, is used. The ratio of rise to span is 0.1333 and values of 0, 0.318, 0.636 for g were assumed. Three types of moving loads 1 lb, 5 lbs and 10 lbs were considered. The computer program, in BASIC language, is listed in Appendix 2 . The results obtained for the various loading cases are tabulated. The sketch given below illustrates the method of determining the stresses.

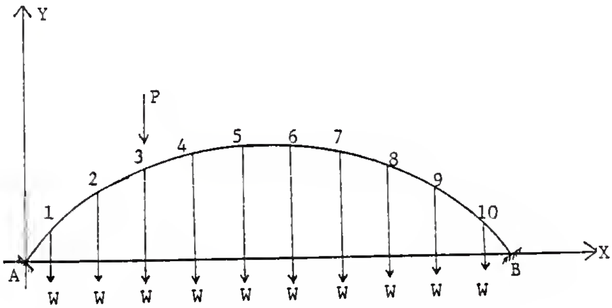



Fig.6 Loading points on the arch

W = Dead load
P = Moving load

## Experimental investigation

To verify the accuracy of the deflection theory, an experimental setup was designed. An arch model, made of steel, with fixed ends was built in the laboratory. The investigation was carried out for a number of loading conditions. Automatic data acquisition system, with an Apple - minicomputer, was used to record the strains registered by the strain gages. The strains were stored on a floppy disk.

It should be mentioned at this stage that, initially a rise of 12 inches and span of 60 inches was taken. But the strain induced in the middle third of the arch due to its profile was found to have crossed the yield strain of the arch material. This was also observed through the permanent strain set in the steel arch. Hence, another arch with a reduced rise of 8 inches and with the same span of 60 inches was built.

A series of experiments were conducted. Moving load was moved from one point to another and at each position the strains were read. There were totally ten loading points. Thus for each moving load there existed ten cases. On the outset, the experiment consisted of two phases. One phase was carried out with dead load and the other without the dead load. Application of dead load was achived by hanging equal load at all the ten loading points.

Moving loads used, for the case without dead load, were 0.5, 1, 2, 4, 6, 8 and 10 lbs. It was observed that there was negligibly small response from the arch when the loads were below 2 lbs. Therefore, only five types of moving loads were considered for the second case when the dead load was applied. The total dead loads considered in the experiment were 10 lbs through 80 lbs at intervals of 10 lbs. For each type of dead load, five tests were carried out for the five moving loads. The data got from all these experiments were stored on a floppy diskette to be retrieved at a later stage. But later on it was discovered that, not all the data had been saved on the disk. Failure of the efforts to retrieve all the data led to the repetition of the experiments.

This time the tests were repeated for dead loads ranging from 10 lbs to 90 lbs at intervals of 10 lbs. The five types of moving loads used were the same as those used previously. The computer was directed to print out the data as and when it received. A computer program was written to calculate the stresses, making use of the strains obtained from the experiment. These stresses were then compared with the stresses calculated from theory. This study showed a discrepancy of as high as 80% at some sections. In an attempt to understand the reason for this, all the stresses were normalized to a unit load. The normalized values were then compared with the corresponding calculated values. The comparison proved to be very much satisfactory, with an average accuracy of 90% , except for the cases when the moving loads were applied at the extreme two points.

This outcome called for a recheck of the experimental setup. Closer inspections indicated the possibility of frictional forces, offered by the pulleys, being the main reason for the discrepancy in the final stresses obtained for the extreme points. Several trial experiments confirmed that the moving loads being used were too small to overcome the frictional resistance coming from the pulleys. This fact led to another set of experiments with moving loads of higher magnitude applied at the two outermost loading points.

A constant dead load of 50 lbs was maintained while the moving loads were varied from 2 lbs to 20 lbs at an interval of 2 lbs. Many sections of the arch were found to respond better when the moving load was above 10 lbs. Another BASIC program was written to make use of this new set of data and to compute the stresses for 1 lb, 5 lb and 10 lbs, by interpolation. The calculation of the stresses indicated an improvement with an accuracy of as high as 75% . The comparison between the experimental and theoretical stresses at the central span section, and the percentage accuracy achieved are given in the tables in Appendix 1. The stresses calculated for the other sections are given in Appendix 2.

## Construction of the flexible arch model

The experiment was conducted on a fixed-fixed parabolic arch of span 60 inches. A wooden formwork for bending the arch into the desired parabolic profile was prepared and bolted on to the steel baseplate. The model was built horizontally on the baseplate which in turn was placed on a table.

To achieve the fixity at the ends, the movement in the three directions was considered and taken care of. The horizontal motion was controlled by two channel sections placed on either side of the arch model. The two sections were securely bolted to the baseplate. In addition a hat section was designed to resist the rotational movement. To allow for free movement of the arch, when loaded, and also to restrict its movement in the transverse direction, rollers were provided underneath the model at five locations.

The loads were applied symmetrically on the arch model at ten points. Five sections were chosen for analysing the stresses induced due to the applied loading. Aluminium wires were made use of for transferring the loads onto the arch. The wire ran parallel to the table-top and over a pulley to be connected to cylindrical loading bowl, prepared for the purpose. Six strain gages, 3 on the topface and 3 on the bottom face, were mounted at each of the five locations.

Material properties of the arch

| | |
|---|---|
| Material | : Cold rolled mild steel |
| Dimensions | : 1 inch wide and 0.125 inch thick |
| Span of the arch | : 60 inches |
| Rise of the arch | : 8 inches |

Steel was selected as the material for making the arch. Three specimens were prepared for tension testing. Riehlers testing machine was made use for the purpose. Two specimens were tested using the extensometer and the automatic graphical ability available in the Riehlers machine. The other specimen was tested for tension on the Riehlers machine, with the help of a dial gage. The two tests yielded comparable results. Fig (2) in Appendix 1 shows the stress-strain curve for the arch material.

The following results were obtained.

| | |
|---|---|
| Maximum load taken by the specimen | = 3670 lbs |
| Ultimate load | = 2800 lbs |
| Young's modulus | = $30 \times 10^6$ psi |

Fixity at the ends

Achieving fixity at the ends of the arch was one of the most important part in the experiment. As it can be visualized, the ends are said to be fixed if the movement of the end section is prevented in the three directions. The movement in the X and Y directions were locked by bolting the arch to two channel sections. To achieve proper lockage, one of the channels was first bolted firmly to the baseplate. The arch was then bolted to the two channel sections. Note that, at this stage the second channel was still not bolted to the baseplate. Only after the arch was bolted tightly to the two sections, was the second channel section secured to the baseplate. To achieve this, slot holes were drilled for the second channel in the baseplate. This procedure was followed to ensure proper fixture of the arch with the channel section.

In order to lock the rotational movement, and also to increase the moment of inertia at the end section, a hat section was designed. Five flat plates were welded togeather, as shown in the sketch, to form the hat section. The welded section was bolted to the channels and the baseplate.

The section thus built was satisfactory. In fact, after the wooden formwork was removed, the steel arch remained in its intended parabolic form. This was tested by putting the formwork back into its place, and the bolts in the formwork went right into the tapped holes made for them in the baseplate.

Roller supports

The main idea of testing the arch by placing it horizontally on the table was to reduce the possibility of the arch's movement in the transverse direction. The arch will move in the transverse direction if the loading points do not pass exactly through the central section of the arch. By providing the rollers underneath the arch would reduce this problem. In the experiment, rollers were provided at five places.

Rollers also helped the arch in its free movement, caused due to the application of loads. The rollers were bolted to wooden blocks which in turn were made to sit under the arch. Care was taken to see that the roller-seat did not cause too much friction to the arch.

Mounting of strain gages

As mentioned earlier, five sections (symmetrical about the center line) were chosen for analysing the stresses. With six gages at each section, totally thirty gages were mounted. The surface where the gage was being mounted was carefully prepared by sanding away the dirt and rust to obtain a smooth, but not a highly polished surface. Solvents such as the degreaser and the neutralizer were then employed to remove all traces of oil or grease and to give the surface a proper chemicall affinity for the adhesive. The location on the arch was accurately marked and the gage positioned with the help of a rigid transparent tape. As the bonded type of strain gage is a high quality precision resistor, it must be attached to the specimen with a suitable adhesive.

M-Bond 200 was used as the adhesive in the present work. Maintaining the position and orientation of the gage by the tape, the adhesive was carefully applied. Since the adhesive is sufficiently strong to control the deformation of the strain-sensitive element in the gage, any residual stresses developed in the adhesive will influence the output of the strain gage. The adhesive was, therefore, subjected to gentle pressures over a suitable length of period to ensure a complete cure. After the gages were properly bonded to the structure, three lead wires were attached to the gage through anchor terminals. Since the strain gages are relatively fragile, care must be taken in attaching the lead wires to the soldering tabs. The properties of the strain gages, classified as Student gages by the Measurement Group Inc, are as follows.

| | | |
|---|---|---|
| Gage type | : | EA - 06 - 240LZ - 120 |
| Resistance in ohms | : | 120.0 $\pm$ 0.3 % |
| Gage factor at 75° F | : | 2.045 $\pm$ 0.5 % |
| Option | : | E |

As described by the suppliers, student strain gages are EA-series gages and are constructed with a 0.001 inch tough, flexible polyimide film backing. All student gages include option E, a polyi mide encapsulation of the grid face, with exposed solder tabs. Normal use temperature range for static strain measurements is -100° F to + 350° F.

The five sections chosen for analysing the stresses along with the positioning of the gages are shown in the sketch below.

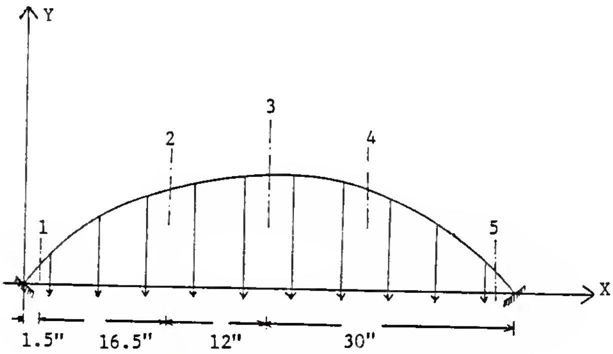



Fig.7 Strain gage sections

Loading applied on the structure was symmetrical. Loads were applied at ten points. Aluminium wires were used to transfer the load on the arch. Calculation of the buckling load was made by making use of the tables given in references [ 1 ] and [ 6 ].

Calculation of the buckling load

From reference [1],

$$q_{cr} = \frac{g_4 EI}{L^3}$$

where $g_4$ is obtained from the table below.

| f/L | 0.1 | 0.2 |
|---|---|---|
| $g_4$ | 60.7 | 101.0 |

By interpolation, for $f/L = 0.1333$, $g_4 = 74.133$

$$q_{cr} = \frac{[74.133 \times 30 \times 10^6 \times \{1 \times (1/8)^3\}]}{60^3 \times 12}$$

$$= 1.67582 \text{ lbs/in}$$

Calculation from reference [6] yielded,

$$q_{cr} = 1.69 \text{ lbs/in}$$

Taking $q_{cr} = 1.67582$ lbs/in ,

$$M_{cr} = \frac{q_{cr} L^2}{8} = \frac{1.67582 \times 60^2}{8}$$

$$= 754.119 \text{ lb - in}$$

$$H_{cr} = \frac{M_{cr}}{f} = \frac{754.119}{8}$$

$$= 94.265 \text{ lbs}$$

Sand and lead weights were used as loads on the structure. Special cylindrical loading bowls were prepared for the purpose. Automatic data acquisition system, coupled with the apple minicomputer, was used to determine the strain. The free end of the lead wires coming from the strain gages were soldered to a pin connector. This pin is inserted into the sockets provided at the back of the data acquisition system.

The controller is essentially the brain of the data acquisition system and contains a microprocessor with several memory devices. The controller activates scanner and controls the time sequence of the switching from one channel to the next. Also, it stores the output, the channel number and the time when the reading is made in its operating memory. The final form of the data is then transmitted to the mini-computer.

## Calculation of the stresses from the strains obtained

Let, Et = Strain obtained from the top surface of the arch.

Eb = Strain obtained from the bottom surface of the arch.

$A_a$ = Cross sectional area of the arch.

M = Moment at the section under consideration.

N = Thrust at the section under consideration.

Both the moment and thrust contribute to the strain at any section. As the arch is basically a compression member, the contribution from the thrust is negative.

$$Et = -\frac{N}{A_a E} - \frac{Mc}{EI}$$

$$Eb = -\frac{N}{A_a E} + \frac{Mc}{EI}$$

Adding the two equations,

$$N = - \frac{AE}{2} (Et + Eb)$$

Subtracting the two equations,

$$M = \frac{EI}{2c} (Eb - Et)$$

Shear (V) can also be calculated if the moments at two sections, a small distance apart, are known.

$$V = \frac{M_1 - M_2}{ds}$$

where, $M_1$ and $M_2$ are the moments at two sections distance ds apart.

Thus, the stresses are determined from the strains obtained from the experiment. A computer program, in BASIC language, was generated to calculate the stresses as explained above.

Numerical resulta

The following types of loadings have been considered and discussed here.

1 A moving load of 10 lbs with no dead load on the structure.

2 A moving load of 1 lb with a dead load of 50 lbs (which is about 53% of the buckling load) on the structure.

3 A moving load of 5 lbs with a dead load of 50 lbs on the structure.

4 A moving load of 10 lbs with a dead load of 50 lbs on the structure.

5 Static loads of 5 lbs, 10 lbs and 10 lbs at fourth, fifth and sixth loading points respectively, in addition to a dead load of 50 lbs on the structure.

A computer program was generated to calculate the moment and thrust from the strain data obtained and has been made to run on the Zenith - 100 mini-computer. A listing of the program is given in Appendix 2. The results obtained are tabulated and compared with the theoretical results. This comparison has been made at the center span. Influence lines for all the above loadings at three locations are drawn and shown through figures in Appendix 1.

Compariaon and Concluaion

As shown in Appendix 1 for the central span section, the moment values are in close agreement with the experimental values. For 10 lbs moving load, Table 2 shows that the accuracy is as high as 97%. The accuracy is found to be 73% when the load is acting at 1, indicating the failure of the load to influence the far off sections. The influence lines, at three sections are shown in Appendix 1 and the variation from the calculated values are marked.

However, it should be noted that at some sections the experimental moment values were normalized before being compared. The influence line diagram for the arch when a dead load of 50 lbs was present, failed to agree with the corresponding theoretical results. The reasons for the disagreement are due to a number of factors, the most significant one being the frictional force.

As it has been explained in an earlier chapter, aluminium wires used for applying the loads on the structure, were carried over pulleys. Careful inspection indicated that the loads applied on the structure failed to overcome the friction exerted by the pulleys. The response from the arch due to some of the loads was observed to be negligibly small. In order to overcome this limitation, a series of experiments were conducted, by increasing the magnitude of the moving load each time, with a constant dead load of 50 lba. The magnitude of the moving loads ranged from 2 lb to 20 lbs at an interval of 2 lbs. In several of the cases, especially when the moving loads were near the ends, the arch was seen to respond only when the magnitude of the moving load was more than 10 lbs.

The results obtained from this aeries of experimenta were then utilised in interpolating the strains for three moving load cases of 1 lb, 5 lbs and 10 lbs. A computer program was generated for this interpolation and for the calculation of the stresses. It was observed that at some sections, the stresses were still not in agreement with the theoretical values. The experimental values were therefore normalized for a unit load. This treatment immediately yielded satisfactory results. The percentage variation of the values from the corresponding theoretical values are given in Appendix 1, for stresses as obtained due to a moving load of 10 lbs. The table indicatea very close agreement as the load approaches the section of interest. From this it could be clearly seen that, the influence of a load at any section of the arch is inversely proportional to its distance from the loaded point. The obvious reason is the frictional resistance from the pulleys.

Though utmost care was practiced in the mounting of strain gages, the possibility of human errors cannot be neglected. The characteristics of the adhesive used in mounting the gage are auch that it can influence apparent gage factor, hysteresis characteristics, resistance to stress relaxation, gage resistance, temperature induced zero drift and insulation resistance[5]. Such sensitiveness could blow up very small errora and might influence the final results. In fact, six of the thirty gages mounted, failed to respond eventhough a check on their mounting and resistance indicated satisfactory results.

From table 1 in the Appendix, it could be seen that the variation in the moments is not linear as the load is incresed from 1 lb to 10 lbs. This proves that the change in geometry of the structure has a considerable effect on the results.

However, further work in the area is required before using the method as a useful tool in the practical field.

## Recommendations

Placing the arch in a vertical position and applying the loads directly, without any pulleys, would yield better results. Such a setup will remove the frictional forces, which influenced the final results considerably, in the present work.

It is also recommended that the wires carrying the load, should be made to sit directly on the arch. Connection of the wire to an eyebolt will generate local moments which are considerably large near the ends. Eye bolts were initially used in the present work, and later removed, at all but middle two loading points of the arch, after the above mentioned phenomena was observed. In the middle section, the alignment of the eye bolts was seen to be along the loading line. The influence line diagram, shown in Fig (3) of Appendix 1, indicates an offset in the values obtained for the middle two points. Thus, it is observed that the local moments due to the eyebolts, however small they were, have affected the final results.

Also, the horizontal component of the displacement was not considered in the present work. Hence, in order to predict the behaviour of the structure with a much higher accuracy, it is recommended that the horizontal component be taken into consideration while formulating the equilibrium conditions in all future works.

## ACKNOWLEDGEMENT

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Thanks are also due to all friends and well wishers who offered their valuable and highly acknowledged help, during the construction of the arch model.

## REFERENCES

1 Timoshenko and Gere, "Theory of Elastic Stability", McGraw-Hill, Second edition, 1961.

2 Chwalla, E., "Theory of Structures", Handbook of Engineering Mechanics, editor Flugge W., McGraw-Hill, first edition, 1962 (pp 30-18).

3 Shortridge, H., and Garrelts, J.M., "Rainbow Arch Bridge over Niagara Gorge", ASCE Transaction vol 110, 1945.

4 Wang, P., "Stress analysis of flexible-inextensible arch with variable cross section", Masters Report, Kansas State University, 1970.

5 Dally, J.W., and Riley, W.F., "Experimental stress analysis", second edition, McGraw Hill, 1978.

6 Frank van der woude, "Deformation of arches : Elastic buckling behaviour", Journal of structural division, vol 105, No ST12, Dec 1979.

7 Hu, K.K., "Linear deflection theory of a long span arch", Taiwan Highway Engineering, 1964.

8 Keller, "Numerical methods for two point boundary-value problem", Blaisdell publishing co., 1968.

9 Gill, S., "A process for the step by step integration of differential equations in an computing machine", Proc. Cambridge Phil. Soc., 47, 96-108, 1951.

# APPENDIX 1

## Tables and figures

TABLE 1

| Loading at | P = 1 lb | | P = 5 lb | | P = 10 lb | |
|---|---|---|---|---|---|---|
| point no. | Calculated | Experimental | Calculated | Experimental | Calculated | Experimental |
| 1 | - 1.80 | - 1.38 | - 1.92 | - 1.51 | - 2.1 | - 1.52 |
| 2 | - 3.00 | - 2.73 | - 3.60 | - 3.38 | - 5.40 | - 4.78 |
| 3 | - 3.00 | - 3.01 | - 5.40 | - 5.29 | - 9.00 | - 8.38 |
| 4 | - 3.12 | - 3.64 | - 6.00 | - 5.69 | - 8.52 | - 7.87 |
| 5 | - 2.40 | - 2.80 | - 1.32 | - 1.01 | - 7.20 | - 6.96 |

Experimental and calculated Influence line coefficients for moment at the central section of the arch

**TABLE 2**

| Loading at point no. | P = 1 lb (%) | P = 5 lbs (%) | P = 10 lbs (%) |
|---|---|---|---|
| 1 | 76.76 | 78.63 | 72.31 |
| 2 | 90.80 | 93.82 | 88.55 |
| 3 | 99.55 | 98.04 | 93.13 |
| 4 | 83.33 | 94.90 | 92.32 |
| 5 | 83.34 | 76.54 | 96.72 |

Variation of Influence line coefficients for moment at the central section of the arch (in percentage)

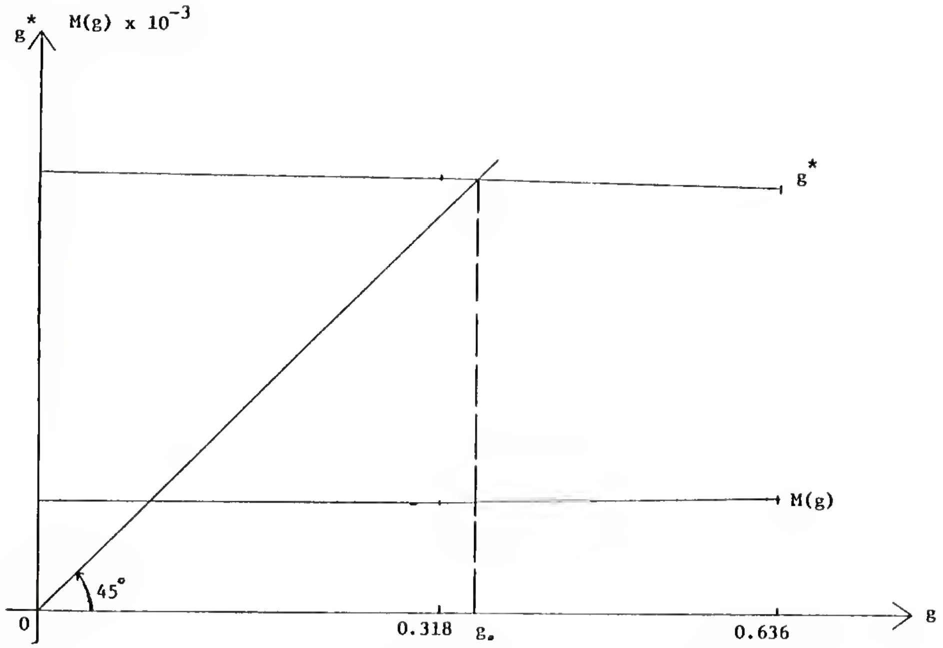



Fig A1 Graphical method to find the actual forces for the central section

Dead load = 50 lbs
Moving load = 10 lbs at loading point 1.

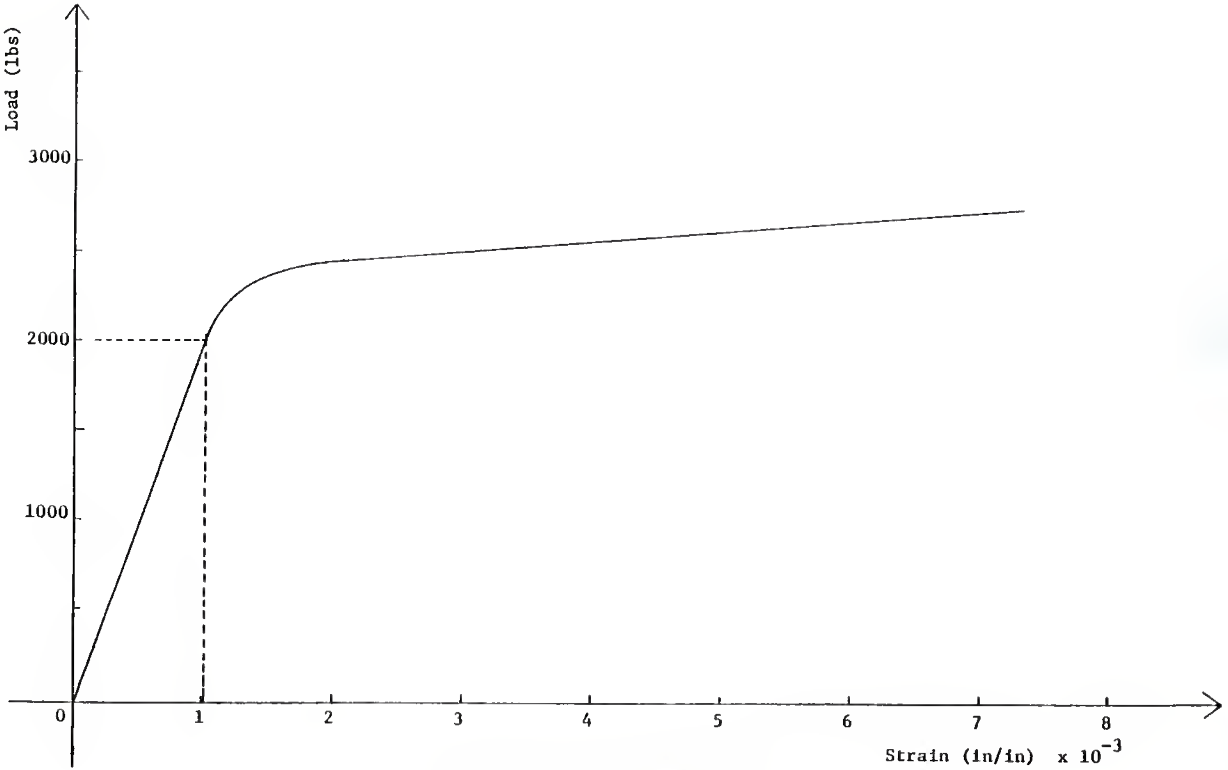



Fig A2    Load vs Strain curve

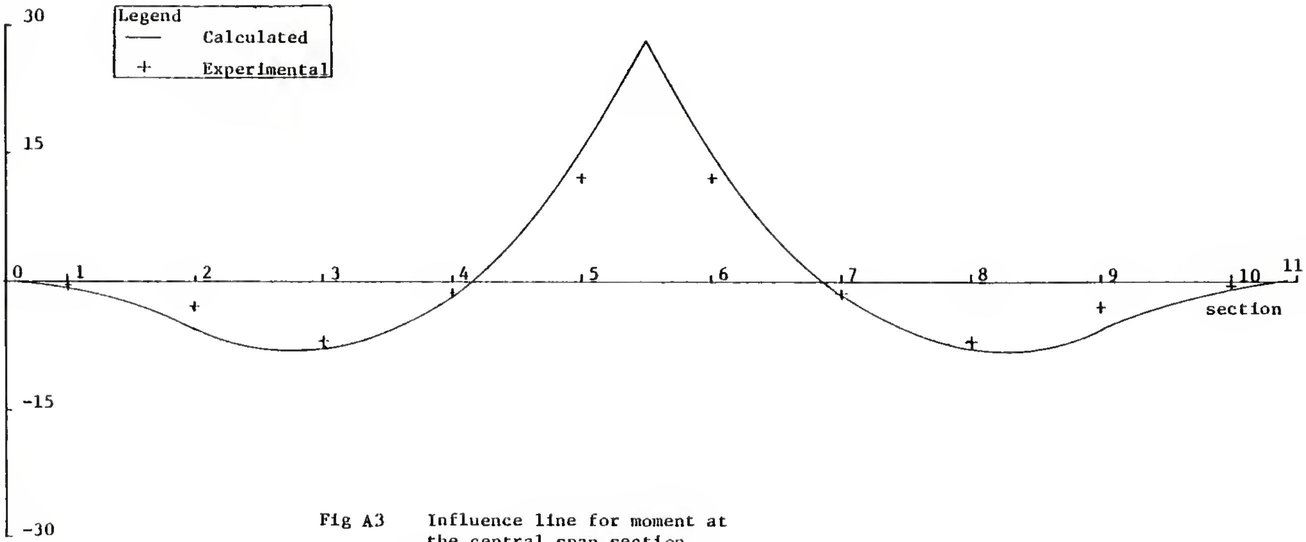



Fig A3 Influence line for moment at the central span section

Dead load = 50 lbs
Moving load = 10 lbs

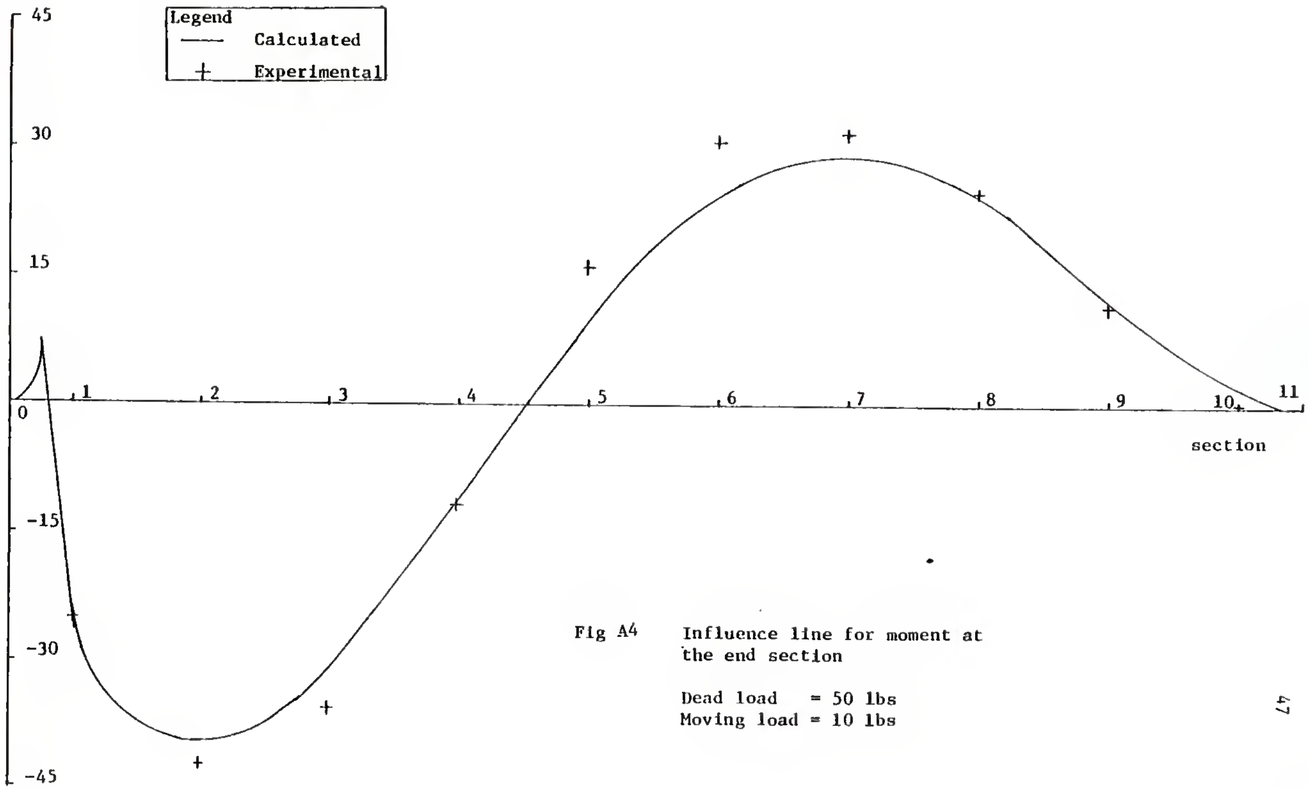



Fig A4 Influence line for moment at the end section

Dead load = 50 lbs
Moving load = 10 lbs

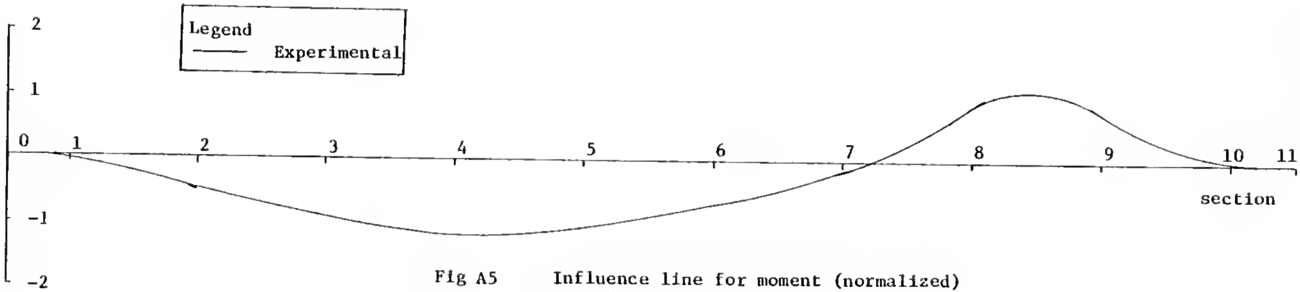



Fig A5 Influence line for moment (normalized) at 18" from right support

Dead load = 50 lbs
Moving load = 10 lbs

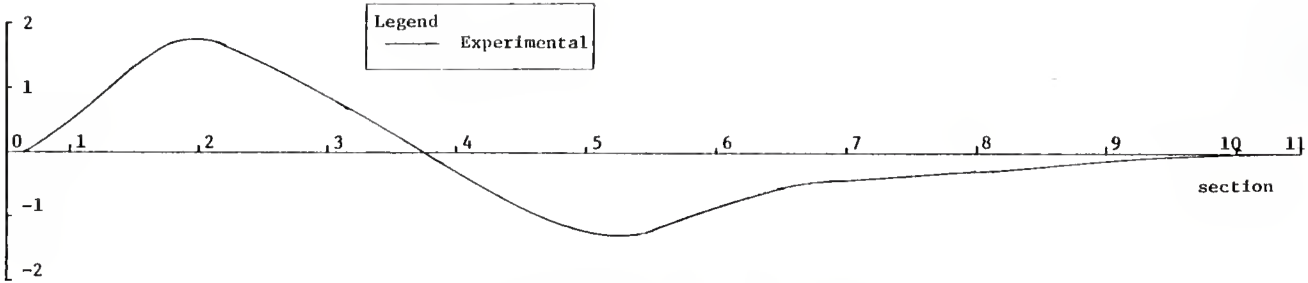
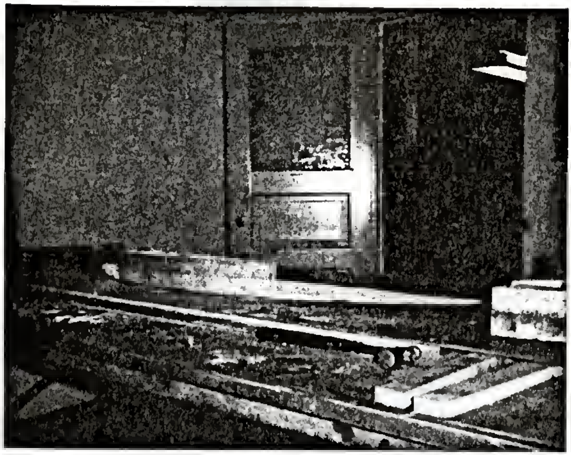
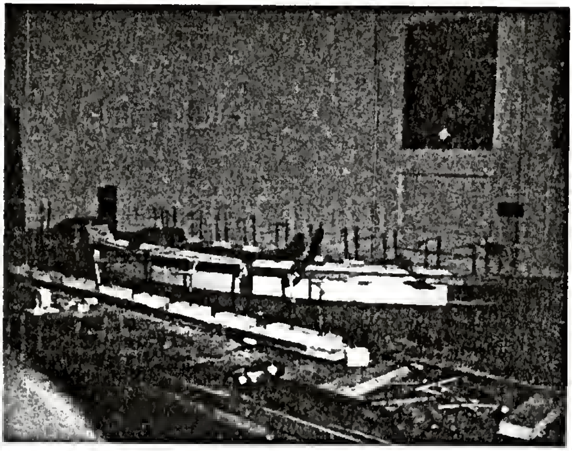



Fig A6 Influence line for moment (normalized) at 18" from left support

Dead load = 50 lbs
Moving load = 10 lbs

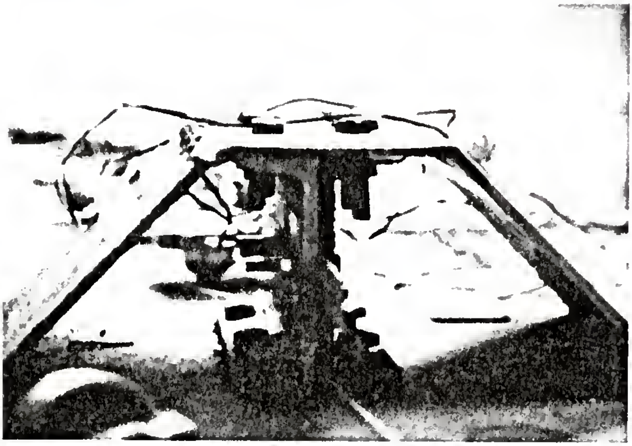


P1 Fixing the formwork

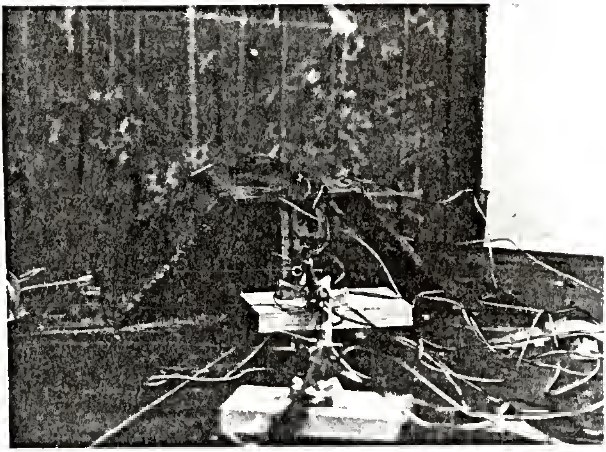


P2 Placing the arch

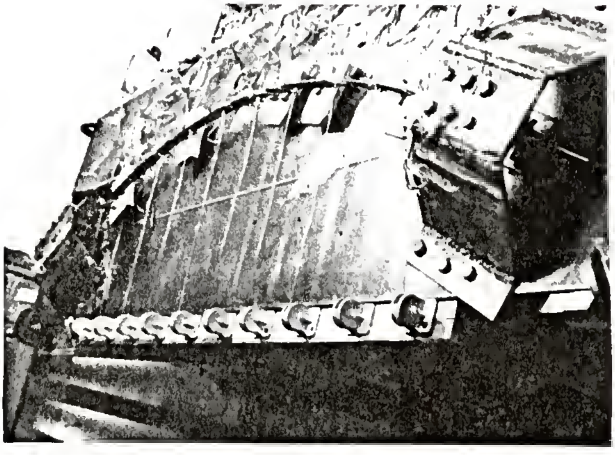
P3 The hat section



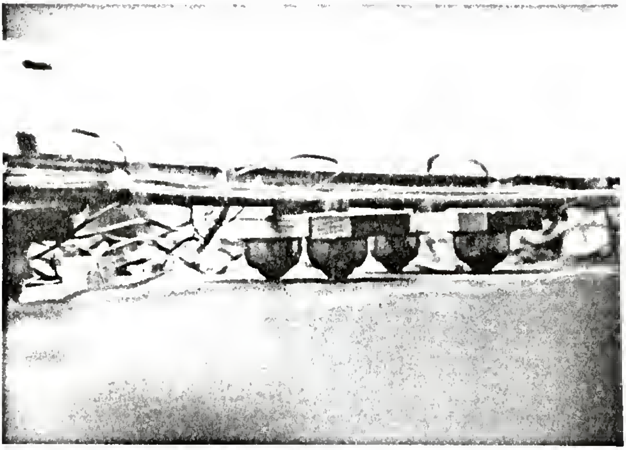
P4 Sectional view of the fixed end



P5 General view of the end section



P6 The arch model



P7 Roller supports

## APPENDIX 2
## Computer programs and results

```
10 REM
20 REM This program calculates the influence line coefficients fo
r a fixed ended arch with constant moment of inertia.
30 REM
40 REM **********************************************************
50 REM Some of the variables used in the program are explained be
low
60 REM AN =>  n=f/L
70 REM G  =>  COS (Theta)
80 REM GP =>  G'= dG/dx
90 REM YP =>  y'= dy/dx
100 REM W1(I,J), TH(I,J), SV(I,J)  => Moment, Thrust and Shear at
 section I of the arch due to unit load at J.
110 REM *********************************************************
120 DIM A(4,5), AA(4,21), AGN(4), ALM(8), AN(4), AP(4), AVN(4)
130 DIM BT(8,6,5), C(4), CN(21), DRIV(21), DX(21), DY(4), E(2)
140 DIM F(21), FA(3,21), G(21), GP(21), HF(4,21), HH(6,5), HX(21)
150 DIM IX(21), PA(3), PSA(8,6,5), PVA(4), Q(4)
160 DIM S(4,10,21), S1P(21), SAN(8,6,5), SMNY(4), SN(21), SPS(4,2
1)
170 DIM SS(6), ST(6), SV(6,21), SYMX(4)
180 DIM T(21), T1(21), TA(4), TH(6,21), TIG(4,21), TJP(4), TWH(4,
21)
190 DIM U(8,6,5), W1(6,21), W2(11,21), W3(11,21), WH(4,4,21)
200 DIM XI(3), Y(4), YP(21), YY(5), Z(5)
210 PI=3.14159265358
220 EI=6000000
230 CLS
240 PRINT "In the present work, the rise to span ratio is 8/60 =
0.1333"
250 INPUT "Rise to span ratio =";AN(3)
260 PRINT : PRINT "Input the assumed values of H/Hcr"
270 PRINT "In the present work, Hcr was calculated as 94.34 [Ref
Elastic Stability by Timoshenko].  Hmax expected was 60 lbs.  H/H
cr = 60/94.34 = 0.636"
280 PRINT "For plotting we need a minimum of three points"
290 PRINT "Hence 0, (0+0.636)/2 and 0.636 were fed in as the inpu
t"
300 PRINT : PRINT : PRINT
310 FOR I=1 TO 3
320 INPUT "H/Hcr=";ALM(I)
330 NEXT I
340 II=3
350 FOR JJ=1 TO 3
360 X=0
370 H=1/20
380 FOR J=1 TO 21
390 G(J)=1/SQR(1+(4*AN(II)*(1-2*X))^2)
400 CN(J)=G(J)
410 YP(J)=4*AN(II)*(1-2*X)
420 SN(J)=YP(J)*CN(J)
430 GP(J)=32*AN(II)^2*(1-2*X)/((1+(4*AN(II)*(1-2*X))^2)^(3/2))
440 X=X+H
450 NEXT J
460 ALM(JJ)=PI*ALM(JJ)
470 NEQ=4
480 FOR J= 1 TO 2
490 MN=J+2
```

```
500 FOR I = 1 TO 4
510 Q(I)=0
520 Y(I)=0
530 NEXT I
540 Y(MN)=1
550 FOR M=1 TO 4
560 WH(M,J,1)=Y(M)
570 NEXT M
580 X=0
590 KK=2
600 FOR K=2 TO 21
610 GOSUB 2360
620 FOR M=1 TO 4
630 WH(M,J,K)=Y(M)
640 NEXT M
650 NEXT K
660 NEXT J
670 KK=1
680 FOR J=1 TO 4
690 WH(J,3,1)=0
700 Y(J)=0
710 Q(J)=0
720 NEXT J
730 X=0
740 FOR J= 2 TO 21
750 GOSUB 2360
760 FOR K=1 TO 4
770 WH(K,3,J)=Y(K)
780 NEXT K
790 NEXT J
800 D=WH(2,1,11)*WH(4,2,11)-WH(2,2,11)*WH(4,1,11)
810 D1=-WH(2,3,11)*WH(4,2,11)+WH(2,2,11)*WH(4,3,11)
820 D2=-WH(2,1,11)*WH(4,3,11)+WH(2,3,11)*WH(4,1,11)
830 C1=D1/D
840 C2=D2/D
850 FOR J= 1 TO 4
860 J1=J+1
870 FOR M= 1 TO 11
880 JK=22-M
890 TWH(J,M)=C1*WH(J,1,M)+C2*WH(J,2,M)+WH(J,3,M)
900 TWH(J,JK)=TWH(J,M)*((-1)↑J1)
910 NEXT M
920 NEXT J
930 FOR J=1 TO 21
940 T1(J)=TWH(2,J)*YP(J)
950 NEXT J
960 N=21
970 GOSUB 2840
980 DTH=AR
990 FOR J=1 TO 21
1000 HF(1,J)=TWH(1,J)/DTH
1010 NEXT J
1020 FOR M=1 TO 21
1030 HF(3,M)=-G(M)*TWH(3,M)
1040 HF(4,M)=-GP(M)*TWH(3,M)-G(M)*TWH(4,M)
1050 NEXT M
1060 FOR J=1 TO 2
1070 MN=J+2
1080 CI=-1
1090 FOR M=1 TO 4
```

```
1100 CI=CI*(-1)
1110 FOR K=1 TO 21
1120 KM=22-K
1130 WH(M,MN,K)=WH(M,J,KM)*CI
1140 NEXT K,M,J
1150 FOR I=2 TO 20
1160 FOR J=1 TO 3
1170 FOR K=1 TO 4
1180 A(J,K)=WH(J,K,I)
1190 FOR L=1 TO 4
1200 A(4,L)=-GP(I)*WH(3,L,I)-G(I)*WH(4,L,I)
1210 A(L,5)=0
1220 NEXT L
1230 NEXT K,J
1240 FOR K=1 TO 4
1250 FOR J=3 TO 4
1260 A(K,J)=-A(K,J)
1270 NEXT J,K
1280 A(4,5)=1
1290 GOSUB 2140
1300 S1P(I)=0
1310 FOR J=1 TO 2
1320 S1P(I)=S1P(I)-A(J,5)*(GP(I)*WH(3,J,I)+G(I)*WH(4,J,I))
1330 NEXT J
1340 FOR J=1 TO 11 STEP2
1350 I1=(J+1)/2
1360 SV(I1,I)=0
1370 W3(I1,I)=0
1380 IF J >= I THEN 1460
1390 FOR K=1 TO 2
1400 SV(I1,I)=SV(I1,I)-(GP(J)*WH(3,K,J)+G(J)*WH(4,K,J))*A(K,5)
1410 W2(I1,I)=HF(3,J)*HF(1,I)
1420 W3(I1,I)=W3(I1,I)-G(J)*A(K,5)*WH(3,K,J)
1430 W1(I1,I)=W3(I1,I)+W2(I1,I)
1440 NEXT K
1450 GOTO 1520
1460 FOR K=3 TO 4
1470 SV(I1,I)=SV(I1,I)-(GP(J)*WH(3,K,J)+G(J)*WH(4,K,J))*A(K,5)
1480 W2(I1,I)=HF(3,J)*HF(1,I)
1490 W3(I1,I)=W3(I1,I)-G(J)*A(K,5)*WH(3,K,J)
1500 W1(I1,I)=W3(I1,I)+W2(I1,I)
1510 NEXT K
1520 NEXT J
1530 NEXT I
1540 FOR I=1 TO 6
1550 W1(I,1)=0 : SV(I,1)=0 : SV(I,21)=0 : W1(I,21)=0
1560 NEXT I
1570 S1P(1)=1
1580 SV(1,1)=1
1590 FOR I=1 TO 6
1600 NP=2*I-1
1610 FOR J=1 TO 21
1620 TH(I,J)=HF(1,J)*CN(NP)+SV(I,J)*SN(NP)
1630 SV(I,J)=(SV(I,J)+HF(4,NP)*HF(1,J))*CN(NP)
1640 NEXT J
1650 ST(1)=HF(1,NP)*CN(NP)+S1P(I)*SN(NP)
1660 SS(I)=(S1P(I)+HF(4,NP)*HF(1,NP))*CN(NP)
1670 NEXT I
1680 FOR XI=1 TO 6
1690 FOR J=1 TO 21
```

```
1700 TWH(1,J)=W1(XI,J)
1710 TWH(2,J)=HF(1,J)
1720 TWH(3,J)=TH(XI,J)
1730 TWH(4,J)=SV(XI,J)
1740 NEXT J
1750 NP=2*XI-1
1760 AJJ=JJ-1
1770 AJJ=AJJ*0.2*PI
1780 LPRINT
1790 LPRINT "LAMBDA= ";AJJ
1800 LPRINT
1810 LPRINT"Influence lines for section #";NP
1820 LPRINT
1830 LPRINT "Moment", : LPRINT "Thrust", : LPRINT "SHEAR"
1840 FOR J=1 TO 21
1850 LPRINT W1(XI,J), : LPRINT TH(XI,J), : LPRINT SV(XI,J)
1860 NEXT J
1870 SYSTEM "T"
1880 IF XI < > 1 THEN 1920
1890 LPRINT
1900 GOTO 1990
1910 REM Change STH to HTS & SSV to VSS
1920 HTS=ST(XI)
1930 VSS=SS(XI)
1940 LPRINT
1950 REM LPRINT "(Special jump point)"
1960 REM LPRINT HTS : REM LPRINT VSS
1970 TJP(3)=HTS
1980 TJP(4)=VSS
1990 GOSUB 2940
2000 IF NP=11 THEN GOSUB 4100
2010 FOR J=1 TO 3
2020 PSA(JJ,XI,J)=PA(J)
2030 SAN(JJ,XI,J)=AGN(J)
2040 NEXT J
2050 FOR K=1 TO 3
2060 BT(JJ,XI,K)=T(K)
2070 NEXT K
2080 NEXT XI
2090 NEXT JJ
2100 PP=600
2110 D=1.3*PI
2120 END
```

```
2130 REM ********************
2140 REM   Subroutine GJR(A)
2150 REM ********************
2160 N=4
2170 N1=N+1
2180 DET=1.0
2190 FOR J=1 TO N
2200 DIV=A(J,J)
2210 S=1/DIV
2220 DET=DET*DIV
2230 FOR K=J TO N1
2240 A(J,K)=A(J,K)*S
2250 NEXT K
2260 FOR L=1 TO N
2270 IF (L-J)=0 THEN 2320
2280 AIJ=-A(L,J)
2290 FOR K=J TO N1
2300 A(L,K)=A(L,K)+AIJ*A(J,K)
2310 NEXT K
2320 NEXT L
2330 NEXT J
2340 RETURN
```

```
2350 REM ******************
2360 REM   Subroutine RKG
2370 REM ******************
2380 REM The independent variable X is incremented in this progra
m.Y(I) & DY(I)
2390 REM are the dependent variable & its derivative.All the Q(I)
 must be initially
2400 REM set to zero in the main program.
2410 REM NEQ = Number of first order equations
2420 REM H = interval size
2430 E(1)=0.2928932188134524
2440 E(2)=1.7071067811865475
2450 H2=0.5*H
2460 GOSUB 2690
2470 FOR I=1 TO NEQ
2480 B=H2*DY(I)-Q(I)
2490 Y(I)=Y(I)+B
2500 Q(I)=Q(I)+3*B-H2*DY(I)
2510 NEXT I
2520 X=X+H2
2530 FOR JK=1 TO 2
2540 GOSUB 2690
2550 FOR I=1 TO NEQ
2560 B=E(JK)*(H*DY(I)-Q(I))
2570 Y(I)=Y(I)+B
2580 Q(I)=Q(I)+3*B-E(JK)*H*DY(I)
2590 NEXT I,JK
2600 X=X+H2
2610 GOSUB 2690
2620 FOR I=1 TO NEQ
2630 B=0.16666666666666666*(H*DY(I)-2*Q(I))
2640 Y(I)=Y(I)+B
2650 Q(I)=Q(I)+3*B-H2*DY(I)
2660 NEXT I
2670 RETURN
```

```
2680 REM *********************
2690 REM   Subroutine deriv
2700 REM *********************
2710 L=NEQ-1
2720 FOR I=1 TO L
2730 DY(I)=Y(I+1)
2740 NEXT I
2750 G=1/SQR(1+(4*AN(II)*(1-2*X))↑2)
2760 GP=32*AN(II)↑2*(1-2*X)/((1+(4*AN(II)*(1-2*X))↑2)↑(3/2))
2770 SB=(-ALM(JJ)↑2)*Y(3)-64*(AN(II)↑2)*(48*AN(II)↑2*(1-2*X)↑2/(1
+16*AN(II)↑2*(1-2*X)↑2)-1)/((1+16*AN(II)↑2*(1-2*X)↑2)↑(3/2))*Y(3)
-2*GP*Y(4)
2780 IF KK=1 THEN 2810
2790 DY(4)=SB/G
2800 GOTO 2820
2810 DY(4)=(-8*AN(II)+SB)/G
2820 RETURN
```

```
2830 REM ************************
2840 REM Subroutine INTGL
2850 REM ************************
2860 AR=T1(1)-T1(N)
2870 M=N-1
2880 FOR I=2 TO M STEP 2
2890 J=I+1
2900 AR=AR+4*T1(I)+2*T1(J)
2910 NEXT I
2920 AR=AR*H/3
2930 RETURN
```

```
2940 REM ***********************
2950 REM Subroutine TINTGO
2960 REM ***********************
2970 REM CHANGE ANV TO AVN ;PAV TO PVA ; A TO AA ; ANG TO AGN ; S
YMN TO SMYN ; Y TO YY
2980 NN=N+1
2990 FOR I=1 TO 3
3000 YY(I)=0
3010 Z(I)=0
3020 NEXT I
3030 FOR J=2 TO 20 STEP 2
3040 J1=J-1
3050 J2=J+1
3060 IF J=2 THEN 3100
3070 B=TWH(1,J1)*TWH(1,J)
3080 IF B > 0 THEN 3100
3090 GOTO 3210
3100 B=TWH(1,J)*TWH(1,J2)
3110 IF B > 0 THEN 3130
3120 GOTO 3290
3130 FOR I=1 TO 3
3140 IF N=1 THEN 3190
3150 IF I < = 2 THEN 3190
3160 IF J=NN THEN 3180
3170 GOTO 3190
3180 TWH(I,J1)=TJP(I)
3190 YY(I)=YY(I)+(TWH(I,J1)+4*TWH(I,J)+TWH(I,J2))/60
3200 NEXT I,J
3210 M=J1
3220 X=ABS(TWH(1,M))/(ABS(TWH(1,M))+ABS(TWH(1,M+1)))
3230 FOR I=1 TO 3
3240 YY(I)=YY(I)+TWH(I,M)*X/40
3250 Z(I)=Z(I)+(TWH(I,M)+4*TWH(I,M+1)+TWH(I,M+2))/60-TWH(I,M)*X/4
0
3260 NEXT I
3270 M=M+3
3280 GOTO 3360
3290 M=J
3300 X=ABS(TWH(1,M))/(ABS(TWH(1,M))+ABS(TWH(1,M+1)))
3310 FOR I=1 TO 3
3320 Z(I)=Z(I)+(1-X)*TWH(I,M+1)/40
3330 YY(I)=YY(I)+(TWH(I,M-1)+4*TWH(I,M)+TWH(I,M+1))/60-Z(I)
3340 NEXT I
3350 M=M+2
3360 FOR J=M TO 20 STEP 2
3370 J1=J-1
3380 J2=J+1
3390 IF J  = 20 THEN 3460
3400 B=TWH(1,J1)*TWH(1,J)
3410 IF B > 0 THEN 3430
3420 GOTO 3560
3430 B=TWH(1,J)*TWH(1,J2)
3440 IF B > 0 THEN 3460
3450 GOTO 3640
3460 FOR I=1 TO 3
3470 IF N=1 THEN 3520
3480 IF I < = 2 THEN 3520
3490 IF J = NN THEN 3510
3500 GOTO 3520
3510 TWH(I,J1)=TJP(I)
```

```
3520 Z(I)=Z(I)+(TWH(I,J1)+4*TWH(I,J)+TWH(I,J2))/60
3530 NEXT I
3540 NEXT J
3550 GOTO 3770
3560 M=J1
3570 X=ABS(TWH(1,M))/(ABS(TWH(1,M))+ABS(TWH(1,M+1)))
3580 FOR I=1 TO 3
3590 Z(I)=Z(I)+TWH(I,M)*X/40
3600 YY(I)=YY(I)+(TWH(I,M)+4*TWH(I,M+1)+TWH(I,M+2))/60-TWH(I,M)*X
/40
3610 NEXT I
3620 M=M+3
3630 GOTO 3710
3640 M=J
3650 X=ABS(TWH(1,M))/(ABS(TWH(1,M))+ABS(TWH(1,M+1)))
3660 FOR I=1 TO 3
3670 YY(I)=YY(I)+(1-X)*TWH(I,M+1)/40
3680 Z(I)=Z(I)+(TWH(I,M-1)+4*TWH(I,M)+TWH(I,M+1))/60-(1-X)*TWH(I,
M+1)/40
3690 NEXT I
3700 M=M+2
3710 FOR J=M TO 20 STEP 2
3720 J1=J-1
3730 J2=J+1
3740 FOR I=1 TO 3
3750 YY(I)=YY(I)+(TWH(I,J1)+4*TWH(I,J)+TWH(I,J2))/60
3760 NEXT I,J
3770 IF YY(1) > 0 THEN 3840
3780 FOR I=1 TO 3
3790 AGN(I)=YY(I)
3800 T(I)=YY(I)+Z(I)
3810 PA(I)=Z(I)
3820 NEXT I
3830 GOTO 3890
3640 FOR I=1 TO 3
3850 PA(I)=YY(I)
3860 AGN(I)=Z(I)
3870 T(I)=YY(I)+Z(I)
3880 NEXT I
3890 GOTO 4040
3900 LPRINT "INTEGRATION OF INFLUENCE LINES"
3910 LPRINT "    ", : LPRINT "MOMENT", : LPRINT "HOR. REACTION",
: LPRINT "THRUST"
3920 LPRINT "T.A.",
3930 FOR I=1 TO 3
3940 LPRINT T(I),
3950 NEXT I : LPRINT
3960 LPRINT "+ M ",
3970 FOR I=1 TO 3
3980 LPRINT PA(I),
3990 NEXT I : LPRINT
4000 LPRINT "- M ",
4010 FOR I=1 TO 3
4020 LPRINT AGN(I),
4030 NEXT I : LPRINT
4040 LPRINT : LPRINT : LPRINT : LPRINT : LPRINT
4050 RETURN
4060 END
```

```
4070 REM ****************
4080 REM Stress Subroutine
4090 REM ****************
4100 REM LO(1) => Moving load of 1 lb. LO(2) => Moving load of 5
lb. LO(3) => Moving load of 10 lb.
4110 LO(1)=1 : LO(2)=5 : LO(3)=10
4120 MS=0 : HS=0
4130 FOR TT=1 TO 3
4140 STOP
4150 FOR BB=2 TO 20 STEP 2
4160 MS=MS+W1(XI,BB)
4170 HS=HS+TH(XI,BB)
4180 NEXT BB
4190 LPRINT "LAMBDA= ";AJJ
4200 LPRINT "Loading Type      ", : LPRINT "H", : LPRINT "M", : LP
RINT "M-n"
4210 LPRINT
4220 FOR CC=2 TO 20 STEP 2
4230 LPRINT
4240 LPRINT "W=5# And P=";LO(TT), : LPRINT "at";CC/2,
4250 H=5*HS+LO(TT)*TH(XI,CC)
4260 M=(5*MS+LO(TT)*W1(XI,CC))*60
4270 LPRINT H,M,
4280 HN=(H-5*HS)/LO(TT)
4290 MN=(M/60 - 5*MS)/LO(TT)
4300 LPRINT MN
4310 NEXT CC
4320 LPRINT : LPRINT : LPRINT
4330 SYSTEM "T"
4340 NEXT TT
4350 RETURN
```

LAMBDA= Ø

Influence lines for section # 1

| Moment | Thrust | SHEAR |
|---|---|---|
| Ø | .470497 | .882402 |
| -.0391564 | .524804 | .844894 |
| -.05979 | .662932 | .746995 |
| -.066213 | .851708 | .60841 |
| -.0621867 | 1.063 | .446069 |
| -.0509659 | 1.27332 | .274332 |
| -.0353365 | 1.46352 | .105186 |
| -.0176485 | 1.61846 | -.051593 |
| 1.5156E-04 | 1.72678 | -.188292 |
| .0164971 | 1.78069 | -.299144 |
| .0301808 | 1.77583 | -.380238 |
| .0403394 | 1.7112 | -.429461 |
| .0464462 | 1.58912 | -.446473 |
| .0483065 | 1.41525 | -.432711 |
| .0460618 | 1.19873 | -.391426 |
| .0401982 | .952287 | -.327756 |
| .0315611 | .692483 | -.248819 |
| .0213748 | .43994 | -.163846 |
| .0112675 | .21967 | -.0843285 |
| 3.30014E-03 | .0614073 | -.0241931 |
| Ø | Ø | Ø |

LAMBDA= 0

Influence lines for section # 3

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 6.94316E-03 | .057351 | -.0326653 |
| .0261098 | .203433 | -.118242 |
| 5.21727E-03 | .795851 | .679846 |
| -7.75269E-03 | 1.0204 | .536402 |
| -.014574 | 1.2448 | .383513 |
| -.0167941 | 1.44892 | .231465 |
| -.0157511 | 1.61685 | .0886846 |
| -.0125902 | 1.7366 | -.038126 |
| -8.27546E-03 | 1.7999 | -.143896 |
| -3.60137E-03 | 1.80208 | -.225106 |
| 7.98412E-04 | 1.74195 | -.279738 |
| 4.4455E-03 | 1.6218 | -.307254 |
| 7.01286E-03 | 1.44739 | -.308592 |
| 8.32459E-03 | 1.22811 | -.286203 |
| 8.35735E-03 | .977082 | -.244102 |
| 7.24549E-03 | .71142 | -.187949 |
| 5.28754E-03 | .452471 | -.125153 |
| 2.95588E-03 | .226145 | -.0649987 |
| 9.08022E-04 | .0632706 | -.0187873 |
| 0 | 0 | 0 |

LAMBDA= 0

Influence lines for section # 5

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 3.74148E-03 | .0601519 | -.0271644 |
| .0144999 | .21359 | -.0987191 |
| .0316093 | .42415 | -.201222 |
| .0544456 | .661116 | -.323061 |
| .0324234 | 1.20352 | .498131 |
| .0149922 | 1.42096 | .365817 |
| 1.63469E-03 | 1.6015 | .23935 |
| -8.13843E-03 | 1.73256 | .124281 |
| -.0147909 | 1.80547 | .0248881 |
| -.0187653 | 1.81523 | -.0557634 |
| -.0204855 | 1.76047 | -.115774 |
| -.0203616 | 1.64341 | -.154394 |
| -.0187923 | 1.46989 | -.17202 |
| -.0161688 | 1.24948 | -.170216 |
| -.0128781 | .995614 | -.151751 |
| -9.30553E-03 | .725868 | -.120663 |
| -5.83787E-03 | .462184 | -.0823338 |
| -2.86553E-03 | .231228 | -.043587 |
| -7.84873E-04 | .0647493 | -.012794 |
| 0 | 0 | 0 |

LAMBDA= 0

Influence lines for section # 7

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 1.23903E-03 | .0625528 | -.0210549 |
| 5.38018E-03 | .22234 | -.0770139 |
| .0129634 | .44204 | -.158094 |
| .0244088 | .689938 | -.255791 |
| .0400261 | .939501 | -.362785 |
| .0600224 | 1.16901 | -.472844 |
| .034509 | 1.5698 | .397251 |
| .013507 | 1.71165 | .29577 |
| -3.04931E-03 | 1.79407 | .204111 |
| -.0153109 | 1.81179 | .124827 |
| -.0235124 | 1.76326 | .0596744 |
| -.0279751 | 1.65062 | 9.61698E-03 |
| -.029109 | 1.47971 | -.0251585 |
| -.0274183 | 1.2602 | -.0452577 |
| -.0235081 | 1.00576 | -.0521011 |
| -.0180919 | .734264 | -.0479619 |
| -.0120014 | .468077 | -.0360157 |
| -6.19676E-03 | .234414 | -.0204025 |
| -1.77854E-03 | .0657 | -6.29892E-03 |
| 0 | 0 | 0 |

LAMBDA= 0

Influence lines for section # 9

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| -5.64198E-04 | .064399 | -.0144542 |
| -1.24933E-03 | .229128 | -.0535406 |
| -7.20626E-04 | .456052 | -.111399 |
| 2.13668E-03 | .712745 | -.182861 |
| 8.23439E-03 | .972058 | -.263396 |
| .0182965 | 1.21174 | -.349061 |
| .0328719 | 1.4141 | -.436455 |
| .0523461 | 1.56571 | -.522678 |
| .0269494 | 1.76323 | .389066 |
| 6.76175E-03 | 1.78907 | .312048 |
| -8.28224E-03 | 1.74757 | .242214 |
| -.0183949 | 1.64072 | .180745 |
| -.0239371 | 1.47434 | .128432 |
| -.0254239 | 1.2581 | .0856773 |
| -.0235327 | 1.00574 | .0524838 |
| -.0191136 | .735278 | .0284445 |
| -.013203 | .469288 | .012721 |
| -7.0378E-03 | .235266 | 4.01773E-03 |
| -2.07299E-03 | .0659989 | 5.4854E-04 |
| 0 | 0 | 0 |

LAMBDA= 0

Influence lines for section # 11

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| -1.66821E-03 | .0655687 | -7.54394E-03 |
| -5.38867E-03 | .233513 | -.0289424 |
| -9.44277E-03 | .465294 | -.0624119 |
| -.0123708 | .728117 | -.106252 |
| -.0129519 | .994508 | -.158835 |
| -.0101857 | 1.24192 | -.218602 |
| -3.27688E-03 | 1.45241 | -.284045 |
| 8.37877E-03 | 1.6123 | -.353705 |
| .025205 | 1.71203 | -.426158 |
| .0474526 | 1.7459 | -.5 |
| .025205 | 1.71203 | .426158 |
| 8.3788E-03 | 1.6123 | .353705 |
| -3.2769E-03 | 1.45241 | .284045 |
| -.0101857 | 1.24192 | .218602 |
| -.0129518 | .994508 | .158836 |
| -.0123708 | .728117 | .106252 |
| -9.44276E-03 | .465294 | .062412 |
| -5.38866E-03 | .233513 | .0289424 |
| -1.66821E-03 | .0655687 | 7.54389E-03 |
| 0 | 0 | 0 |

LAMBDA= Ø

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 1 at 1 | 46.9531 | -1.38Ø93 | -.166825 |
| W=5# And P= 1 at 2 | 47.3527 | -1.84741 | -.944294 |
| W=5# And P= 1 at 3 | 47.8818 | -2.Ø5795 | -1.2952 |
| W=5# And P= 1 at 4 | 48.3396 | -1.47744 | -.327677 |
| W=5# And P= 1 at 5 | 48.5991 | .231482 | 2.52Ø52 |
| W=5# And P= 1 at 6 | 48.5991 | .231483 | 2.52Ø52 |
| W=5# And P= 1 at 7 | 48.3396 | -1.47744 | -.327682 |
| W=5# And P= 1 at 8 | 47.8818 | -2.Ø5795 | -1.29519 |
| W=5# And P= 1 at 9 | 47.3527 | -1.84741 | -.944293 |
| W=5# And P= 1 at 10 | 46.9531 | -1.38Ø93 | -.166826 |

LAMBDA= 0
Loading Type

| | H | M | M-n |
|---|---|---|---|
| W=5# And P= 1 at 1 | 46.9531 | -1.38093 | -.166825 |
| W=5# And P= 1 at 2 | 47.3527 | -1.84741 | -.944294 |
| W=5# And P= 1 at 3 | 47.8818 | -2.05795 | -1.2952 |
| W=5# And P= 1 at 4 | 48.3396 | -1.47744 | -.327677 |
| W=5# And P= 1 at 5 | 48.5991 | .231482 | 2.52052 |
| W=5# And P= 1 at 6 | 48.5991 | .231483 | 2.52052 |
| W=5# And P= 1 at 7 | 48.3396 | -1.47744 | -.327682 |
| W=5# And P= 1 at 8 | 47.8818 | -2.05795 | -1.29519 |
| W=5# And P= 1 at 9 | 47.3527 | -1.84741 | -.944293 |
| W=5# And P= 1 at 10 | 46.9531 | -1.38093 | -.166826 |

LAMBDA= 0

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 5 at 1 | 94.1028 | -3.06214 | -.166825 |
| W=5# And P= 5 at 2 | 96.101 | -5.39454 | -.944294 |
| W=5# And P= 5 at 3 | 98.7464 | -6.44725 | -1.2952 |
| W=5# And P= 5 at 4 | 101.035 | -3.54469 | -.327677 |
| W=5# And P= 5 at 5 | 102.333 | 4.9999 | 2.52052 |
| W=5# And P= 5 at 6 | 102.333 | 4.99991 | 2.52052 |
| W=5# And P= 5 at 7 | 101.035 | -3.54471 | -.327682 |
| W=5# And P= 5 at 8 | 98.7464 | -6.44724 | -1.29519 |
| W=5# And P= 5 at 9 | 96.101 | -5.39454 | -.944293 |
| W=5# And P= 5 at 10 | 94.1028 | -3.06214 | -.166826 |

LAMBDA= 0

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 10 at 1 | 141.318 | -4.84344 | -.166825 |
| W=5# And P= 10 at 2 | 145.314 | -9.50826 | -.944294 |
| W=5# And P= 10 at 3 | 150.605 | -11.6137 | -1.2952 |
| W=5# And P= 10 at 4 | 155.183 | -5.80856 | -.327677 |
| W=5# And P= 10 at 5 | 157.779 | 11.2806 | 2.52052 |
| W=5# And P= 10 at 6 | 157.779 | 11.2806 | 2.52052 |
| W=5# And P= 10 at 7 | 155.183 | -5.80858 | -.327682 |
| W=5# And P= 10 at 8 | 150.605 | -11.6137 | -1.29519 |
| W=5# And P= 10 at 9 | 145.314 | -9.50825 | -.944293 |
| W=5# And P= 10 at 10 | 141.318 | -4.84345 | -.166826 |

LAMBDA= .628319

Influence lines for section # 1

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | .470497 | .882402 |
| -.0392444 | .524524 | .845171 |
| -.0600514 | .662217 | .747767 |
| -.0666355 | .85079 | .609586 |
| -.0627064 | 1.0622 | .447402 |
| -.0515005 | 1.27297 | .275553 |
| -.0358054 | 1.4638 | .106066 |
| -.0179874 | 1.61942 | -.0512013 |
| -1.71661E-05 | 1.7283 | -.188434 |
| .0165121 | 1.78253 | -.299772 |
| .030368 | 1.77769 | -.381227 |
| .0406665 | 1.71275 | -.430639 |
| .0468657 | 1.59008 | -.447654 |
| .0487635 | 1.41546 | -.433724 |
| .0465019 | 1.19815 | -.392151 |
| .0405753 | .951075 | -.328143 |
| .0318443 | .690929 | -.248901 |
| .0215531 | .438447 | -.163731 |
| .0113519 | .21863 | -.0841658 |
| 3.32133E-03 | .0610223 | -.024112 |
| 0 | 0 | 0 |

LAMBDA= .628319

Influence lines for section # 3

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 6.94835E-03 | .057396 | -.0320222 |
| .026108 | .204062 | -.115752 |
| 5.16221E-03 | .797482 | .684138 |
| -7.87624E-03 | 1.02308 | .541344 |
| -.0147505 | 1.24859 | .388179 |
| -.016993 | 1.45379 | .235177 |
| -.0159383 | 1.62261 | .0910195 |
| -.012736 | 1.74295 | -.0373442 |
| -8.35906E-03 | 1.80644 | -.144631 |
| -3.61306E-03 | 1.80836 | -.227148 |
| 8.57249E-04 | 1.74752 | -.282754 |
| 4.56332E-03 | 1.62629 | -.310836 |
| 7.17047E-03 | 1.45056 | -.312317 |
| 8.49849E-03 | 1.2299 | -.289679 |
| 8.52357E-03 | .97764 | -.247016 |
| 7.38333E-03 | .711074 | -.190107 |
| 5.3835E-03 | .451695 | -.126504 |
| 3.00666E-03 | .225438 | -.0656404 |
| 9.22608E-04 | .0629717 | -.018951 |
| 0 | 0 | 0 |

LAMBDA= .628319

Influence lines for section # 5

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 3.78323E-03 | .0599679 | -.0270771 |
| .0146449 | .213341 | -.0982947 |
| .031874 | .424409 | -.200019 |
| .0547868 | .662636 | -.320375 |
| .0327487 | 1.20666 | .502061 |
| .0152356 | 1.4256 | .369855 |
| 1.76575E-03 | 1.60738 | .242691 |
| -8.12393E-03 | 1.7393 | .12644 |
| -.0148797 | 1.81259 | .0256547 |
| -.0189328 | 1.82219 | -.0563658 |
| -.0207025 | 1.76677 | -.117545 |
| -.0205979 | 1.64862 | -.157009 |
| -.0190212 | 1.47372 | -.175086 |
| -.0163691 | 1.25183 | -.173327 |
| -.0130361 | .996603 | -.154546 |
| -9.41573E-03 | .725822 | -.122869 |
| -5.90269E-03 | .461587 | -.083807 |
| -2.89435E-03 | .230603 | -.0443389 |
| -7.917E-04 | .0644704 | -.0130033 |
| 0 | 0 | 0 |

LAMBDA= .628319

Influence lines for section # 7

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 1.27291E-03 | .062233 | -.021255 |
| 5.50521E-03 | .221571 | -.0776821 |
| .0132158 | .441169 | -.159245 |
| .0247954 | .689506 | -.257138 |
| .0405161 | .940059 | -.363718 |
| .0605374 | 1.17101 | -.472427 |
| .0349347 | 1.57329 | .399032 |
| .0137676 | 1.71627 | .297998 |
| -2.98271E-03 | 1.79934 | .206158 |
| -.0154302 | 1.81719 | .126324 |
| -.0237843 | 1.76826 | .0604591 |
| -.0283506 | 1.65478 | 9.69763E-03 |
| -.0295326 | 1.48271 | -.0256532 |
| -.0278357 | 1.26193 | -.0461251 |
| -.0238734 | 1.00631 | -.0531106 |
| -.0183732 | .73392 | -.0488976 |
| -.0121846 | .467302 | -.0367163 |
| -6.28787E-03 | .233704 | -.0207936 |
| -1.8032E-03 | .0653978 | -6.41631E-03 |
| 0 | 0 | 0 |

LAMBDA= .628319

Influence lines for section # 9

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| -5.55884E-04 | .0640213 | -.0147283 |
| -1.21348E-03 | .228136 | -.0545214 |
| -6.34806E-04 | .454693 | -.113308 |
| 2.29385E-03 | .711456 | -.185673 |
| 8.47709E-03 | .97128 | -.266821 |
| .0186223 | 1.21181 | -.352532 |
| .033252 | 1.41518 | -.439133 |
| .0527135 | 1.56782 | -.523459 |
| .0272074 | 1.76611 | .39029 |
| 6.85523E-03 | 1.79228 | .314383 |
| -8.36133E-03 | 1.75062 | .244988 |
| -.0186201 | 1.64321 | .183485 |
| -.0242634 | 1.47596 | .130837 |
| -.0257675 | 1.25874 | .0875874 |
| -.0238804 | 1.00548 | .0538549 |
| -.0193995 | .734383 | .0293172 |
| -.0133992 | .468183 | .0131918 |
| -7.13982E-03 | .234399 | 4.21096E-03 |
| -2.10172E-03 | .065655 | 5.91385E-04 |
| 0 | 0 | 0 |

LAMBDA= .628319

Influence lines for section # 11

| Moment | Thrust | SHEAR |
|---|---|---|
| Ø | Ø | Ø |
| -1.68451E-03 | .0651908 | -7.74203E-03 |
| -5.44258E-03 | .23252 | -.0296811 |
| -9.53616E-03 | .463922 | -.0639283 |
| -.0124872 | .726784 | -.108648 |
| -.0130604 | .993621 | -.162057 |
| -.0102493 | 1.24176 | -.22242 |
| -3.26172E-03 | 1.45307 | -.288041 |
| 8.49195E-03 | 1.61371 | -.357263 |
| .0254082 | 1.71395 | -.428453 |
| .0476975 | 1.748 | -.5 |
| .0254083 | 1.71395 | .428453 |
| 8.4919E-03 | 1.61371 | .357262 |
| -3.26182E-03 | 1.45307 | .288041 |
| -.0102493 | 1.24176 | .22242 |
| -.0130604 | .993621 | .162057 |
| -.0124871 | .726784 | .108648 |
| -9.53618E-03 | .463922 | .0639282 |
| -5.44258E-03 | .23252 | .0296811 |
| -1.68453E-03 | .0651908 | 7.74196E-03 |
| Ø | Ø | Ø |

LAMBDA= .628319

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 1 at 1 | 46.9521 | -1.38182 | -.168456 |
| W=5# And P= 1 at 2 | 47.3508 | -1.85293 | -.953643 |
| W=5# And P= 1 at 3 | 47.8803 | -2.06437 | -1.30605 |
| W=5# And P= 1 at 4 | 48.3397 | -1.47645 | -.326172 |
| W=5# And P= 1 at 5 | 48.6005 | .243769 | 2.54086 |
| W=5# And P= 1 at 6 | 48.6005 | .243772 | 2.54086 |
| W=5# And P= 1 at 7 | 48.3397 | -1.47645 | -.32617 |
| W=5# And P= 1 at 8 | 47.8803 | -2.06437 | -1.30605 |
| W=5# And P= 1 at 9 | 47.3508 | -1.85293 | -.953635 |
| W=5# And P= 1 at 10 | 46.9521 | -1.38182 | -.168457 |

LAMBDA= .628319

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 5 at 1 | 94.0999 | -3.06686 | -.168456 |
| W=5# And P= 5 at 2 | 96.093 | -5.42242 | -.953643 |
| W=5# And P= 5 at 3 | 98.7409 | -6.47964 | -1.30605 |
| W=5# And P= 5 at 4 | 101.038 | -3.54 | -.326172 |
| W=5# And P= 5 at 5 | 102.342 | 5.06108 | 2.54086 |
| W=5# And P= 5 at 6 | 102.342 | 5.06109 | 2.54086 |
| W=5# And P= 5 at 7 | 101.038 | -3.54 | -.32617 |
| W=5# And P= 5 at 8 | 98.7409 | -6.47964 | -1.30605 |
| W=5# And P= 5 at 9 | 96.093 | -5.42239 | -.953635 |
| W=5# And P= 5 at 10 | 94.0998 | -3.06686 | -.168457 |

LAMBDA= .628319

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 10 at 1 | 141.313 | -4.85297 | -.168456 |
| W=5# And P= 10 at 2 | 145.299 | -9.56409 | -.953643 |
| W=5# And P= 10 at 3 | 150.595 | -11.6785 | -1.30605 |
| W=5# And P= 10 at 4 | 155.188 | -5.79926 | -.326172 |
| W=5# And P= 10 at 5 | 157.796 | 11.4029 | 2.54086 |
| W=5# And P= 10 at 6 | 157.796 | 11.4029 | 2.54086 |
| W=5# And P= 10 at 7 | 155.188 | -5.79926 | -.32617 |
| W=5# And P= 10 at 8 | 150.595 | -11.6785 | -1.30605 |
| W=5# And P= 10 at 9 | 145.299 | -9.56405 | -.953635 |
| W=5# And P= 10 at 10 | 141.313 | -4.85298 | -.168457 |

LAMBDA= 1.25664

Influence lines for section # 1

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | .470497 | .882402 |
| -.0395172 | .523664 | .846017 |
| -.060862 | .66003 | .750153 |
| -.0679522 | .847935 | .613237 |
| -.0643354 | 1.05975 | .45157 |
| -.0531829 | 1.27189 | .279388 |
| -.0372877 | 1.46469 | .108848 |
| -.0190662 | 1.6224 | -.0499325 |
| -5.62757E-04 | 1.73301 | -.188831 |
| .0165462 | 1.78824 | -.301692 |
| .0309477 | 1.78343 | -.384288 |
| .0416908 | 1.71752 | -.434308 |
| .0481851 | 1.59303 | -.451342 |
| .0502045 | 1.41606 | -.436902 |
| .047892 | 1.19634 | -.394439 |
| .041768 | .947291 | -.329383 |
| .0327408 | .686107 | -.249191 |
| .0221182 | .433831 | -.163402 |
| .0116199 | .215429 | -.0836814 |
| 3.3888E-03 | .0598416 | -.0238684 |
| 0 | 0 | 0 |

LAMBDA= 1.25664

Influence lines for section # 3

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 6.96214E-03 | .0575783 | -.0300192 |
| .026096 | .206137 | -.108029 |
| 4.98413E-03 | .802785 | .697473 |
| -8.2687E-03 | 1.03182 | .556789 |
| -.0153084 | 1.26094 | .402844 |
| -.0176208 | 1.46963 | .24692 |
| -.0165296 | 1.64136 | .0984902 |
| -.0131967 | 1.76366 | -.0347407 |
| -8.62281E-03 | 1.82779 | -.146812 |
| -3.64882E-03 | 1.82887 | -.233476 |
| 1.04489E-03 | 1.76577 | -.29219 |
| 4.93765E-03 | 1.64108 | -.3221 |
| 7.67089E-03 | 1.46114 | -.324062 |
| 9.0504E-03 | 1.23605 | -.300658 |
| 9.05075E-03 | .979809 | -.256232 |
| 7.82025E-03 | .710311 | -.196937 |
| 5.68733E-03 | .449485 | -.130781 |
| 3.16725E-03 | .223351 | -.0676733 |
| 9.68672E-04 | .0620779 | -.0194704 |
| 0 | 0 | 0 |

LAMBDA= 1.25664 

Influence lines for section # 5

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| 3.91315E-03 | .0594543 | -.0267763 |
| .0150963 | .212759 | -.0968766 |
| .0326978 | .425569 | -.196114 |
| .0558512 | .667882 | -.31186 |
| .033769 | 1.21712 | .514433 |
| .0160048 | 1.4409 | .38257 |
| 2.18631E-03 | 1.6267 | .253248 |
| -8.06804E-03 | 1.76142 | .133295 |
| -.0151486 | 1.83595 | .0281245 |
| -.0194521 | 1.8451 | -.0582332 |
| -.0213805 | 1.78756 | -.12313 |
| -.0213407 | 1.6659 | -.165287 |
| -.0197434 | 1.48655 | -.184812 |
| -.0170032 | 1.25989 | -.183214 |
| -.0135375 | 1.00026 | -.163435 |
| -9.766E-03 | .726099 | -.129886 |
| -6.10915E-03 | .459999 | -.0884914 |
| -2.98636E-03 | .228802 | -.0467285 |
| -8.1357E-04 | .0636479 | -.0136678 |
| 0 | 0 | 0 |

LAMBDA= 1.25664

Influence lines for section # 7

| Moment | Thrust | SHEAR |
|---|---|---|
| Ø | Ø | Ø |
| 1.38047E-03 | .0612805 | -.0218692 |
| 5.90192E-03 | .219308 | -.0797284 |
| .0140151 | .438695 | -.162758 |
| .0260178 | .688511 | -.261229 |
| .0420615 | .942257 | -.366514 |
| .0621601 | 1.1778 | -.47108 |
| .0362795 | 1.58479 | .404556 |
| .0145954 | 1.73136 | .304905 |
| -2.76374E-03 | 1.81653 | .212518 |
| -.0157929 | 1.83479 | .130975 |
| -.0246382 | 1.78461 | .0628915 |
| -.0295361 | 1.66844 | 9.92646E-03 |
| -.0308737 | 1.4927 | -.027232 |
| -.0291599 | 1.26784 | -.0488774 |
| -.0250339 | 1.00842 | -.0563092 |
| -.0192674 | .733165 | -.0518612 |
| -.0127672 | .465104 | -.0389343 |
| -6.5777E-03 | .231614 | -.022031 |
| -1.88164E-03 | .0644972 | -6.78732E-03 |
| Ø | Ø | Ø |

LAMBDA= 1.25664

Influence lines for section # 9

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| -5.28219E-04 | .0628705 | -.0155949 |
| -1.0953E-03 | .225111 | -.0576211 |
| -3.55294E-04 | .450551 | -.119334 |
| 2.80141E-03 | .707554 | -.194537 |
| 9.25326E-03 | .968987 | -.277591 |
| .0196562 | 1.21216 | -.363427 |
| .0344498 | 1.41872 | -.447542 |
| .0538654 | 1.57457 | -.525993 |
| .0280153 | 1.77531 | .393986 |
| 7.14596E-03 | 1.80248 | .321599 |
| -8.6133E-03 | 1.76035 | .253653 |
| -.0193326 | 1.65115 | .192115 |
| -.0252829 | 1.48121 | .138465 |
| -.0269387 | 1.2609 | .09369 |
| -.0249813 | 1.0048 | .0582664 |
| -.0203048 | .731727 | .0321454 |
| -.0140206 | .464848 | .0147292 |
| -7.46286E-03 | .231773 | 4.8478E-03 |
| -2.19265E-03 | .0646118 | 7.34169E-04 |
| 0 | 0 | 0 |

LAMBDA= 1.25664

Influence lines for section # 11

| Moment | Thrust | SHEAR |
|---|---|---|
| 0 | 0 | 0 |
| -1.73529E-03 | .0640343 | -8.37794E-03 |
| -5.61024E-03 | .229467 | -.032051 |
| -9.82654E-03 | .459693 | -.068784 |
| -.0128479 | .722666 | -.116304 |
| -.0133965 | .990865 | -.172319 |
| -.0104454 | 1.24124 | -.234534 |
| -3.21328E-03 | 1.4551 | -.300663 |
| 8.84377E-03 | 1.61805 | -.368441 |
| .0260379 | 1.71989 | -.435624 |
| .0484544 | 1.75451 | -.5 |
| .0260379 | 1.71989 | .435624 |
| 8.84385E-03 | 1.61805 | .368441 |
| -3.2133E-03 | 1.4551 | .300663 |
| -.0104455 | 1.24124 | .234534 |
| -.0133965 | .990865 | .172319 |
| -.012848 | .722666 | .116304 |
| -9.82649E-03 | .459693 | .0687842 |
| -5.61023E-03 | .229467 | .032051 |
| -1.73527E-03 | .0640343 | 8.37805E-03 |
| 0 | 0 | 0 |

LAMBDA= 1.25664

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 1 at 1 | 46.9492 | -1.38416 | -.173529 |
| W=5# And P= 1 at 2 | 47.3448 | -1.86965 | -.982666 |
| W=5# And P= 1 at 3 | 47.8759 | -2.08384 | -1.33966 |
| W=5# And P= 1 at 4 | 48.34 | -1.47283 | -.321306 |
| W=5# And P= 1 at 5 | 48.6047 | .282246 | 2.60382 |
| W=5# And P= 1 at 6 | 48.6047 | .282247 | 2.60382 |
| W=5# And P= 1 at 7 | 48.34 | -1.47284 | -.321319 |
| W=5# And P= 1 at 8 | 47.8759 | -2.08384 | -1.33965 |
| W=5# And P= 1 at 9 | 47.3448 | -1.86964 | -.982664 |
| W=5# And P= 1 at 10 | 46.9492 | -1.38417 | -.173531 |

LAMBDA= 1.25664

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 5 at 1 | 94.0905 | -3.08068 | -.173529 |
| W=5# And P= 5 at 2 | 96.0684 | -5.50809 | -.982666 |
| W=5# And P= 5 at 3 | 98.7237 | -6.57907 | -1.33966 |
| W=5# And P= 5 at 4 | 101.044 | -3.52401 | -.321306 |
| W=5# And P= 5 at 5 | 102.368 | 5.25137 | 2.60382 |
| W=5# And P= 5 at 6 | 102.368 | 5.25137 | 2.60382 |
| W=5# And P= 5 at 7 | 101.044 | -3.52405 | -.321319 |
| W=5# And P= 5 at 8 | 98.7237 | -6.57905 | -1.33965 |
| W=5# And P= 5 at 9 | 96.0684 | -5.50809 | -.982664 |
| W=5# And P= 5 at 10 | 94.0905 | -3.08069 | -.173531 |

LAMBDA= 1.25664

| Loading Type | H | M | M-n |
|---|---|---|---|
| W=5# And P= 10 at 1 | 141.296 | -4.88131 | -.173529 |
| W=5# And P= 10 at 2 | 145.252 | -9.73614 | -.982666 |
| W=5# And P= 10 at 3 | 150.562 | -11.8781 | -1.33966 |
| W=5# And P= 10 at 4 | 155.203 | -5.76798 | -.321306 |
| W=5# And P= 10 at 5 | 157.851 | 11.7828 | 2.60382 |
| W=5# And P= 10 at 6 | 157.851 | 11.7828 | 2.60382 |
| W=5# And P= 10 at 7 | 155.203 | -5.76805 | -.321319 |
| W=5# And P= 10 at 8 | 150.562 | -11.878 | -1.33965 |
| W=5# And P= 10 at 9 | 145.252 | -9.73612 | -.982664 |
| W=5# And P= 10 at 10 | 141.296 | -4.88133 | -.173531 |

Experimental results

```
10 REM
20 REM This program reads the strain values obtained from the exxperiment conducted on the fixed ended arch,
 and calculates the stresses at the required sections.
30 REM The program also interpolates the strain values for any loading and determines the corresponding
stresses.
40 REM
50 CLS
60 C1=30/16
70 C2=30/768
80 INPUT "Input the increment of the load ";DP
90 DIM A(6,3), B(3,3), G(3,3), EB(6), ET(6), PT(3), PB(3), CT(3), CB(3), PI(4)
100 FOR I=1 TO 6
110 A(I,1)=1
120 A(I,2)=(I-1)*DP
130 A(I,3)=A(I,2)^2
140 NEXT I
150 FOR I=1 TO 3
160 FOR J=1 TO 3
170 B(I,J)=0
180 FOR K=1 TO 6
190 B(I,J)=B(I,J)+A(K,I)*A(K,J)
200 NEXT K
210 NEXT J
220 NEXT I
230 G(1,1)=B(2,2)*B(3,3)-B(2,3)*B(3,2)
240 G(2,1)=-(B(2,1)*B(3,3)-B(2,3)*B(3,1))
250 G(3,1)=B(2,1)*B(3,2)-B(2,2)*B(3,1)
260 G(1,2)=G(2,1)
270 G(2,2)=B(1,1)*B(3,3)-B(1,3)*B(3,1)
280 G(3,2)=-(B(1,1)*B(3,2)-B(1,2)*B(3,1))
290 G(1,3)=G(3,1)
300 G(2,3)=G(3,2)
310 G(3,3)=B(1,1)*B(2,2)-B(1,2)*B(2,1)
320 D=B(1,1)*G(1,1)+B(1,2)*G(2,1)+B(1,3)*G(3,1)
330 FOR I=1 TO 3
340 FOR J=1 TO 3
350 G(I,J)=G(I,J)/D
360 NEXT J,I
370 FOR I=1 TO 3
380 FOR J=1 TO 3
390 GB(I,J)=0
400 FOR K=1 TO 3
410 GB(I,J)=GB(I,J)+B(I,K)*G(K,J)
420 NEXT K,J,I
430 REM NT = No. of tests.
440 REM NE = No. of experiments.
450 REM ET = Strains recorded by the gages on top of the arch.
460 REM EB = Strains recorded by the gages on bottom of the arch.
470 NT=10
480 REM NG = No. of pairs of gages
490 NG = 8
500 FOR BB=1 TO NG
510 LPRINT "*****************************"
520 IF BB=1 THEN LPRINT "* Strain gage nos. 3 and 4" : GOTO 600
530 IF BB=2 THEN LPRINT "* Strain gage nos. 7 and 8" : GOTO 600
540 IF BB=3 THEN LPRINT "* Strain gage nos. 13 and 14" : GOTO 600
550 IF BB=4 THEN LPRINT "* Strain gage nos. 17 and 18" : GOTO 600
560 IF BB=5 THEN LPRINT "* Strain gage nos. 19 and 20" : GOTO 600
```

```
570 IF BB=6 THEN LPRINT "* Strain gage nos. 21 and 22" : GOTO 600
580 IF BB=7 THEN LPRINT "* Strain gage nos. 23 and 24" : GOTO 600
590 IF BB=8 THEN LPRINT "* Strain gage nos. 25 and 26"
600 LPRINT "****************************"
610 LPRINT
620 FOR NE = 1 TO NT
630 FOR I=1 TO 6
640 READ EB(I)
650 IF NE < 6 THEN 740
660 IF BB=1 THEN EB(I)=EB(I)-3.9 : GOTO 820
670 IF BB=2 THEN EB(I)=EB(I)-.9  : GOTO 820
680 IF BB=3 THEN EB(I)=EB(I)-.9  : GOTO 820
690 IF BB=4 THEN EB(I)=EB(I)-2.9 : GOTO 820
700 IF BB=5 THEN EB(I)=EB(I)-.9  : GOTO 820
710 IF BB=6 THEN EB(I)=EB(I)-3.9 : GOTO 820
720 IF BB=7 THEN EB(I)=EB(I)-1.9 : GOTO 820
730 IF BB=8 THEN EB(I)=EB(I)-3.9 : GOTO 820
740 IF BB=1 THEN EB(I)=EB(I)-4.8 : GOTO 820
750 IF BB=2 THEN EB(I)=EB(I)-3.9 : GOTO 820
760 IF BB=3 THEN EB(I)=EB(I)-1.9 : GOTO 820
770 IF BB=4 THEN EB(I)=EB(I)     : GOTO 820
780 IF BB=5 THEN EB(I)=EB(I)-1.9 : GOTO 820
790 IF BB=6 THEN EB(I)=EB(I)-.9  : GOTO 820
800 IF BB=7 THEN EB(I)=EB(I)-1.9 : GOTO 820
810 IF BB=8 THEN EB(I)=EB(I)-5.8 : GOTO 820
820 NEXT I
830 FOR I=1 TO 6
840 READ ET(I)
850 IF NE < 6 THEN 940
860 IF BB=1 THEN ET(I)=ET(I)-2.9 : GOTO 1020
870 IF BB=2 THEN ET(I)=ET(I)-.9  : GOTO 1020
880 IF BB=3 THEN ET(I)=ET(I)-1.9 : GOTO 1020
890 IF BB=4 THEN ET(I)=ET(I)-3.9 : GOTO 1020
900 IF BB=5 THEN ET(I)=ET(I)-3.9 : GOTO 1020
910 IF BB=6 THEN ET(I)=ET(I)-.9  : GOTO 1020
920 IF BB=7 THEN ET(I)=ET(I)-1.9 : GOTO 1020
930 IF BB=8 THEN ET(I)=ET(I)     : GOTO 1020
940 IF BB=1 THEN ET(I)=ET(I)-3.9 : GOTO 1020
950 IF BB=2 THEN ET(I)=ET(I)+9.7 : GOTO 1020
960 IF BB=3 THEN ET(I)=ET(I)-1.9 : GOTO 1020
970 IF BB=4 THEN ET(I)=ET(I)-4.8 : GOTO 1020
980 IF BB=5 THEN ET(I)=ET(I)-.9  : GOTO 1020
990 IF BB=6 THEN ET(I)=ET(I)-1.9 : GOTO 1020
1000 IF BB=7 THEN ET(I)=ET(I)-1.9 : GOTO 1020
1010 IF BB=8 THEN ET(I)=ET(I)-.9  : GOTO 1020
1020 NEXT I
1030 FOR I=1 TO 3
1040 PT(I)=0 : PB(I)=0
1050 FOR K=1 TO 6
1060 PT(I)=PT(I)+A(K,I)*ET(K)
1070 PB(I)=PB(I)+A(K,I)*EB(K)
1080 NEXT K,I
1090 FOR I=1 TO 3
1100 CT(I)=0
1110 CB(I)=0
1120 FOR K=1 TO 3
1130 CT(I)=CT(I)+G(I,K)*PT(K)
1140 CB(I)=CB(I)+G(I,K)*PB(K)
1150 NEXT K,I
1160 PRINT
```

```
1170 LPRINT
1180 LPRINT "Loads at loading point #";NE
1190 LPRINT
1200 LPRINT "Coefficients C1, C2 and C3 for equations of curve fitting"
1210 LPRINT "--------------------------------------------------------"
1220 LPRINT " ", : LPRINT "Top gages", : LPRINT "Bot. gages"
1230 LPRINT
1240 FOR I=1 TO 3
1250 LPRINT "C";I,
1260 LPRINT CT(I),CB(I)
1270 NEXT I
1280 PI(0)=0
1290 P1(1)=1
1300 P1(2)=5
1310 P1(3)=10
1320 FOR J=0 TO 3
1330 RT(J)=(CT(3)*PI(J)+CT(2))*P1(J)+CT(1)
1340 RB(J)=(CB(3)*PI(J)+CB(2))*PI(J)+CB(1)
1350 N=C1*(RB(J)+RT(J))
1360 M=C2*(RB(J)-RT(J))
1370 IF N>1 THEN N=-N
1380 LPRINT
1390 LPRINT "W=5# and P=";PI(J);"  Strain in top gage=";RT(J)
1400 LPRINT "                   Strain in bottom gage=";RB(J)
1410 LPRINT "          Moment M=";M : LPRINT "         Thrust N=";N
1420 NEXT J
1430 FOR J=1 TO 3
1440 RT(J)=RT(J)-RT(0)
1450 RB(J)=RB(J)-RB(0) : N=C1*(RB(J)+RT(J))/P1(J) : M=C2*(RB(J)-RT(J))/P1(J)
1460 IF N>1 THEN N=-N
1470 LPRINT "W=0 and P=";P1(J) : LPRINT "         Normalized Moment =";M : LPRINT "         Normalized Thrust
 =";N
1480 NEXT J
1490 LPRINT CHR$(12)
1500 LPRINT : LPRINT : PRINT
1510 NEXT NE
1520 NEXT BB
1530 PRINT
1540 END
```

```
1550 REM *********************************
1560 REM          DATA STATEMENTS
1570 REM *********************************
1580 DATA 94.7,84,75.2,65.4,47.8,43.9 : REM Data for gage #3 at loading point 1- W5P0; W5P2, W5P4, W5P6, W5P8,
W5P10. All data given below are in the same order.
1590 DATA -92.8,-83,-69.3,-63.5,-43.9,-41 : REM Data for gage #4 at 1.
1600 DATA 91.8,35.1,-25.4,-16.6,-71.3,-101.6 : REM Data for #3 at 2.
1610 DATA -91.8,-34.2,28.3,13.6,70.3,100.6 : REM Data for #4 at 2.
1620 DATA 46.9,40,11.7,4.8,-16.6,-52.7 : REM Data for #3 at 3.
1630 DATA -43.9,-43.9,-14.6,-9.7,9.7,43.9 : REM Data for #4 at 3.
1640 DATA 23.4,27.3,33.2,35.1,39,42.9 : REM Data for #3 at 4.
1650 DATA -28.3,-30.2,-40,-43.9,-50.8,-57.6 : REM Data for #4 at 4.
1660 DATA 22.4,27.3,57.6,58.6,88.9,92.8 : REM Data for #3 at 5.
1670 DATA -22.4,-35.1,-70.3,-72.3,-102.6,-109.4 : REM Data for #4 at 5.
1680 DATA 53.7,70.3,97.7,130.9,164.1,198.3 : REM Data for #3 at 6.
1690 DATA -69.3,-85,-109.4,-142.6,-175.8,-212 : REM Data for #4 at 6.
1700 DATA 82,88.9,109.4,144.6,168,175.8 : REM Data for #3 at 7.
1710 DATA -85.9,-93.8,-113.3,-152.4,-175.8,-186.6 : REM Data for #4 at 7.
1720 DATA 74.2,75.2,91.8,107.4,145.6,183.7 : REM Data for #3 at 8.
1730 DATA -76.2,-78.1,-94.7,-107.4,-148.5,-187.6 : REM Data for #4 at 6.
1740 DATA 85,85.9,88.9,106.5,116.2,119.2 : REM Data for #3 at 9.
1750 DATA -80.1,-82,-84,-105.5,-113.3,-115.3 : REM Data for #4 at 9.
1760 DATA 65.4,73.2,66.4,70.3,71.3,66.4 : REM Data for #3 at 10.
1770 DATA -60.5,-60.4,-60.5,-64.4,-64.4,-61.5 : REM Data for #4 at 10.
```

```
1780 REM *********************************
1790 REM     Data for channels 7 and 8
1800 REM *********************************
1810 DATA -88.9,-90.8,-77.1,-85,-79.1,-78.1 : REM Data for #7 at 1.
1820 DATA -837.4,-854,-868.7,-892.1,-921.5,-932.2 : REM Data for #8 at 1.
1830 DATA -87.9,-35.1,28.3,17.5,70.3,101.6 : REM Data for #7 at 2.
1840 DATA -788.6,-1099.3,-1279.1,-1451.1,-1145.2,-1104.2 : REM Data for #8 at 2.
1850 DATA -37.1,-28.3,-4.8,3.9,22.4,57.6 : REM Data for #7 at 3.
1860 DATA -1340.7,-1386.6,-1422.8,-1457.9,-1529.3,-1418.8 :REM Data for #8 at 3.
1870 DATA -34.2,-43.9,-67.4,-83,-105.5,-126 : REM Data for #7 at 4.
1880 DATA -1479.4,-1468.7,-1514.6,-1540,-1538.1,-1471.6 : REM Data for #8 at 4.
1890 DATA -38.1,-50.8,-97.7,-103.5,-148.5,-163.1 : REM Data for #7 at 5.
1900 DATA -1668,-1671,-1635.8,-1635.8,-1589.9,-1425.7 : REM Data for #8 at 5.
1910 DATA -53.7,-76.2,-84,-116.2,-148.5,-184.6 : REM Data for #7 at 6.
1920 DATA -11.7,5.8,12.7,-4.8,-15.6,108.4 : REM Data for #8 at 6.
1930 DATA -66.4,-72.3,-83,-102.6,-111.4,-112.3 : REM Data for #7 at 7.
1940 DATA -117.2,-116.2,-107.4,-97.7,-104.5,-117.2 : REM Data for #8 at 7.
1950 DATA -60.5,-50.8,-59.6,-59.6,-78.1,-96.7 : REM Data for #7 at 8.
1960 DATA -169,-153.4,-141.6,-149.5,-150.4,-139.7 : REM Data for #8 at 8.
1970 DATA -50.8,-53.7,-49.8,-60.5,-59.6,-55.7 : REM Data for #7 at 9.
1980 DATA -182.7,-190.5,-197.3,-185.6,-157.3,-160.2 : REM Data for #8 at 9.
1990 DATA -37.1,-42.9,-37.1,-38.1,-38.1,-33.2 : REM Data for #7 at 10.
2000 DATA -202.2,-194.4,-204.2,-209.1,-204.2,-214.9 : REM Data for #8 at 10.
```

```
2010 REM ********************************
2020 REM    Data for channels 13 and 14
2030 REM ********************************
2040 DATA -16.6,-17.5,-19.5,-16.6,-18.5,-20.5 : REM Data for #13 at 1.
2050 DATA 23.4,25.4,30.2,26.3,28.3,28.3 : REM Data for #14 at 1.
2060 DATA -14.6,-24.4,-51.7,-44.9,-59.6,-67.4 : REM Data for #13 at 2.
2070 DATA 22.4,33.2,58.6,50.8,63.5,69.3 : REM Data for #14 at 2.
2080 DATA -30.2,-50.8,-68.4,-78.1,-90.8,-117.2 : REM Data for #13 at 3.
2090 DATA 39,57.6,72.3,79.1,86.9,111.4 : REM Data for #14 at 3.
2100 DATA -40,-58.6,-68.4,-78.1,-85.9,-95.7 : REM Data for #13 at 4.
2110 DATA 42,58.6,67.4,74.2,82,86.9 : REM Data for #14 at 4.
2120 DATA -36.1,-36.1,34.2,42.9,96.7,131.9 : REM Data for #13 at 5.
2130 DATA 42,32.2,-35.1,-47.8,-93.8,-128.9 : REM Data for #14 at 5.
2140 DATA -36.1,-9.7,9.7,49.8,93.8,123.1 : REM Data for #13 at 6.
2150 DATA 23.4,-4.8,-22.4,-55.7,-99.6,-127 : REM Data for #14 at 6.
2160 DATA -22.4,-31.2,-39,-36.1,-57.6,-77.1 : REM Data for #13 at 7.
2170 DATA 26.3,33.2,39,32.2,55.7,72.3 : REM Data for #14 at 7.
2180 DATA -3.9,-32.2,-42,-66.4,-87.9,-136.8 : REM Data for #13 at 8.
2190 DATA 4.8,36.1,46.9,72.3,92.8,137.7 : REM Data for #14 at 8.
2200 DATA -27.3,-28.3,-36.1,-39,-65.4,-77.1 : REM Data for #13 at 9.
2210 DATA 34.2,35.1,47.8,46.9,75.2,83 : REM Data for #14 at 9.
2220 DATA -21.4,-14.6,-24.4,-31.2,-27.3,-31.2 : REM Data for #13 at 10.
2230 DATA 35.1,28.3,39,44.9,40,44.9 : REM Data for #14 at 10
```

```
2240 REM ********************************
2250 REM   Data for channels 17 and 18
2260 REM ********************************
2270 DATA -19.5,-21.4,-23.4,-22.4,-22.4,-25.4 : REM Data for #17 at 1.
2280 DATA 19.5,17.5,23.4,20.5,19.5,19.5 : REM Data for #18 at 1.
2290 DATA -19.5,-30.2,-51.7,-45.9,-61.5,-68.4 : REM Data for #17 at 2.
2300 DATA 16.6,24.4,47.8,41,52.7,61.5 : REM Data for #18 at 2.
2310 DATA -33.2,-52.7,-70.3,-82,-94.7,-121.1 : REM Data for #17 at 3.
2320 DATA 30.2,47.8,62.5,71.3,80.1,105.5 : REM Data for #18 at 3.
2330 DATA -47.8,-64.4,-76.2,-87.9,-101.6,-116.2 : REM Data for #17 at 4.
2340 DATA 33.2,51.7,63.5,71.3,82,91.8 : REM Data for #18 at 4.
2350 DATA -46.9,-49.8,2.9,6.8,46.9,76.2 : REM Data for #17 at 5.
2360 DATA 40,34.2,-20.5,-29.3,-67.4,-94.7 : REM Data for #18 at 5.
2370 DATA -26.3,3.9,42.9,86.9,142.6,176.8 : REM Data for #17 at 6.
2380 DATA 15.6,-15.6,-47.8,-89.9,-142.6,-177.8 : REM Data for #18 at 6.
2390 DATA -11.7,-20.5,-27.3,-10.7,-30.2,-51.7 : REM Data for #17 at 7.
2400 DATA 19.5,26.3,30.2,11.7,31.2,55.7 : REM Data for #18 at 7.
2410 DATA 2.9,-27.3,-39,-64.4,-80.1,-129.9 : REM Data for #17 at 8.
2420 DATA 3.9,34.2,44.9,71.3,87.9,131.9 : REM Data for #18 at 8.
2430 DATA -22.4,-20.5,-33.2,-33.2,-64.4,-74.2 : REM Data for #17 at 9.
2440 DATA 29.3,31.2,43.9,42,72.3,81.1 : REM Data for #18 at 9.
2450 DATA -21.4,-13.6,-24.4,-30.2,-26.3,-31.2 : REM Data for #17 at 10.
2460 DATA 31.2,24.4,37.1,42.9,39,43.9 : REM Data for #18 at 10.
```

```
2470 REM ********************************
2480 REM   Data for channels 19 and 20
2490 REM ********************************
2500 DATA 39,33.2,37.1,35.1,31.2,33.2 : REM Data for #19 at 1.
2510 DATA -40,-37.1,-37.1,-34.2,-34.2,-35.1 : REM Data for #20 at 1.
2520 DATA 35.1,31.2,39,28.3,32.2,30.2 : REM Data for #19 at 2.
2530 DATA -34.2,-35.1,-42,-31.2,-37.1,-36.1 : REM Data for #20 at 2.
2540 DATA 37.1,30.2,34.2,24.4,19.5,15.6 : REM Data for #19 at 3.
2550 DATA -38.1,-35.1,-39,-34.2,-29.3,-27.3 : REM Data for #20 at 3.
2560 DATA 14.6,11.7,7.8,2.9,-2.9,-6.8 : REM Data for #19 at 4.
2570 DATA -24.4,-19.5,-17.5,-13.6,-9.7,-8.7 : REM Data for #20 at 4.
2580 DATA 4.8,2.9,-22.4,-27.3,-47.8,-76.2 : REM Data for #19 at 5.
2590 DATA -7.8,-16.6,2.9,9.7,33.2,60.5 : REM Data for #20 at 5.
2600 DATA 48.8,18.5,17.5,-5.8,-36.1,-56.6 : REM Data for #19 at 6.
2610 DATA -63.5,-30.2,-29.3,-2.9,30.2,50.8 : REM Data for #20 at 6.
2620 DATA 53.7,49.8,46.9,46.9,54.7,81.1 : REM Data for #19 at 7.
2630 DATA -53.7,-47.8,-52.7,-51.7,-57.6,-85 : REM Data for #20 at 7.
2640 DATA 67.4,96.7,131.9,194.4,252.1,316.6 : REM data for #19 at 8.
2650 DATA -67.4,-94.7,-128,-188.6,-248.2,-316.6 : REM Data for #20 at 8.
2660 DATA 96.7,110.4,140.7,179.8,230.6,267.7 : REM Data for #19 at 9.
2670 DATA -85,-100.6,-132.8,-171.9,-224.7,-263.8 : REM Data for #20 at 9.
2680 DATA 80.1,80.1,86.9,96.7,87.9,99.6 : REM Data for #19 at 10.
2690 DATA -68.4,-69.3,-72.3,-85,-77.1,-85.9 : REM Data for #20 at 10.
```

```
2700 REM ********************************
2710 REM   Data for channels 21 and 22
2720 REM ********************************
2730 DATA 31.2,29.3,33.2,28.3,28.3,27.3 : REM Data for #21 at 1.
2740 DATA -33.2,-32.2,-31.2,-29.3,-29.3,-30.2 : REM Data for #22 at 1.
2750 DATA 30.2,29.3,32.2,21.4,26.3,25.4 : REM Data for #21 at 2.
2760 DATA -30.2,-30.2,-35.1,-24.4,-30.2,-31.2 : REM Data for #22 at 2.
2770 DATA 33.2,25.4,30.2,22.4,15.6,11.7 : REM Data for #21 at 3.
2780 DATA -32.2,-27.3,-35.1,-29.3,-24.4,-22.4 : REM Data for #22 at 3.
2790 DATA 14.6,9.7,7.8,.9,-3.9,-7.8 : REM Data for #21 at 4.
2800 DATA -18.5,-16.6,-13.6,-9.7,-6.8,-7.8 : REM Data for #22 at 4.
2810 DATA 3.9,.9,-21.4,-27.3,-47.8,-75.2 : REM Data for #21 at 5.
2820 DATA -5.8,-10.7,7.8,11.7,36.1,61.5 : REM Data for #22 at 5.
2830 DATA 42.9,11.7,12.7,-13.6,-45.9,-65.4 : REM Data for #21 at 6.
2840 DATA -59.6,-26.3,-26.3,1.9,35.1,53.7 : REM Data for #22 at 6.
2850 DATA 43.9,39,39,34.2,36.1,60.5 : REM Data for #21 at 7.
2860 DATA -49.8,-42.9,-42.9,-40,-42,-68.4 : REM Data for #22 at 7.
2870 DATA 62.5,87.9,116.2,171,221.8,276.5 : REM Data for #21 at 8.
2880 DATA -62.5,-87.9,-116.2,-171,-222.8,-280.4 : REM Data for #22 at 8.
2890 DATA 85.9,101.6,130.7,182.7,234.5,282.4 : REM Data for #21 at 9.
2900 DATA -80.1,-98.6,-133.8,-175.8,-227.6,-277.5 : REM Data for #22 at 9.
2910 DATA 72.3,73.2,77.1,92.8,84,94.7 : REM Data for #21 at 10.
2920 DATA -63.5,-67.4,-69.3,-84,-74.2,-86.9 : REM Data for #22 at 10.
```

```
2930 REM ********************************
2940 REM   Data for channels 23 and 24
2950 REM ********************************
2960 DATA 33.2,15.6,29.3,14.6,12.7,13.6 : REM Data for #23 at 1.
2970 DATA -29.3,-27.3,-25.4,-23.4,-21.4,-25.4 : REM Data for #24 at 1.
2980 DATA 14.6,14.6,17.5,8.7,12.7,13.6 : REM Data for #23 at 2.
2990 DATA -24.4,-23.4,-29.3,-20.5,-24.4,-25.4 : REM Data for #24 at 2.
3000 DATA 17.5,8.7,18.5,5.8,0,-3.9 : REM Data for #23 at 3.
3010 DATA -25.4,-22.4,-30.2,-24.4,-21.4,-17.5
3020 DATA -5.8,-6.8,-9.7,-13.6,-19.5,-21.4
3030 DATA -14.6,-8.7,-9.7,-5.8,-2.9,-5.8
3040 DATA 3.9,-13.6,-31.2,-36.1,-53.7,-83
3050 DATA -1.9,-6.8,8.7,11.7,33.2,59.6
3060 DATA 38.1,6.8,8.7,-18.5,-48.8,-70.3
3070 DATA -57.6,-25.4,-24.4,3.9,37.1,53.7
3080 DATA 39,31.2,30.2,19.5,20.5,42.9
3090 DATA -45.9,-40,-38.1,-31.2,-29.3,-52.7
3100 DATA 59.6,87.9,111.4,159.2,204.2,250.1
3110 DATA -60.5,-82,-103.5,-151.4,-196.4,-243.3
3120 DATA 87.9,106.5,147.5,192.5,247.2,300.9
3130 DATA -75.2,-95.7,-134.8,-179.8,-232.5,-288.2
3140 DATA 75.2,80.1,82,97.7,90.8,102.6
3150 DATA -59.6,-60.5,-64.4,-77.1,-70.3,-82
```

```
3160 REM ******************************
3170 REM   Data for channels 25 and 26
3180 REM ******************************
3190 DATA -53.7,-50.8,-48.8,-47.8,-43.9,-46.9
3200 DATA 88.9,85,88.9,85.9,84,82
3210 DATA -49.8,-44.9,-43.9,-40,-37.1,-33.2
3220 DATA 87.9,84,81.1,76.2,74.2,68.4
3230 DATA -45.9,-40,-36.1,-29.3,-17.5,-3.9
3240 DATA 85.9,75.2,74.2,63.5,50.8,35.1
3250 DATA -24.4,-22.4,-14.6,-6.8,.9,6.8
3260 DATA 59.6,55.7,47.8,41,31.2,20.5
3270 DATA -4.8,-15.6,.9,1.9,29.3,50.8
3280 DATA 44.9,46.9,27.3,24.4,2.9,-18.5
3290 DATA -89.9,-67.4,-83,-67.4,-51.7,-47.8
3300 DATA 142.6,120.1,138.7,127,114.3,110.4
3310 DATA -81.1,-82,-96.7,-116.2,-140.7,-171.9
3320 DATA 146.5,148.5,163.1,181.7,204.2,233.5
3330 DATA -82,-104.5,-126,-172.9,-231.5,-300.9
3340 DATA 153.4,177.8,201.3,244.3,300,365.4
3350 DATA -97.7,-117.2,-153.4,-197.3,-252.1,-304.8
3360 DATA 180.7,196.4,229.6,272.6,319.5,370.3
3370 DATA -76.2,-80.1,-77.1,-86.9,-74.2,-82
3380 DATA 160.2,162.2,159.2,168,155.3,163.1
```

```
****************************
* Strain gage nos. 3 and 4
****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
----------------------------------------------------------

              Top gages      Bot. gages

C 1           -97.42496       90.22856
C 2            5.945145      -5.266419
C 3           -4.866028E-02 -5.355835E-03

W=5# and P= 0   Strain in top gage=-97.42496
                Strain in bottom gage= 90.22855
         Moment M= 7.330216
         Thrust N=-13.49324

W=5# and P= 1   Strain in top gage=-91.52848
                Strain in bottom gage= 84.95579
         Moment M= 6.893955
         Thrust N=-12.32191

W=5# and P= 5   Strain in top gage=-68.91575
                Strain in bottom gage= 63.76258
         Moment M= 5.182747
         Thrust N=-9.662189

W=5# and P= 10   Strain in top gage=-42.83954
                Strain in bottom gage= 37.02879
         Moment M= 3.119857
         Thrust N=-10.89515
W=0 and P= 1
          Normalized Moment =-.4362601
          Normalized Thrust =-1.171331
W=0 and P= 5
          Normalized Moment =-.4294938
          Normalized Thrust = .7662106
W=0 and P= 10
          Normalized Moment =-.4210359
          Normalized Thrust = .2598095
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -88.9964 | 81.01428 |
| C 2 | 25.1409 | -25.17716 |
| C 3 | -.712946 | .692854 |

W=5# and P= 0  Strain in top gage=-88.9964
Strain in bottom gage= 81.01428
Moment M= 6.641042
Thrust N=-14.96647

W=5# and P= 1  Strain in top gage=-64.56845
Strain in bottom gage= 56.52999
Moment M= 4.730407
Thrust N=-15.07211

W=5# and P= 5  Strain in top gage= 18.88445
Strain in bottom gage=-27.55014
Moment M=-1.813851
Thrust N=-16.24817

W=5# and P= 10  Strain in top gage= 91.11801
Strain in bottom gage=-101.4719
Moment M=-7.523042
Thrust N=-19.41347

W=0 and P= 1
Normalized Moment =-1.910635
Normalized Thrust =-.1056433

W=0 and P= 5
Normalized Moment =-1.690979
Normalized Thrust =-.2563391

W=0 and P= 10
Normalized Moment =-1.416408
Normalized Thrust =-.4447003

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -49.02143 | 42.02857 |
| C 2 | 2.772499 | -4.35286 |
| C 3 | .5866075 | -.5285721 |

W=50 and P= 0 Strain in top gage=-49.02143
Strain in bottom gage= 42.02857
Moment M= 3.556641
Thrust N=-13.11163

W=50 and P= 1 Strain in top gage=-45.66233
Strain in bottom gage= 37.14713
Moment M= 3.234744
Thrust N=-15.96598

W=50 and P= 5 Strain in top gage=-20.49375
Strain in bottom gage= 7.049965
Moment M= 1.075926
Thrust N=-25.2071

W=50 and P= 10 Strain in top gage= 37.3643
Strain in bottom gage=-54.35724
Moment M=-3.582873
Thrust N=-31.86175

W=0 and P= 1
Normalized Moment =-.3218961
Normalized Thrust =-2.854357

W=0 and P= 5
Normalized Moment =-.4961428
Normalized Thrust =-2.419094

W=0 and P= 10
Normalized Moment =-.7139514
Normalized Thrust =-1.875013

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -31.31072 | 18.60001 |
| C 2 | -2.455551 | 2.27858 |
| C 3 | -5.758858E-02 | -.0357132 |

```
W=5# and P= 0   Strain in top gage=-31.31072
                Strain in bottom gage= 18.60001
        Moment M= 1.949638
        Thrust N=-23.83258

W=5# and P= 1   Strain in top gage=-33.82385
                Strain in bottom gage= 20.84287
        Moment M= 2.135419
        Thrust N=-24.33934

W=5# and P= 5   Strain in top gage=-45.02819
                Strain in bottom gage= 29.10008
        Moment M= 2.895635
        Thrust N=-29.86521

W=5# and P= 10   Strain in top gage=-61.62509
                Strain in bottom gage= 37.81448
        Moment M= 3.884358
        Thrust N=-44.64488
W=0 and P= 1
         Normalized Moment = .1857814
         Normalized Thrust =-.5067587
W=0 and P= 5
         Normalized Moment = .1891935
         Normalized Thrust =-1.206525
W=0 and P= 10
         Normalized Moment = .1934721
         Normalized Thrust =-2.08123
```

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -23.98212 | 14.42139 |
| C 2 | -11.32767 | 7.906098 |
| C 3 | .2191925 | -2.231789E-02 |

W=50 and P= 0 Strain in top gage=-23.98212
Strain in bottom gage= 14.42139
Moment M= 1.500137
Thrust N=-17.92637

W=50 and P= 1 Strain in top gage=-35.09059
Strain in bottom gage= 22.30517
Moment M= 2.242022
Thrust N=-23.97267

W=50 and P= 5 Strain in top gage=-75.14064
Strain in bottom gage= 53.39393
Moment M= 5.020882
Thrust N=-40.77509

W=50 and P= 10 Strain in top gage=-115.3395
Strain in bottom gage= 91.25058
Moment M= 8.069926
Thrust N=-45.16682

W=0 and P= 1
Normalized Moment = .741885
Normalized Thrust =-6.045304

W=0 and P= 5
Normalized Moment = .704149
Normalized Thrust =-4.569743

W=0 and P= 10
Normalized Moment = .656979
Normalized Thrust =-2.724044

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -70.65356 | 47.77136 |
| C 2 | -8.411255 | 9.858581 |
| C 3 | -.6147308 | .4964257 |

W=5# and P= 0  Strain in top gage=-70.65356
Strain in bottom gage= 47.77136
Moment M= 4.625974
Thrust N=-42.90413

W=5# and P= 1  Strain in top gage=-79.67955
Strain in bottom gage= 58.12637
Moment M= 5.383044
Thrust N=-40.41221

W=5# and P= 5  Strain in top gage=-128.0781
Strain in bottom gage= 109.4749
Moment M= 9.279415
Thrust N=-34.88099

W=5# and P= 10  Strain in top gage=-216.2392
Strain in bottom gage= 195.9997
Moment M= 16.10309
Thrust N=-37.94898

W=0 and P= 1
Normalized Moment = .7570701
Normalized Thrust =-2.491915

W=0 and P= 5
Normalized Moment = .9306882
Normalized Thrust =-1.604628

W=0 and P= 10
Normalized Moment = 1.147711
Normalized Thrust = .4955149

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -82.9964 | 72.21076 |
| C 2 | -9.921936 | 9.874084 |
| C 3 | -.1343842 | 7.188416E-02 |

W=5# and P= 0 Strain in top gage=-82.9964
Strain in bottom gage= 72.21076
Moment M= 6.06278
Thrust N=-20.22308

W=5# and P= 1 Strain in top gage=-93.05272
Strain in bottom gage= 82.15673
Moment M= 6.844119
Thrust N=-20.42999

W=5# and P= 5 Strain in top gage=-135.9657
Strain in bottom gage= 123.3783
Moment M= 10.13062
Thrust N=-23.60138

W=5# and P= 10 Strain in top gage=-195.6542
Strain in bottom gage= 178.14
Moment M= 14.60134
Thrust N=-32.83905

W=0 and P= 1
Normalized Moment = .7813395
Normalized Thrust =-.2059092

W=0 and P= 5
Normalized Moment = .8135689
Normalized Thrust =-.6756592

W=0 and P= 10
Normalized Moment = .8538556
Normalized Thrust =-1.261597

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -79.443 | 69.9607 |
| C 2 | 1.522888 | -1.076965 |
| C 3 | -1.267868 | 1.213841 |

W=5# and P= 0   Strain in top gage=-79.443
Strain in bottom gage= 69.9607
Moment M= 5.836082
Thrust N=-17.77931

W=5# and P= 1   Strain in top gage=-79.18798
Strain in bottom gage= 70.03756
Moment M= 5.831466
Thrust N=-17.04452

W=5# and P= 5   Strain in top gage=-103.5253
Strain in bottom gage= 94.92188
Moment M= 7.751841
Thrust N=-16.13133

W=5# and P= 10   Strain in top gage=-191.0009
Strain in bottom gage= 180.5751
Moment M= 14.51469
Thrust N=-19.54843

W=0 and P= 1
Normalized Moment =-4.615188E-03
Normalized Thrust = .7347965

W=0 and P= 5
Normalized Moment = .3831519
Normalized Thrust = .3295956

W=0 and P= 10
Normalized Moment = .8678606
Normalized Thrust =-.1769114

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -80.19645 | 78.63925 |
| C 2 | -3.104859 | 2.327698 |
| C 3 | -.1058044 | .1665154 |

W=5# and P= 0   Strain in top gage=-80.19645
Strain in bottom gage= 78.63925
Moment M= 6.20452
Thrust N=-2.919731

W=5# and P= 1   Strain in top gage=-83.40711
Strain in bottom gage= 81.13347
Moment M= 6.427367
Thrust N=-4.263067

W=5# and P= 5   Strain in top gage=-98.36584
Strain in bottom gage= 94.44062
Moment M= 7.531583
Thrust N=-7.359782

W=5# and P= 10   Strain in top gage=-121.8255
Strain in bottom gage= 118.5678
Moment M= 9.390361
Thrust N=-6.108198

W=0 and P= 1
Normalized Moment = .2228469
Normalized Thrust =-1.343336

W=0 and P= 5
Normalized Moment = .2653967
Normalized Thrust =-.88801

W=0 and P= 10
Normalized Moment = .3185842
Normalized Thrust =-.3188467

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -65.07145 | 62.78214 |
| C 2 | -.955719 | 1.487686 |
| C 3 | 9.999848E-02 | -.1441937 |

```
W=5# and P= 0   Strain in top gage=-65.07145
                Strain in bottom gage= 62.78214
         Moment M= 4.994281
         Thrust N=-4.29245

W=5# and P= 1   Strain in top gage=-65.92716
                Strain in bottom gage= 64.12563
         Moment M= 5.080188
         Thrust N=-3.377881

W=5# and P= 5   Strain in top gage=-67.35008
                Strain in bottom gage= 66.61573
         Moment M= 5.233039
         Thrust N=-1.37691

W=5# and P= 10   Strain in top gage=-64.62878
                 Strain in bottom gage= 63.23963
         Moment M= 4.99486
         Thrust N=-2.604661
W=0 and P= 1
          Normalized Moment = 8.590669E-02
          Normalized Thrust = .9145689
W=0 and P= 5
          Normalized Moment = 4.775173E-02
          Normalized Thrust = .583108
W=0 and P= 10
          Normalized Moment = 5.796552E-05
          Normalized Thrust = .1687789
```

```
*****************************
* Strain gage nos. 7 and 8
*****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
----------------------------------------------------------
               Top gages     Bot. gages

C 1            -826.3672     -93.86069
C 2            -8.690918      1.905518
C 3            -.1308289     -7.455635E-02

W=5# and P= 0   Strain in top gage=-826.3672
                Strain in bottom gage=-93.86069
         Moment M= 28.61353
         Thrust N=-1725.427

W=5# and P= 1   Strain in top gage=-835.189
                Strain in bottom gage=-92.02972
         Moment M= 29.02966
         Thrust N=-1738.535

W=5# and P= 5   Strain in top gage=-873.0925
                Strain in bottom gage=-86.19701
         Moment M= 30.73811
         Thrust N=-1798.668

W=5# and P= 10   Strain in top gage=-926.3592
                Strain in bottom gage=-82.26115
         Moment M= 32.97258
         Thrust N=-1891.163
W=0 and P= 1
          Normalized Moment = .4161227
          Normalized Thrust =-13.10778
W=0 and P= 5
          Normalized Moment = .4249143
          Normalized Thrust =-14.64812
W=0 and P= 10
          Normalized Moment = .4359047
          Normalized Thrust =-16.5736
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -779.7315 | -86.53216 |
| C 2 | -192.2041 | 24.59055 |
| C 3 | 16.52365 | -.6691952 |

W=5# and P= 0 Strain in top gage=-779.7315
Strain in bottom gage=-86.53216
Moment M= 27.0781
Thrust N=-1624.244

W=5# and P= 1 Strain in top gage=-955.4119
Strain in bottom gage=-62.61082
Moment M= 34.87504
Thrust N=-1908.793

W=5# and P= 5 Strain in top gage=-1327.661
Strain in bottom gage= 19.69068
Moment M= 52.63092
Thrust N=-2452.444

W=5# and P= 10 Strain in top gage=-1049.407
Strain in bottom gage= 92.45377
Moment M= 44.60395
Thrust N=-1794.288

W=0 and P= 1
Normalized Moment = 7.796945
Normalized Thrust =-284.5483

W=0 and P= 5
Normalized Moment = 5.110563
Normalized Thrust =-165.6399

W=0 and P= 10
Normalized Moment = 1.752585
Normalized Thrust =-17.00437

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -1317.172 | -40.25714 |
| C 2 | -40.82031 | 4.06144 |
| C 3 | 2.662427 | .5 |

W=5# and P= 0   Strain in top gage=-1317.172
Strain in bottom gage=-40.25714
Moment M= 49.87949
Thrust N=-2545.179

W=5# and P= 1   Strain in top gage=-1355.13
Strain in bottom gage=-35.6957
Moment M= 51.5404
Thrust N=-2607.798

W=5# and P= 5   Strain in top gage=-1449.713
Strain in bottom gage=-7.449944
Moment M= 56.33839
Thrust N=-2732.18

W=5# and P= 10   Strain in top gage=-1439.132
Strain in bottom gage= 50.35726
Moment M= 58.18319
Thrust N=-2603.953

W=0 and P= 1
Normalized Moment = 1.660911
Normalized Thrust =-62.61834

W=0 and P= 5
Normalized Moment = 1.291782
Normalized Thrust =-37.40014

W=0 and P= 10
Normalized Moment = .8303706
Normalized Thrust =-5.877385

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -1450.478 | -36.44284 |
| C 2 | -23.771 | -7.187927 |
| C 3 | 2.09906 | -.223217 |

W=5# and P= 0    Strain in top gage=-1450.478
Strain in bottom gage=-36.44284
Moment M= 55.23575
Thrust N=-2787.977

W=5# and P= 1    Strain in top gage=-1472.15
Strain in bottom gage=-43.85399
Moment M= 55.79281
Thrust N=-2842.507

W=5# and P= 5    Strain in top gage=-1516.857
Strain in bottom gage=-77.96291
Moment M= 56.20678
Thrust N=-2990.286

W=5# and P= 10    Strain in top gage=-1478.282
Strain in bottom gage=-130.6438
Moment M= 52.64212
Thrust N=-3016.736

W=0 and P= 1
Normalized Moment = .5570598
Normalized Thrust =-54.53067

W=0 and P= 5
Normalized Moment = .1942059
Normalized Thrust =-40.46193

W=0 and P= 10
Normalized Moment =-.2593634
Normalized Thrust =-22.87593

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -1646.27 | -38.30353 |
| C 2 | -10.4502 | -13.11371 |
| C 3 | 3.923279 | -8.487701E-03 |

W=5# and P= 0    Strain in top gage=-1646.27
Strain in bottom gage=-38.30353
Moment M= 62.8112
Thrust N=-3158.575

W=5# and P= 1    Strain in top gage=-1660.797
Strain in bottom gage=-51.42573
Moment M= 62.06606
Thrust N=-3210.418

W=5# and P= 5    Strain in top gage=-1640.439
Strain in bottom gage=-104.0643
Moment M= 60.01386
Thrust N=-3270.981

W=5# and P= 10    Strain in top gage=-1438.444
Strain in bottom gage=-170.2894
Moment M= 49.53729
Thrust N=-3016.375

W=0 and P= 1
Normalized Moment = 5.486951E-02
Normalized Thrust =-51.84197

W=0 and P= 5
Normalized Moment =-.5594671
Normalized Thrust =-22.48113

W=0 and P= 10
Normalized Moment =-1.32739
Normalized Thrust =-14.22001

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 5.325012 | -56.77161 |
| C 2 | -13.2002 | -5.497803 |
| C 3 | 2.061162 | -.7410851 |

W=5# and P= 0   Strain in top gage= 5.325012
Strain in bottom gage=-56.77161
Moment M=-2.425649
Thrust N=-96.46236

W=5# and P= 1   Strain in top gage=-5.814021
Strain in bottom gage=-63.0105
Moment M=-2.234237
Thrust N=-129.046

W=5# and P= 5   Strain in top gage=-9.146914
Strain in bottom gage=-102.7878
Moment M=-3.657845
Thrust N=-209.8775

W=5# and P= 10   Strain in top gage= 79.43926
Strain in bottom gage=-185.8581
Moment M=-10.36318
Thrust N=-199.5354

W=0 and P= 1
Normalized Moment = .1914119
Normalized Thrust =-32.5836

W=0 and P= 5
Normalized Moment =-.2464392
Normalized Thrust =-22.68303

W=0 and P= 10
Normalized Moment =-.793753
Normalized Thrust =-10.3073

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -121.925 | -64.12146 |
| C 2 | 6.483734 | -6.689636 |
| C 3 | -.5843811 | .1455307 |

W=5# and P= 0 Strain in top gage=-121.925
Strain in bottom gage=-64.12146
Moment M= 2.25795
Thrust N=-348.8371

W=5# and P= 1 Strain in top gage=-116.0256
Strain in bottom gage=-70.66556
Moment M= 1.771878
Thrust N=-350.046

W=5# and P= 5 Strain in top gage=-104.1158
Strain in bottom gage=-93.93138
Moment M= .3978309
Thrust N=-371.3385

W=5# and P= 10 Strain in top gage=-115.5258
Strain in bottom gage=-116.4648
Moment M=-3.667951E-02
Thrust N=-434.9822

W=0 and P= 1
Normalized Moment =-.4860726
Normalized Thrust =-1.208911

W=0 and P= 5
Normalized Moment =-.3720239
Normalized Thrust =-4.500289

W=0 and P= 10
Normalized Moment =-.229463
Normalized Thrust =-8.614511

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -166.5249 | -60.40363 |
| C 2 | 5.470093 | 4.293427 |
| C 3 | -.3361626 | -.8049164 |

W=5# and P= 0   Strain in top gage=-166.5249
Strain in bottom gage=-60.40363
Moment M= 4.145363
Thrust N=-425.491

W=5# and P= 1   Strain in top gage=-161.391
Strain in bottom gage=-56.91512
Moment M= 4.081088
Thrust N=-409.3239

W=5# and P= 5   Strain in top gage=-147.5785
Strain in bottom gage=-59.0594
Moment M= 3.457778
Thrust N=-387.4461

W=5# and P= 10   Strain in top gage=-145.4402
Strain in bottom gage=-97.961
Moment M= 1.854658
Thrust N=-456.3773

W=0 and P= 1
Normalized Moment =-6.427408E-02
Normalized Thrust =-16.16707

W=0 and P= 5
Normalized Moment =-.137517
Normalized Thrust =-7.608982

W=0 and P= 10
Normalized Moment =-.2290705
Normalized Thrust =-3.088632

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -186.0035 | -50.82855 |
| C 2 | -4.164551 | -1.737854 |
| C 3 | .7361603 | 9.821319E-02 |

W=5# and P= 0  Strain in top gage=-186.0035
Strain in bottom gage=-50.82855
Moment M= 5.280271
Thrust N=-444.0601

W=5# and P= 1  Strain in top gage=-189.4319
Strain in bottom gage=-52.4682
Moment M= 5.350144
Thrust N=-453.5626

W=5# and P= 5  Strain in top gage=-188.4222
Strain in bottom gage=-57.06249
Moment M= 5.13124
Thrust N=-460.2839

W=5# and P= 10  Strain in top gage=-154.033
Strain in bottom gage=-58.38578
Moment M= 3.736218
Thrust N=-398.2851

W=0 and P= 1
Normalized Moment = 6.987304E-02
Normalized Thrust =-9.502559

W=0 and P= 5
Normalized Moment =-.0298062
Normalized Thrust =-3.244758

W=0 and P= 10
Normalized Moment =-.1544052
Normalized Thrust =-4.577494

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -200.7534 | -39.19646 |
| C 2 | .1072998 | -.0826752 |
| C 3 | -.150444 | .1352644 |

W=5# and P= 0 Strain in top gage=-200.7534
Strain in bottom gage=-39.19646
Moment M= 6.310817
Thrust N=-449.9059

W=5# and P= 1 Strain in top gage=-200.7965
Strain in bottom gage=-39.94387
Moment M= 6.283307
Thrust N=-451.3882

W=5# and P= 5 Strain in top gage=-203.978
Strain in bottom gage=-40.22822
Moment M= 6.396475
Thrust N=-457.8866

W=5# and P= 10 Strain in top gage=-214.7248
Strain in bottom gage=-34.49677
Moment M= 7.040157
Thrust N=-467.2904

W=0 and P= 1
Normalized Moment =-2.751008E-02
Normalized Thrust =-1.482303

W=0 and P= 5
Normalized Moment = .0171316
Normalized Thrust =-1.59614

W=0 and P= 10
Normalized Moment = 7.293396E-02
Normalized Thrust =-1.738447

```
****************************
* Strain gage nos. 13 and 14
****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
---------------------------------------------------------
              Top gages     Bot. gages

C 1            21.72856     -19.00359
C 2            1.365006     -5.230713E-02
C 3           -9.464264E-02 -2.276802E-02

W=5# and P= 0   Strain in top gage= 21.72856
                Strain in bottom gage=-19.00359
         Moment M=-1.5911
         Thrust N=-5.109329

W=5# and P= 1   Strain in top gage= 22.99893
                Strain in bottom gage=-19.07866
         Moment M=-1.643656
         Thrust N=-7.350494

W=5# and P= 5   Strain in top gage= 26.18752
                Strain in bottom gage=-19.83432
         Moment M=-1.797728
         Thrust N=-11.91225

W=5# and P= 10   Strain in top gage= 25.91435
                Strain in bottom gage=-21.80346
         Moment M=-1.863977
         Thrust N=-7.707925
W=0 and P= 1
          Normalized Moment =-5.255617E-02
          Normalized Thrust =-2.241165
W=0 and P= 5
          Normalized Moment =-4.132576E-02
          Normalized Thrust =-1.360585
W=0 and P= 10
          Normalized Moment =-2.728775E-02
          Normalized Thrust = .2598596
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 20.53571 | -16.15717 |
| C 2 | 7.921082 | -7.879273 |
| C 3 | -.3383923 | .2696419 |

W=5# and P= 0 Strain in top gage= 20.53571
Strain in bottom gage=-16.15717
Moment M=-1.433315
Thrust N=-8.209763

W=5# and P= 1 Strain in top gage= 28.1184
Strain in bottom gage=-23.7668
Moment M=-2.026765
Thrust N=-8.159248

W=5# and P= 5 Strain in top gage= 51.68131
Strain in bottom gage=-48.81248
Moment M=-3.925539
Thrust N=-5.379045

W=5# and P= 10 Strain in top gage= 65.9073
Strain in bottom gage=-67.9857
Moment M=-5.230196
Thrust N=-3.897014

W=0 and P= 1
Normalized Moment =-.59345
Normalized Thrust =-5.051494E-02

W=0 and P= 5
Normalized Moment =-.4984447
Normalized Thrust =-.5661435

W=0 and P= 10
Normalized Moment =-.379688
Normalized Thrust =-1.210678

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 39.97504 | -34.70722 |
| C 2 | 6.439453 | -7.647492 |
| C 3 | 8.487701E-03 | -4.197312E-02 |

W=5# and P= 0   Strain in top gage= 39.97504
Strain in bottom gage=-34.70722
Moment M=-2.917276
Thrust N=-9.877167

W=5# and P= 1   Strain in top gage= 46.42298
Strain in bottom gage=-42.39668
Moment M=-3.469518
Thrust N=-7.54931

W=5# and P= 5   Strain in top gage= 72.3845
Strain in bottom gage=-73.99401
Moment M=-5.71791
Thrust N=-3.017836

W=5# and P= 10   Strain in top gage= 105.2183
Strain in bottom gage=-115.3794
Moment M=-8.617101
Thrust N=-19.05207

W=0 and P= 1
Normalized Moment =-.5522424
Normalized Thrust =-2.327857

W=0 and P= 5
Normalized Moment =-.5601269
Normalized Thrust =-2.579001

W=0 and P= 10
Normalized Moment =-.5699825
Normalized Thrust =-2.892923

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 41.36069 | -43.48569 |
| C 2 | 7.097351 | -7.608612 |
| C 3 | -.2790165 | .2321434 |

W=5# and P= 0 Strain in top gage= 41.36069
Strain in bottom gage=-43.48569
Moment M=-3.314312
Thrust N=-3.984375

W=5# and P= 1 Strain in top gage= 48.17903
Strain in bottom gage=-50.86216
Moment M=-3.868796
Thrust N=-5.030873

W=5# and P= 5 Strain in top gage= 69.87203
Strain in bottom gage=-75.72516
Moment M=-5.607391
Thrust N=-10.97461

W=5# and P= 10 Strain in top gage= 84.43255
Strain in bottom gage=-96.35747
Moment M=-7.06211
Thrust N=-22.35922

W=0 and P= 1
Normalized Moment =-.5544846
Normalized Thrust =-1.046498

W=0 and P= 5
Normalized Moment =-.4746158
Normalized Thrust =-1.398048

W=0 and P= 10
Normalized Moment =-.3747739
Normalized Thrust =-1.837485

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 46.01779 | -45.51432 |
| C 2 | -15.94482 | 12.90503 |
| C 3 | -.1043796 | .4910698 |

W=5# and P= 0   Strain in top gage= 46.01779
Strain in bottom gage=-45.51432
Moment M=-3.575473
Thrust N= .9440231

W=5# and P= 1   Strain in top gage= 29.88859
Strain in bottom gage=-32.11821
Moment M=-2.422141
Thrust N=-4.180548

W=5# and P= 5   Strain in top gage=-38.31582
Strain in bottom gage= 31.28756
Moment M= 2.718883
Thrust N=-13.17794

W=5# and P= 10   Strain in top gage=-131.8684
Strain in bottom gage= 132.643
Moment M= 10.33248
Thrust N=-1.452284

W=0 and P= 1
Normalized Moment = 1.153332
Normalized Thrust =-5.124572

W=0 and P= 5
Normalized Moment = 1.258871
Normalized Thrust =-2.824393

W=0 and P= 10
Normalized Moment = 1.390795
Normalized Thrust = 5.082608E-02

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 20.79999 | -37.64646 |
| C 2 | -10.76358 | 11.33981 |
| C 3 | -.4517899 | .5040169 |

W=5# and P= 0 Strain in top gage= 20.79999
Strain in bottom gage=-37.64646
Moment M=-2.283064
Thrust N=-31.58713

W=5# and P= 1 Strain in top gage= 9.584618
Strain in bottom gage=-25.80262
Moment M=-1.382314
Thrust N=-30.40876

W=5# and P= 5 Strain in top gage=-44.31256
Strain in bottom gage= 31.65303
Moment M= 2.96741
Thrust N=-23.73681

W=5# and P= 10 Strain in top gage=-132.0148
Strain in bottom gage= 126.1534
Moment M= 10.08469
Thrust N=-10.99019

W=0 and P= 1
Normalized Moment = .9007501
Normalized Thrust =-1.178362

W=0 and P= 5
Normalized Moment = 1.050095
Normalized Thrust =-1.570064

W=0 and P= 10
Normalized Moment = 1.236776
Normalized Thrust =-2.059693

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 27.55356 | -26.26068 |
| C 2 | -1.173019 | -.1623383 |
| C 3 | .532589 | -.4834824 |

W=5# and P= 0 Strain in top gage= 27.55356
Strain in bottom gage=-26.26068
Moment M=-2.102119
Thrust N=-2.424145

W=5# and P= 1 Strain in top gage= 26.91313
Strain in bottom gage=-26.9065
Moment M=-2.102329
Thrust N= 1.242399E-02

W=5# and P= 5 Strain in top gage= 35.00319
Strain in bottom gage=-39.15943
Moment M=-2.896977
Thrust N=-7.792962

W=5# and P= 10 Strain in top gage= 69.08226
Strain in bottom gage=-76.2323
Moment M=-5.67635
Thrust N=-13.40633

W=0 and P= 1
Normalized Moment =-2.105534E-04
Normalized Thrust =-2.411721

W=0 and P= 5
Normalized Moment =-.1589717
Normalized Thrust =-2.043421

W=0 and P= 10
Normalized Moment =-.3574231
Normalized Thrust =-1.583047

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 8.12854 | -10.20715 |
| C 2 | 7.517884 | -5.541046 |
| C 3 | .4767914 | -.6687546 |

W=5# and P= 0  Strain in top gage= 8.12854
Strain in bottom gage=-10.20715
Moment M=-.716238
Thrust N=-3.8974

W=5# and P= 1  Strain in top gage= 16.12322
Strain in bottom gage=-16.41695
Moment M=-1.2711
Thrust N=-.5507613

W=5# and P= 5  Strain in top gage= 57.63774
Strain in bottom gage=-54.63125
Moment M=-4.385508
Thrust N=-5.637174

W=5# and P= 10  Strain in top gage= 130.9865
Strain in bottom gage=-132.4931
Moment M=-10.29217
Thrust N=-2.824803

W=0 and P= 1
Normalized Moment =-.5548623
Normalized Thrust =-3.346639

W=0 and P= 5
Normalized Moment =-.7338539
Normalized Thrust =-1.906915

W=0 and P= 10
Normalized Moment =-.9575933
Normalized Thrust = .1072598

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 31.61072 | -28.10358 |
| C 2 | .8655091 | .5212403 |
| C 3 | .4325924 | -.5709858 |

W=5# and P= 0 Strain in top gage= 31.61072
Strain in bottom gage=-28.10358
Moment M=-2.33259
Thrust N=-6.57589

W=5# and P= 1 Strain in top gage= 32.90882
Strain in bottom gage=-28.15332
Moment M=-2.38524
Thrust N=-8.91656

W=5# and P= 5 Strain in top gage= 46.75308
Strain in bottom gage=-39.77202
Moment M=-3.379887
Thrust N=-13.08948

W=5# and P= 10 Strain in top gage= 83.52505
Strain in bottom gage=-79.98976
Moment M=-6.387297
Thrust N=-6.628676

W=0 and P= 1
Normalized Moment =-5.265035E-02
Normalized Thrust =-2.340671

W=0 and P= 5
Normalized Moment =-.2094594
Normalized Thrust =-1.302718

W=0 and P= 10
Normalized Moment =-.4054708
Normalized Thrust = 5.278588E-03

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 30.13927 | -19.13214 |
| C 2 | 1.459839 | -1.399468 |
| C 3 | -1.741028E-02 | 5.803108E-03 |

W=5# and P= 0   Strain in top gage= 30.13927
Strain in bottom gage=-19.13214
Moment M=-1.924664
Thrust N=-20.63836

W=5# and P= 1   Strain in top gage= 31.5817
Strain in bottom gage=-20.52581
Moment M=-2.035449
Thrust N=-20.72979

W=5# and P= 5   Strain in top gage= 37.00321
Strain in bottom gage=-25.9844
Moment M=-2.460453
Thrust N=-20.66026

W=5# and P= 10   Strain in top gage= 42.99663
Strain in bottom gage=-32.54651
Moment M=-2.950904
Thrust N=-19.59398

W=0 and P= 1
Normalized Moment =-.1107849
Normalized Thrust = 9.143114E-02

W=0 and P= 5
Normalized Moment =-.1071578
Normalized Thrust = 4.378796E-03

W=0 and P= 10
Normalized Moment =-.1026239
Normalized Thrust =-.1044381

```
*****************************
* Strain gage nos. 17 and 18
*****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
---------------------------------------------------------
                Top gages     Bot. gages

C 1              13.91428     -20.01786
C 2              .8300018     -.5616074
C 3             -7.857132E-02  .0111599

W=5# and P= 0   Strain in top gage= 13.91428
                Strain in bottom gage=-20.01786
         Moment M=-1.325474
         Thrust N=-11.44421

W=5# and P= 1   Strain in top gage= 14.66571
                Strain in bottom gage=-20.56831
         Moment M=-1.376329
         Thrust N=-11.05736

W=5# and P= 5   Strain in top gage= 16.10001
                Strain in bottom gage=-22.5469
         Moment M=-1.509645
         Thrust N=-12.08792

W=5# and P= 10   Strain in top gage= 14.35717
                 Strain in bottom gage=-24.51795
         Moment M=-1.518559
         Thrust N=-19.05145
W=0 and P= 1
          Normalized Moment =-5.085461E-02
          Normalized Thrust = .3768432
W=0 and P= 5
          Normalized Moment =-3.683411E-02
          Normalized Thrust =-.1287425
W=0 and P= 10
          Normalized Moment =-1.930848E-02
          Normalized Thrust =-.7607246
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 11.76427 | -19.90714 |
| C 2 | 6.188935 | -6.653214 |
| C 3 | -.1866074 | .1901779 |

W=5# and P= 0   Strain in top gage= 11.76427
Strain in bottom gage=-19.90714
Moment M=-1.237164
Thrust N=-15.26788

W=5# and P= 1   Strain in top gage= 17.76659
Strain in bottom gage=-26.37017
Moment M=-1.724032
Thrust N=-16.13171

W=5# and P= 5   Strain in top gage= 38.04376
Strain in bottom gage=-48.41876
Moment M=-3.377442
Thrust N=-19.45313

W=5# and P= 10   Strain in top gage= 54.99288
Strain in bottom gage=-67.42148
Moment M=-4.701811
Thrust N=-23.30363

W=0 and P= 1
Normalized Moment =-.4869282
Normalized Thrust =-.8638287

W=0 and P= 5
Normalized Moment =-.4280555
Normalized Thrust =-.8370495

W=0 and P= 10
Normalized Moment =-.3544647
Normalized Thrust =-.8035755

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 27.90711 | -35.32504 |
| C 2 | 6.201111 | -7.580506 |
| C 3 | 6.874848E-02 | -6.652451E-02 |

W=5# and P= 0   Strain in top gage= 27.90711
Strain in bottom gage=-35.32504
Moment M=-2.470006
Thrust N=-13.90663

W=5# and P= 1   Strain in top gage= 34.17697
Strain in bottom gage=-42.97208
Moment M=-3.013634
Thrust N=-16.49083

W=5# and P= 5   Strain in top gage= 60.63137
Strain in bottom gage=-74.89069
Moment M=-5.293831
Thrust N=-26.73622

W=5# and P= 10   Strain in top gage= 96.79306
Strain in bottom gage=-117.7826
Moment M=-8.38106
Thrust N=-39.35529

W=0 and P= 1
Normalized Moment =-.5436285
Normalized Thrust =-2.582195

W=0 and P= 5
Normalized Moment =-.564765
Normalized Thrust =-2.565517

W=0 and P= 10
Normalized Moment =-.5911854
Normalized Thrust =-2.544665

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 29.95355 | -48.97144 |
| C 2 | 7.734101 | -6.754303 |
| C 3 | -.2138386 | 1.071549E-02 |

W=5# and P= 0 Strain in top gage= 29.95355
Strain in bottom gage=-48.97144
Moment M=-3.083007
Thrust N=-35.65853

W=5# and P= 1 Strain in top gage= 37.47382
Strain in bottom gage=-55.71503
Moment M=-3.640189
Thrust N=-34.20226

W=5# and P= 5 Strain in top gage= 63.27809
Strain in bottom gage=-82.47507
Moment M=-5.693483
Thrust N=-35.99433

W=5# and P= 10 Strain in top gage= 85.9107
Strain in bottom gage=-115.4429
Moment M=-7.865376
Thrust N=-55.37291

W=0 and P= 1
Normalized Moment =-.5571817
Normalized Thrust =-1.456268

W=0 and P= 5
Normalized Moment =-.5220951
Normalized Thrust =-6.715965E-02

W=0 and P= 10
Normalized Moment =-.4782368
Normalized Thrust =-1.971438

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 40.31079 | -52.36429 |
| C 2 | -12.26663 | 8.055359 |
| C 3 | -.1834831 | .4937516 |

W=5# and P= 0   Strain in top gage= 40.31079
Strain in bottom gage=-52.36429
Moment M=-3.62012
Thrust N=-22.60031

W=5# and P= 1   Strain in top gage= 27.86068
Strain in bottom gage=-43.81518
Moment M=-2.799838
Thrust N=-29.91469

W=5# and P= 5   Strain in top gage=-25.60945
Strain in bottom gage= .2562943
Moment M= 1.010381
Thrust N=-47.53717

W=5# and P= 10   Strain in top gage=-100.7038
Strain in bottom gage= 77.56446
Moment M= 6.963606
Thrust N=-43.38636

W=0 and P= 1
Normalized Moment = .8202823
Normalized Thrust =-7.314384

W=0 and P= 5
Normalized Moment = .9261001
Normalized Thrust =-4.987373

W=0 and P= 10
Normalized Moment = 1.058373
Normalized Thrust =-2.078605

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 12.9715 | -32 |
| C 2 | -15.30505 | 17.20508 |
| C 3 | -.4553566 | .3875008 |

W=50 and P= 0  Strain in top gage= 12.9715
Strain in bottom gage=-32
Moment M=-1.756699
Thrust N=-35.67845

W=50 and P= 1  Strain in top gage=-2.788914
Strain in bottom gage=-14.40742
Moment M=-.453848
Thrust N=-32.24313

W=50 and P= 5  Strain in top gage=-74.93768
Strain in bottom gage= 63.71291
Moment M= 5.416039
Thrust N=-21.04646

W=50 and P= 10  Strain in top gage=-185.6147
Strain in bottom gage= 178.8009
Moment M= 14.23498
Thrust N=-12.77596

W=0 and P= 1
Normalized Moment = 1.302851
Normalized Thrust =-3.435316

W=0 and P= 5
Normalized Moment = 1.434548
Normalized Thrust =-2.926397

W=0 and P= 10
Normalized Moment = 1.599168
Normalized Thrust =-2.290249

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 21.52501 | -19.87502 |
| C 2 | -4.205185 | 2.066971 |
| C 3 | .6736622 | -.5102702 |

W=5# and P= 0 Strain in top gage= 21.52501
Strain in bottom gage=-19.87502
Moment M=-1.617189
Thrust N=-3.093739

W=5# and P= 1 Strain in top gage= 17.99349
Strain in bottom gage=-18.31831
Moment M=-1.41843
Thrust N=-.609051

W=5# and P= 5 Strain in top gage= 17.34064
Strain in bottom gage=-22.29691
Moment M=-1.548342
Thrust N=-9.293814

W=5# and P= 10 Strain in top gage= 46.83938
Strain in bottom gage=-50.23232
Moment M=-3.791864
Thrust N=-6.361764

W=0 and P= 1
Normalized Moment = .1987588
Normalized Thrust =-3.70279

W=0 and P= 5
Normalized Moment = 1.376931E-02
Normalized Thrust =-2.477351

W=0 and P= 10
Normalized Moment =-.2174675
Normalized Thrust =-.9455501

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 4.824921 | -5.42865 |
| C 2 | 7.7099 | -7.022125 |
| C 3 | .4111595 | -.5089341 |

W=5# and P= 0 Strain in top gage= 4.824921
Strain in bottom gage=-5.42865
Moment M=-.4005301
Thrust N=-1.131992

W=5# and P= 1 Strain in top gage= 12.94598
Strain in bottom gage=-12.95971
Moment M=-1.011941
Thrust N=-2.574206E-02

W=5# and P= 5 Strain in top gage= 53.65341
Strain in bottom gage=-53.26263
Moment M=-4.176407
Thrust N= .7327151

W=5# and P= 10 Strain in top gage= 123.0399
Strain in bottom gage=-126.5433
Moment M=-9.749343
Thrust N=-6.568938

W=0 and P= 1
Normalized Moment =-.6114109
Normalized Thrust =-1.10625

W=0 and P= 5
Normalized Moment =-.7551755
Normalized Thrust = .3729415

W=0 and P= 10
Normalized Moment =-.9348813
Normalized Thrust =-.5436945

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 25.13928 | -24.19641 |
| C 2 | .7512818 | .3337402 |
| C 3 | .4683037 | -.5915184 |

```
W=5# and P= 0   Strain in top gage= 25.13928
                Strain in bottom gage=-24.19641
        Moment M=-1.927176
        Thrust N=-1.767883

W=5# and P= 1   Strain in top gage= 26.35887
                Strain in bottom gage=-24.45419
        Moment M=-1.984885
        Thrust N=-3.571272

W=5# and P= 5   Strain in top gage= 40.60328
                Strain in bottom gage=-37.31567
        Moment M=-3.043709
        Thrust N=-6.164274

W=5# and P= 10   Strain in top gage= 79.48247
                Strain in bottom gage=-80.01085
        Moment M=-6.230208
        Thrust N=-.990715
W=0 and P= 1
         Normalized Moment =-5.770952E-02
         Normalized Thrust =-1.003389
W=0 and P= 5
         Normalized Moment =-.2233067
         Normalized Thrust = .8792782
W=0 and P= 10
         Normalized Moment =-.4303032
         Normalized Thrust =-.2758598
```

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 23.96785 | -21.0607 |
| C 2 | 1.968399 | -1.117333 |
| C 3 | -3.526688E-02 | -2.098274E-02 |

W=5# and P= 0  Strain in top gage= 23.96785
Strain in bottom gage=-21.0607
Moment M=-1.758928
Thrust N=-5.450907

W=5# and P= 1  Strain in top gage= 25.90098
Strain in bottom gage=-22.19902
Moment M=-1.878986
Thrust N=-6.941189

W=5# and P= 5  Strain in top gage= 32.92817
Strain in bottom gage=-27.17193
Moment M=-2.34766
Thrust N=-10.79296

W=5# and P= 10  Strain in top gage= 40.12515
Strain in bottom gage=-34.3323
Moment M=-2.908494
Thrust N=-10.8616

W=0 and P= 1
Normalized Moment =-.1199784
Normalized Thrust =-1.490282

W=0 and P= 5
Normalized Moment =-.1177465
Normalized Thrust =-1.06841

W=0 and P= 10
Normalized Moment =-.1149566
Normalized Thrust = .5410695

```
****************************
* Strain gage nos. 19 and 20
****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
---------------------------------------------------------
              Top gages     Bot. gages

C 1           -40.89287      36.00714
C 2            1.363922     -.8767776
C 3           -.0048217      3.482151E-02

W=5# and P= 0   Strain in top gage=-40.89287
                Strain in bottom gage= 36.00714
         Moment M= 3.003907
         Thrust N=-9.160738

W=5# and P= 1   Strain in top gage=-39.61377
                Strain in bottom gage= 35.16519
         Moment M= 2.921053
         Thrust N=-8.341098

W=5# and P= 5   Strain in top gage=-36.1938
                Strain in bottom gage= 32.49379
         Moment M= 2.683109
         Thrust N=-6.937523

W=5# and P= 10   Strain in top gage=-35.73582
                Strain in bottom gage= 30.72152
         Moment M= 2.59599
         Thrust N=-9.401816
W=0 and P= 1
          Normalized Moment =-8.285374E-02
          Normalized Thrust = .8196402
W=0 and P= 5
          Normalized Moment =-6.415951E-02
          Normalized Thrust = .444643
W=0 and P= 10
          Normalized Moment =-4.079171E-02
          Normalized Thrust =-.0241077
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -35.71073 | 32.70358 |
| C 2 | -.6698151 | -.1876755 |
| C 3 | 6.026554E-02 | -2.723122E-02 |

W=5# and P= 0   Strain in top gage=-35.71073
Strain in bottom gage= 32.70358
Moment M= 2.672434
Thrust N=-5.63839

W=5# and P= 1   Strain in top gage=-36.32028
Strain in bottom gage= 32.48868
Moment M= 2.68785
Thrust N=-7.104243

W=5# and P= 5   Strain in top gage=-37.55316
Strain in bottom gage= 31.08443
Moment M= 2.681156
Thrust N=-12.12888

W=5# and P= 10   Strain in top gage=-36.38232
Strain in bottom gage= 28.10371
Moment M= 2.518985
Thrust N=-15.5224

W=0 and P= 1
Normalized Moment = 1.541585E-02
Normalized Thrust =-1.545854

W=0 and P= 5
Normalized Moment = 1.744375E-03
Normalized Thrust =-1.298098

W=0 and P= 10
Normalized Moment =-1.534484E-02
Normalized Thrust =-.9884012

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -38.37857 | 34.37859 |
| C 2 | -.2596436 | -1.214645 |
| C 3 | .13482 | -9.196377E-02 |

W=5# and P= 0 Strain in top gage=-38.37857
Strain in bottom gage= 34.37859
Moment M= 2.842076
Thrust N=-7.499972

W=5# and P= 1 Strain in top gage=-38.5034
Strain in bottom gage= 33.07198
Moment M= 2.795913
Thrust N=-10.18391

W=5# and P= 5 Strain in top gage=-36.30629
Strain in bottom gage= 26.00626
Moment M= 2.434084
Thrust N=-19.31255

W=5# and P= 10 Strain in top gage=-27.49301
Strain in bottom gage= 13.03576
Moment M= 1.583155
Thrust N=-27.10735

W=0 and P= 1
Normalized Moment =-.0461635
Normalized Thrust =-2.68394

W=0 and P= 5
Normalized Moment =-8.159846E-02
Normalized Thrust =-2.362516

W=0 and P= 10
Normalized Moment =-.1258922
Normalized Thrust =-1.960738

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -25.16072 | 13.02143 |
| C 2 | 2.128391 | -1.661785 |
| C 3 | -5.312538E-02 | -5.624998E-02 |

```
W=5# and P= 0   Strain in top gage=-25.16072
                Strain in bottom gage= 13.02143
        Moment M= 1.49149
        Thrust N=-22.76117

W=5# and P= 1   Strain in top gage=-23.08545
                Strain in bottom gage= 11.30339
        Moment M= 1.343314
        Thrust N=-22.09136

W=5# and P= 5   Strain in top gage=-15.8469
                Strain in bottom gage= 3.306255
        Moment M= .7481699
        Thrust N=-23.5137

W=5# and P= 10   Strain in top gage=-9.189342
                Strain in bottom gage=-9.22142
        Moment M=-1.253039E-03
        Thrust N=-34.52018
W=0 and P= 1
         Normalized Moment =-.1481758
         Normalized Thrust = .6698084
W=0 and P= 5
         Normalized Moment =-.148664
         Normalized Thrust =-.1505073
W=0 and P= 10
         Normalized Moment =-.1492743
         Normalized Thrust =-1.175902
```

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -11.10358 | 3.832123 |
| C 2 | -1.662308 | -2.970566 |
| C 3 | .0772326 | -.5058041 |

W=50 and P= 0  Strain in top gage=-11.10358
Strain in bottom gage= 3.832123
Moment M= .5834258
Thrust N=-13.63398

W=50 and P= 1  Strain in top gage=-11.88865
Strain in bottom gage= .355753
Moment M= .4782971
Thrust N=-21.62419

W=50 and P= 5  Strain in top gage= 2.515699
Strain in bottom gage=-23.66581
Moment M=-1.022715
Thrust N=-39.65645

W=50 and P= 10  Strain in top gage= 59.9966
Strain in bottom gage=-76.45395
Moment M=-5.330099
Thrust N=-30.85752

W=0 and P= 1
Normalized Moment =-.1051287
Normalized Thrust =-7.99021

W=0 and P= 5
Normalized Moment =-.3212282
Normalized Thrust =-5.204496

W=0 and P= 10
Normalized Moment =-.5913525
Normalized Thrust =-1.722355

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -63.14644 | 43.76428 |
| C 2 | 8.214829 | -7.156784 |
| C 3 | .2915182 | -.3044653 |

W=5# and P= 0   Strain in top gage=-63.14644
Strain in bottom gage= 43.76428
Moment M= 4.1762
Thrust N=-36.34155

W=5# and P= 1   Strain in top gage=-54.64009
Strain in bottom gage= 36.30303
Moment M= 3.552466
Thrust N=-34.38199

W=5# and P= 5   Strain in top gage=-14.78434
Strain in bottom gage= .3687287
Moment M= .5919168
Thrust N=-27.02927

W=5# and P= 10   Strain in top gage= 48.15367
Strain in bottom gage=-58.25009
Moment M=-4.156397
Thrust N=-18.93079

W=0 and P= 1
Normalized Moment =-.6237343
Normalized Thrust =-1.959558

W=0 and P= 5
Normalized Moment =-.7168567
Normalized Thrust =-1.862454

W=0 and P= 10
Normalized Moment =-.8332597
Normalized Thrust =-1.741076

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -58.92502 | 55.34641 |
| C 2 | 4.970154 | -6.506943 |
| C 3 | -.7611618 | .8674107 |

W=5# and P= 0 Strain in top gage=-58.92502
Strain in bottom gage= 55.34641
Moment M= 4.463728
Thrust N=-6.7099

W=5# and P= 1 Strain in top gage=-54.71603
Strain in bottom gage= 49.70687
Moment M= 4.07902
Thrust N=-9.392166

W=5# and P= 5 Strain in top gage=-53.1033
Strain in bottom gage= 44.49696
Moment M= 3.81251
Thrust N=-16.13689

W=5# and P= 10 Strain in top gage=-85.33966
Strain in bottom gage= 77.01805
Moment M= 6.342098
Thrust N=-15.60303

W=0 and P= 1
Normalized Moment =-.3847081
Normalized Thrust =-2.682266

W=0 and P= 5
Normalized Moment =-.1302435
Normalized Thrust =-1.885397

W=0 and P= 10
Normalized Moment = .187837
Normalized Thrust =-.8893132

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -70.08911 | 64.68555 |
| C 2 | -11.37378 | 13.47791 |
| C 3 | -1.387055 | 1.1875 |

W=5# and P= 0   Strain in top gage=-70.08911
Strain in bottom gage= 64.68555
Moment M= 5.264635
Thrust N=-10.13168

W=5# and P= 1   Strain in top gage=-82.84995
Strain in bottom gage= 79.35095
Moment M= 6.335973
Thrust N=-6.560612

W=5# and P= 5   Strain in top gage=-161.6344
Strain in bottom gage= 161.7626
Moment M= 12.63269
Thrust N= .2403832

W=5# and P= 10   Strain in top gage=-322.5324
Strain in bottom gage= 318.2146
Moment M= 25.02918
Thrust N=-8.09578

W=0 and P= 1
Normalized Moment = 1.071338
Normalized Thrust =-3.571072

W=0 and P= 5
Normalized Moment = 1.473612
Normalized Thrust =-2.074413

W=0 and P= 10
Normalized Moment = 1.976454
Normalized Thrust = .2035904

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -85.68933 | 92.30713 |
| C 2 | -9.724426 | 9.040405 |
| C 3 | -.8924256 | .8883896 |

W=5# and P= 0   Strain in top gage=-85.68933
Strain in bottom gage= 92.30713
Moment M= 6.952987
Thrust N=-12.40837

W=5# and P= 1   Strain in top gage=-96.30618
Strain in bottom gage= 102.2359
Moment M= 7.755552
Thrust N=-11.11026

W=5# and P= 5   Strain in top gage=-156.6221
Strain in bottom gage= 159.7189
Moment M= 12.35707
Thrust N=-5.806504

W=5# and P= 10   Strain in top gage=-272.1762
Strain in bottom gage= 271.5502
Moment M= 21.23931
Thrust N=-1.173763

W=0 and P= 1
Normalized Moment = .8025643
Normalized Thrust =-1.290107

W=0 and P= 5
Normalized Moment = 1.080817
Normalized Thrust =-1.322374

W=0 and P= 10
Normalized Moment = 1.428632
Normalized Thrust =-1.358213

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -71.16068 | 78.08216 |
| C 2 | -1.948731 | 2.04126 |
| C 3 | 1.830292E-02 | -1.741028E-02 |

W=5# and P= 0 Strain in top gage=-71.16068
Strain in bottom gage= 78.08216
Moment M= 5.829798
Thrust N=-12.97777

W=5# and P= 1 Strain in top gage=-73.0911
Strain in bottom gage= 80.106
Moment M= 5.984263
Thrust N=-13.15294

W=5# and P= 5 Strain in top gage=-80.44676
Strain in bottom gage= 87.85319
Moment M= 6.574217
Thrust N=-13.88708

W=5# and P= 10 Strain in top gage=-88.81769
Strain in bottom gage= 96.75372
Moment M= 7.248883
Thrust N=-14.88007

W=0 and P= 1
Normalized Moment = .154464
Normalized Thrust = .1751661

W=0 and P= 5
Normalized Moment = .1488838
Normalized Thrust = .1818609

W=0 and P= 10
Normalized Moment = .1419085
Normalized Thrust = .1902294

```
*****************************
* Strain gage nos. 21 and 22
*****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
----------------------------------------------------------
               Top gages     Bot. gages

C 1            -35.43215      29.99643
C 2             .9683914      .1041107
C 3            -.0602684     -4.955292E-02

W=5# and P= 0   Strain in top gage=-35.43215
                Strain in bottom gage= 29.99643
         Moment M= 2.555804
         Thrust N=-10.19197

W=5# and P= 1   Strain in top gage=-34.52402
                Strain in bottom gage= 30.05099
         Moment M= 2.522462
         Thrust N=-8.386938

W=5# and P= 5   Strain in top gage=-32.0969
                Strain in bottom gage= 29.27816
         Moment M= 2.397463
         Thrust N=-5.285132

W=5# and P= 10   Strain in top gage=-31.77507
                Strain in bottom gage= 26.08225
         Moment M= 2.260051
         Thrust N=-10.67405
W=0 and P= 1
          Normalized Moment =-3.334239E-02
          Normalized Thrust =-1.805027
W=0 and P= 5
          Normalized Moment =-.0316681
          Normalized Thrust = .9813666
W=0 and P= 10
          Normalized Moment =-2.957523E-02
          Normalized Thrust =-4.820824E-02
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -33.03574 | 30.17143 |
| C 2 | .4653473 | -.9828415 |
| C 3 | -3.839398E-02 | 3.571415E-02 |

W=5# and P= 0 Strain in top gage=-33.03574
Strain in bottom gage= 30.17143
Moment M= 2.46903
Thrust N=-5.370569

W=5# and P= 1 Strain in top gage=-32.60878
Strain in bottom gage= 29.22431
Moment M= 2.415355
Thrust N=-6.345899

W=5# and P= 5 Strain in top gage=-31.66885
Strain in bottom gage= 26.15008
Moment M= 2.258552
Thrust N=-10.3477

W=5# and P= 10 Strain in top gage=-32.22166
Strain in bottom gage= 23.91443
Moment M= 2.192816
Thrust N=-15.57605

W=0 and P= 1
Normalized Moment =-5.367503E-02
Normalized Thrust =-.9753299

W=0 and P= 5
Normalized Moment =-4.209563E-02
Normalized Thrust =-.9954257

W=0 and P= 10
Normalized Moment =-2.762139E-02
Normalized Thrust =-1.020548

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -32.72502 | 30.91786 |
| C 2 | -.7134018 | -.8662452 |
| C 3 | .1620531 | -.1200886 |

W=5# and P= 0   Strain in top gage=-32.72502
Strain in bottom gage= 30.91786
Moment M= 2.48605
Thrust N=-3.388424

W=5# and P= 1   Strain in top gage=-33.27637
Strain in bottom gage= 29.93153
Moment M= 2.469059
Thrust N=-6.271581

W=5# and P= 5   Strain in top gage=-32.2407
Strain in bottom gage= 23.58442
Moment M= 2.180669
Thrust N=-16.23053

W=5# and P= 10   Strain in top gage=-23.65373
Strain in bottom gage= 10.24655
Moment M= 1.32423
Thrust N=-25.13846

W=0 and P= 1
Normalized Moment =-1.699157E-02
Normalized Thrust =-2.883157

W=0 and P= 5
Normalized Moment =-6.107624E-02
Normalized Thrust =-2.568421

W=0 and P= 10
Normalized Moment =-.1161821
Normalized Thrust =-2.175003

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -21.15356 | 13.66429 |
| C 2 | 1.905174 | -1.986786 |
| C 3 | -6.651783E-02 | -2.946437E-02 |

W=5# and P= 0   Strain in top gage=-21.15356
Strain in bottom gage= 13.66429
Moment M= 1.360872
Thrust N=-14.04239

W=5# and P= 1   Strain in top gage=-19.3149
Strain in bottom gage= 11.64804
Moment M= 1.20949
Thrust N=-14.37538

W=5# and P= 5   Strain in top gage=-13.29064
Strain in bottom gage= 2.993748
Moment M= .6361086
Thrust N=-19.30666

W=5# and P= 10   Strain in top gage=-8.753601
Strain in bottom gage=-9.150009
Moment M=-1.548469E-02
Thrust N=-33.56927

W=0 and P= 1
Normalized Moment =-.1505823
Normalized Thrust =-.3329873

W=0 and P= 5
Normalized Moment =-.1447927
Normalized Thrust =-1.052855

W=0 and P= 10
Normalized Moment =-.1375557
Normalized Thrust =-1.952688

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -9.053589 | 3.55716 |
| C 2 | -.9483795 | -2.696427 |
| C 3 | .7816973 | -.5125008 |

W=50 and P= 0   Strain in top gage=-9.053589
Strain in bottom gage= 3.55716
Moment M= .4926074
Thrust N=-10.30581

W=50 and P= 1   Strain in top gage=-9.220271
Strain in bottom gage= .3482323
Moment M= .3737697
Thrust N=-16.63507

W=50 and P= 5   Strain in top gage= 5.746946
Strain in bottom gage=-22.73749
Moment M=-1.112673
Thrust N=-31.85728

W=50 and P= 10   Strain in top gage= 59.63234
Strain in bottom gage=-74.65718
Moment M=-5.245685
Thrust N=-28.17158

W=0 and P= 1
Normalized Moment =-.1188377
Normalized Thrust =-6.329268

W=0 and P= 5
Normalized Moment =-.3218561
Normalized Thrust =-4.310294

W=0 and P= 10
Normalized Moment =-.5738292
Normalized Thrust =-1.786577

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -56.5893 | 34.9536 |
| C 2 | 8.479828 | -7.245178 |
| C 3 | .2647324 | -.3334847 |

W=5# and P= 0 Strain in top gage=-56.5893
Strain in bottom gage= 34.9536
Moment M= 3.575894
Thrust N=-40.56693

W=5# and P= 1 Strain in top gage=-47.84474
Strain in bottom gage= 27.37494
Moment M= 2.938268
Thrust N=-38.38088

W=5# and P= 5 Strain in top gage=-7.571846
Strain in bottom gage=-9.609409
Moment M=-7.959232E-02
Thrust N=-32.21486

W=5# and P= 10 Strain in top gage= 54.68222
Strain in bottom gage=-70.84665
Moment M=-4.903472
Thrust N=-30.30831

W=0 and P= 1
Normalized Moment =-.637626
Normalized Thrust =-2.186058

W=0 and P= 5
Normalized Moment =-.7310973
Normalized Thrust =-1.670416

W=0 and P= 10
Normalized Moment =-.8479365
Normalized Thrust =-1.025863

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -52.71073 | 42.42496 |
| C 2 | 6.541611 | -5.886597 |
| C 3 | -.7790203 | .6879473 |

W=5# and P= 0   Strain in top gage=-52.71073
Strain in bottom gage= 42.42496
Moment M= 3.716238
Thrust N=-19.28581

W=5# and P= 1   Strain in top gage=-46.94814
Strain in bottom gage= 37.22631
Moment M= 3.288064
Thrust N=-18.22843

W=5# and P= 5   Strain in top gage=-39.47818
Strain in bottom gage= 30.19066
Moment M= 2.721439
Thrust N=-17.41411

W=5# and P= 10   Strain in top gage=-65.19665
Strain in bottom gage= 52.35372
Moment M= 4.591811
Thrust N=-24.0805

W=0 and P= 1
Normalized Moment =-.4281734
Normalized Thrust =-1.057384

W=0 and P= 5
Normalized Moment =-.1989597
Normalized Thrust = .3743405

W=0 and P= 10
Normalized Moment = 8.755736E-02
Normalized Thrust =-.4794681

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -62.23572 | 57.125 |
| C 2 | -10.74469 | 11.24921 |
| C 3 | -1.138397 | 1.055809 |

W=5# and P= 0   Strain in top gage=-62.23572
Strain in bottom gage= 57.125
Moment M= 4.662528
Thrust N=-9.582596

W=5# and P= 1   Strain in top gage=-74.11881
Strain in bottom gage= 69.43001
Moment M= 5.607376
Thrust N=-8.79148

W=5# and P= 5   Strain in top gage=-144.4191
Strain in bottom gage= 139.7663
Moment M= 11.10099
Thrust N=-8.72406

W=5# and P= 10   Strain in top gage=-283.5224
Strain in bottom gage= 275.198
Moment M= 21.82501
Thrust N=-15.6082

W=0 and P= 1
Normalized Moment = .9448478
Normalized Thrust = .7911158

W=0 and P= 5
Normalized Moment = 1.287693
Normalized Thrust = .1717072

W=0 and P= 10
Normalized Moment = 1.716248
Normalized Thrust =-.6025601

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -78.62146 | 78.34998 |
| C 2 | -10.25537 | 10.54761 |
| C 3 | -.9973221 | .9812546 |

W=5# and P= 0   Strain in top gage=-78.62146
Strain in bottom gage= 78.34998
Moment M= 6.131697
Thrust N=-.5090332

W=5# and P= 1   Strain in top gage=-89.87416
Strain in bottom gage= 89.87884
Moment M= 7.021601
Thrust N= 8.783341E-03

W=5# and P= 5   Strain in top gage=-154.8314
Strain in bottom gage= 155.6194
Moment M= 12.12698
Thrust N=-1.477547

W=5# and P= 10   Strain in top gage=-280.9074
Strain in bottom gage= 281.9515
Moment M= 21.98668
Thrust N=-1.957741

W=0 and P= 1
Normalized Moment = .8899045
Normalized Thrust = .5178166

W=0 and P= 5
Normalized Moment = 1.199057
Normalized Thrust = .397316

W=0 and P= 10
Normalized Moment = 1.585498
Normalized Thrust = .2466774

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -64.08566 | 66.90716 |
| C 2 | -2.297882 | 2.367523 |
| C 3 | 1.250267E-02 | -8.031845E-03 |

W=5# and P= 0  Strain in top gage=-64.08566
Strain in bottom gage= 66.90716
Moment M= 5.116907
Thrust N=-5.290318

W=5# and P= 1  Strain in top gage=-66.37104
Strain in bottom gage= 69.26666
Moment M= 5.298348
Thrust N=-5.429278

W=5# and P= 5  Strain in top gage=-75.26251
Strain in bottom gage= 78.54398
Moment M= 6.008066
Thrust N=-6.152773

W=5# and P= 10  Strain in top gage=-85.81422
Strain in bottom gage= 89.77921
Moment M= 6.859119
Thrust N=-7.434368

W=0 and P= 1
Normalized Moment = .1814401
Normalized Thrust = .1389599

W=0 and P= 5
Normalized Moment = .1782317
Normalized Thrust = .1724911

W=0 and P= 10
Normalized Moment = .1742211
Normalized Thrust = .2144051

```
****************************
* Strain gage nos. 23 and 24
****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
----------------------------------------------------------
              Top gages     Bot. gages

C 1           -31.8286       28.39643
C 2            1.881447     -3.078037
C 3           -.132144       .1343756

W=5# and P= 0   Strain in top gage=-31.8286
                Strain in bottom gage= 28.39643
        Moment M= 2.35254
        Thrust N=-6.435313

W=5# and P= 1   Strain in top gage=-30.0793
                Strain in bottom gage= 25.45277
        Moment M= 2.169222
        Thrust N=-8.674736

W=5# and P= 5   Strain in top gage=-25.72497
                Strain in bottom gage= 16.36564
        Moment M= 1.644164
        Thrust N=-17.54874

W=5# and P= 10   Strain in top gage=-26.22853
                Strain in bottom gage= 11.05362
        Moment M= 1.456334
        Thrust N=-28.45296
W=0 and P= 1
         Normalized Moment =-.1833189
         Normalized Thrust =-2.239423
W=0 and P= 5
         Normalized Moment =-.1416752
         Normalized Thrust =-2.222686
W=0 and P= 10
         Normalized Moment =-8.962065E-02
         Normalized Thrust =-2.201765
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -26.64288 | 13.63929 |
| C 2 | .1007233 | -.6758919 |
| C 3 | -8.930206E-03 | .0397327 |

W=5# and P= 0 Strain in top gage=-26.64288
Strain in bottom gage= 13.63929
Moment M= 1.573522
Thrust N=-24.38174

W=5# and P= 1 Strain in top gage=-26.55109
Strain in bottom gage= 13.00313
Moment M= 1.545087
Thrust N=-25.40243

W=5# and P= 5 Strain in top gage=-26.36252
Strain in bottom gage= 11.25315
Moment M= 1.469362
Thrust N=-28.33008

W=5# and P= 10 Strain in top gage=-26.52867
Strain in bottom gage= 10.85364
Moment M= 1.460247
Thrust N=-29.39068

W=0 and P= 1
Normalized Moment =-2.843563E-02
Normalized Thrust =-1.020686

W=0 and P= 5
Normalized Moment =-2.083205E-02
Normalized Thrust =-.7896678

W=0 and P= 10
Normalized Moment =-1.132758E-02
Normalized Thrust =-.5008945

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -26.06072 | 14.025 |
| C 2 | -1.439461 | -.390893 |
| C 3 | .212946 | -.1691965 |

```
W=5# and P= 0   Strain in top gage=-26.06072
                Strain in bottom gage= 14.025
         Moment M= 1.565849
         Thrust N=-22.56698

W=5# and P= 1   Strain in top gage=-27.28724
                Strain in bottom gage= 13.46491
         Moment M= 1.591881
         Thrust N=-25.91686

W=5# and P= 5   Strain in top gage=-27.93438
                Strain in bottom gage= 7.840623
         Moment M= 1.397461
         Thrust N=-37.67579

W=5# and P= 10   Strain in top gage=-19.16074
                Strain in bottom gage=-6.803576
         Moment M= .4827016
         Thrust N=-48.68309
W=0 and P= 1
          Normalized Moment = 2.603226E-02
          Normalized Thrust =-3.349882
W=0 and P= 5
          Normalized Moment =-3.367751E-02
          Normalized Thrust =-3.021762
W=0 and P= 10
          Normalized Moment =-.1083147
          Normalized Thrust =-2.611611
```

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -16.17142 | -7.11071 |
| C 2 | 2.20071 | -.977684 |
| C 3 | -.1267858 | -7.366085E-02 |

W=5# and P= 0   Strain in top gage=-16.17142
Strain in bottom gage=-7.11071
Moment M= .353934
Thrust N=-43.654

W=5# and P= 1   Strain in top gage=-14.0975
Strain in bottom gage=-8.162055
Moment M= .2318532
Thrust N=-41.73666

W=5# and P= 5   Strain in top gage=-8.337513
Strain in bottom gage=-13.84065
Moment M=-.2149564
Thrust N=-41.58406

W=5# and P= 10   Strain in top gage=-6.842894
Strain in bottom gage=-24.25364
Moment M=-.6801071
Thrust N=-58.30599

W=0 and P= 1
Normalized Moment =-.1220889
Normalized Thrust =-1.917338

W=0 and P= 5
Normalized Moment =-.1137801
Normalized Thrust = .4139876

W=0 and P= 10
Normalized Moment =-.1034041
Normalized Thrust =-1.4652

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -4.489289 | -1.050049 |
| C 2 | -1.90802 | -5.361786 |
| C 3 | .8058033 | -.2633953 |

W=5# and P= 0 Strain in top gage=-4.489289
Strain in bottom gage=-1.050049
Moment M= .1343453
Thrust N=-10.38626

W=5# and P= 1 Strain in top gage=-5.591505
Strain in bottom gage=-6.67523
Moment M=-4.233301E-02
Thrust N=-23.00013

W=5# and P= 5 Strain in top gage= 6.115694
Strain in bottom gage=-34.44386
Moment M=-1.584358
Thrust N=-53.11532

W=5# and P= 10 Strain in top gage= 57.01084
Strain in bottom gage=-81.00744
Moment M=-5.39134
Thrust N=-44.99362

W=0 and P= 1
Normalized Moment =-.1766783
Normalized Thrust =-12.61387

W=0 and P= 5
Normalized Moment =-.3437406
Normalized Thrust =-8.545812

W=0 and P= 10
Normalized Moment =-.5525685
Normalized Thrust =-3.460736

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -56.15715 | 31.92142 |
| C 2 | 8.765014 | -6.951767 |
| C 3 | .2267857 | -.3562527 |

W=5# and P= 0 Strain in top gage=-56.15715
Strain in bottom gage= 31.92142
Moment M= 3.440569
Thrust N=-45.442

W=5# and P= 1 Strain in top gage=-47.16535
Strain in bottom gage= 24.6134
Moment M= 2.803857
Thrust N=-42.28491

W=5# and P= 5 Strain in top gage=-6.662438
Strain in bottom gage=-11.74374
Moment M=-.1984882
Thrust N=-34.51158

W=5# and P= 10 Strain in top gage= 54.17156
Strain in bottom gage=-73.22152
Moment M=-4.976292
Thrust N=-35.71867
W=0 and P= 1
Normalized Moment =-.6367117
Normalized Thrust =-3.157085
W=0 and P= 5
Normalized Moment =-.7278115
Normalized Thrust =-2.186085
W=0 and P= 10
Normalized Moment =-.8416861
Normalized Thrust = .9723329

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -50.51074 | 39.77857 |
| C 2 | 6.611603 | -7.431059 |
| C 3 | -.6540203 | .7098226 |

W=5# and P= 0   Strain in top gage=-50.51074
Strain in bottom gage= 39.77857
Moment M= 3.526926
Thrust N=-20.12283

W=5# and P= 1   Strain in top gage=-44.55316
Strain in bottom gage= 33.05732
Moment M= 3.031659
Thrust N=-21.5547

W=5# and P= 5   Strain in top gage=-33.80324
Strain in bottom gage= 20.36879
Moment M= 2.116035
Thrust N=-25.18959

W=5# and P= 10   Strain in top gage=-49.79675
Strain in bottom gage= 36.45015
Moment M= 3.369019
Thrust N=-25.02487

W=0 and P= 1
Normalized Moment =-.4952666
Normalized Thrust =-1.431871

W=0 and P= 5
Normalized Moment =-.2821663
Normalized Thrust =-1.013351

W=0 and P= 10
Normalized Moment =-1.579069E-02
Normalized Thrust =-.4902041

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -61.3501 | 57.48578 |
| C 2 | -8.778198 | 11.50641 |
| C 3 | -.9866181 | .7767945 |

W=5# and P= 0 Strain in top gage=-61.3501
Strain in bottom gage= 57.48578
Moment M= 4.642027
Thrust N=-7.245598

W=5# and P= 1 Strain in top gage=-71.11491
Strain in bottom gage= 69.76898
Moment M= 5.503278
Thrust N=-2.523623

W=5# and P= 5 Strain in top gage=-129.9065
Strain in bottom gage= 134.4377
Moment M= 10.32595
Thrust N=-8.495894

W=5# and P= 10 Strain in top gage=-247.7939
Strain in bottom gage= 250.2293
Moment M= 19.45403
Thrust N=-4.566422

W=0 and P= 1
Normalized Moment = .8612508
Normalized Thrust =-4.721976

W=0 and P= 5
Normalized Moment = 1.136784
Normalized Thrust =-3.148298

W=0 and P= 10
Normalized Moment = 1.481201
Normalized Thrust =-1.181202

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -74.71423 | 82.78931 |
| C 2 | -11.43427 | 11.60596 |
| C 3 | -1.02858 | 1.02813 |

W=5# and P= 0 Strain in top gage=-74.71423
Strain in bottom gage= 82.78931
Moment M= 6.152482
Thrust N=-15.14076

W=5# and P= 1 Strain in top gage=-87.17708
Strain in bottom gage= 95.42339
Moment M= 7.132831
Thrust N=-15.46184

W=5# and P= 5 Strain in top gage=-157.6001
Strain in bottom gage= 166.5223
Moment M= 12.66103
Thrust N=-16.72929

W=5# and P= 10 Strain in top gage=-291.9149
Strain in bottom gage= 301.6618
Moment M= 23.18659
Thrust N=-18.27559

W=0 and P= 1
Normalized Moment = .9803489
Normalized Thrust = .3210783

W=0 and P= 5
Normalized Moment = 1.30171
Normalized Thrust = .3177052

W=0 and P= 10
Normalized Moment = 1.703411
Normalized Thrust = .3134823

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | -60.54285 | 72.92502 |
| C 2 | -1.701447 | 2.671265 |
| C 3 | -5.000115E-02 | -3.120422E-03 |

W=5# and P= 0 Strain in top gage=-60.54285
Strain in bottom gage= 72.92502
Moment M= 5.213589
Thrust N=-23.21657

W=5# and P= 1 Strain in top gage=-62.2943
Strain in bottom gage= 75.59316
Moment M= 5.386229
Thrust N=-24.93538

W=5# and P= 5 Strain in top gage=-70.30011
Strain in bottom gage= 86.20333
Moment M= 6.113416
Thrust N=-29.81854

W=5# and P= 10 Strain in top gage=-82.55743
Strain in bottom gage= 99.32562
Moment M= 7.104807
Thrust N=-31.44037

W=0 and P= 1
Normalized Moment = .1726404
Normalized Thrust =-1.718803

W=0 and P= 5
Normalized Moment = .1799654
Normalized Thrust =-1.320394

W=0 and P= 10
Normalized Moment = .1891218
Normalized Thrust = .8223796

```
*****************************
* Strain gage nos. 25 and 26
*****************************


Loads at loading point # 1

Coefficients C1, C2 and C3 for equations of curve fitting
---------------------------------------------------------

              Top gages     Bot. gages

C 1           86.96079     -59.73218
C 2           3.302002E-02  1.773422
C 3          -6.115723E-02 -.0977726

W=5# and P= 0   Strain in top gage= 86.96079
                Strain in bottom gage=-59.73218
         Moment M=-5.730194
         Thrust N=-51.05364

W=5# and P= 1   Strain in top gage= 86.93265
                Strain in bottom gage=-58.05653
         Moment M=-5.663639
         Thrust N=-54.14273

W=5# and P= 5   Strain in top gage= 85.59696
                Strain in bottom gage=-53.30938
         Moment M=-5.426029
         Thrust N=-60.53921

W=5# and P= 10   Strain in top gage= 81.17526
                Strain in bottom gage=-51.77522
         Moment M=-5.193378
         Thrust N=-55.12509
W=0 and P= 1
          Normalized Moment = 6.655425E-02
          Normalized Thrust =-3.08909
W=0 and P= 5
          Normalized Moment = 6.083304E-02
          Normalized Thrust =-1.897113
W=0 and P= 10
          Normalized Moment = 5.368158E-02
          Normalized Thrust = .407145
```

Loads at loading point # 2

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 86.79645 | -55.00716 |
| C 2 | -1.619446 | 1.459641 |
| C 3 | -2.633667E-02 | 1.160431E-02 |

```
W=5# and P= 0   Strain in top gage= 86.79645
                Strain in bottom gage=-55.00716
         Moment M=-5.539203
         Thrust N=-59.60492

W=5# and P= 1   Strain in top gage= 85.15066
                Strain in bottom gage=-53.53591
         Moment M=-5.417445
         Thrust N=-59.27767

W=5# and P= 5   Strain in top gage= 78.0408
                Strain in bottom gage=-47.41885
         Moment M=-4.900768
         Thrust N=-57.41617

W=5# and P= 10   Strain in top gage= 67.96833
                Strain in bottom gage=-39.25032
         Moment M=-4.188228
         Thrust N=-53.84625
W=0 and P= 1
          Normalized Moment = .1217589
          Normalized Thrust =-.3272581
W=0 and P= 5
          Normalized Moment = .1276872
          Normalized Thrust =-.4377508
W=0 and P= 10
          Normalized Moment = .1350975
          Normalized Thrust =-.5758667
```

Loads at loading point # 3

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 83.07858 | -50.71787 |
| C 2 | -1.621765 | .9319687 |
| C 3 | -.3205338 | .3129454 |

W=5# and P= 0 Strain in top gage= 83.07858
Strain in bottom gage=-50.71787
Moment M=-5.226424
Thrust N=-60.67635

W=5# and P= 1 Strain in top gage= 81.13628
Strain in bottom gage=-49.47295
Moment M=-5.101924
Thrust N=-59.36875

W=5# and P= 5 Strain in top gage= 66.95641
Strain in bottom gage=-38.23439
Moment M=-4.109016
Thrust N=-53.8538

W=5# and P= 10 Strain in top gage= 34.80756
Strain in bottom gage=-10.10364
Moment M=-1.754344
Thrust N=-46.31984

W=0 and P= 1
Normalized Moment = .1245005
Normalized Thrust =-1.307595

W=0 and P= 5
Normalized Moment = .2234816
Normalized Thrust =-1.364509

W=0 and P= 10
Normalized Moment = .347208
Normalized Thrust =-1.435651

Loads at loading point # 4

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 58.95716 | -31.43929 |
| C 2 | -2.082855 | 2.485893 |
| C 3 | -.1857147 | 8.526754E-02 |

W=5# and P= 0 Strain in top gage= 58.95716
Strain in bottom gage=-31.43929
Moment M=-3.531111
Thrust N=-51.596

W=5# and P= 1 Strain in top gage= 56.68859
Strain in bottom gage=-28.86813
Moment M=-3.342059
Thrust N=-52.16336

W=5# and P= 5 Strain in top gage= 43.90001
Strain in bottom gage=-16.87813
Moment M=-2.374146
Thrust N=-50.66602

W=5# and P= 10 Strain in top gage= 19.55713
Strain in bottom gage= 1.9464
Moment M=-.6879191
Thrust N=-40.31912

W=0 and P= 1
Normalized Moment = .189052
Normalized Thrust = .5673588

W=0 and P= 5
Normalized Moment = .231393
Normalized Thrust =-.1859958

W=0 and P= 10
Normalized Moment = .2843192
Normalized Thrust =-1.127688

Loads at loading point # 5

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 45.27857 | -12.72501 |
| C 2 | -.0932147 | -3.246246 |
| C 3 | -.55625 | .9156256 |

W=5# and P= 0 Strain in top gage= 45.27857
Strain in bottom gage=-12.72501
Moment M=-2.265765
Thrust N=-61.03794

W=5# and P= 1 Strain in top gage= 43.82911
Strain in bottom gage=-15.05563
Moment M=-2.300185
Thrust N=-53.95028

W=5# and P= 5 Strain in top gage= 26.90625
Strain in bottom gage=-6.065599
Moment M=-1.207963
Thrust N=-39.07623

W=5# and P= 10 Strain in top gage=-19.27857
Strain in bottom gage= 46.37509
Moment M= 2.564596
Thrust N=-50.80598

W=0 and P= 1
Normalized Moment =-3.442023E-02
Normalized Thrust =-7.087657

W=0 and P= 5
Normalized Moment = .1955604
Normalized Thrust =-4.392343

W=0 and P= 10
Normalized Moment = .4830361
Normalized Thrust =-1.023196

Loads at loading point # 6

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 137.1787 | -89.36426 |
| C 2 | -1.278259 | 2.465378 |
| C 3 | -.1437416 | .1437473 |

W=5# and P= 0  Strain in top gage= 137.1787
Strain in bottom gage=-89.36426
Moment M=-8.849332
Thrust N=-89.65199

W=5# and P= 1  Strain in top gage= 135.7567
Strain in bottom gage=-86.75514
Moment M=-8.691866
Thrust N=-91.87784

W=5# and P= 5  Strain in top gage= 127.1938
Strain in bottom gage=-73.44369
Moment M=-7.837403
Thrust N=-100.7815

W=5# and P= 10  Strain in top gage= 110.0219
Strain in bottom gage=-50.33575
Moment M=-6.263971
Thrust N=-111.9115

W=0 and P= 1
Normalized Moment = .1574656
Normalized Thrust =-2.225862

W=0 and P= 5
Normalized Moment = .202386
Normalized Thrust =-2.225902

W=0 and P= 10
Normalized Moment = .2585362
Normalized Thrust =-2.225955

Loads at loading point # 7

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 145.2535 | -83.61774 |
| C 2 | 1.362671 | -.7667236 |
| C 3 | .7504501 | -.8513336 |

W=5# and P= 0 Strain in top gage= 145.2535
Strain in bottom gage=-83.61774
Moment M=-8.940282
Thrust N=-115.567

W=5# and P= 1 Strain in top gage= 147.3666
Strain in bottom gage=-85.23579
Moment M=-9.086031
Thrust N=-116.4953

W=5# and P= 5 Strain in top gage= 170.8281
Strain in bottom gage=-108.7347
Moment M=-10.92042
Thrust N=-116.4251

W=5# and P= 10 Strain in top gage= 233.9252
Strain in bottom gage=-176.4183
Moment M=-16.02905
Thrust N=-107.8254

W=0 and P= 1
Normalized Moment =-.1457495
Normalized Thrust = .9282589

W=0 and P= 5
Normalized Moment =-.3960279
Normalized Thrust = .1716213

W=0 and P= 10
Normalized Moment =-.7088763
Normalized Thrust =-.7741642

Loads at loading point # 8

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 155.2643 | -87.58203 |
| C 2 | 6.092407 | -4.654907 |
| C 3 | 1.490189 | -1.709374 |

W=5# and P= 0 Strain in top gage= 155.2643
Strain in bottom gage=-87.58203
Moment M=-9.486184
Thrust N=-126.9042

W=5# and P= 1 Strain in top gage= 162.8469
Strain in bottom gage=-93.94631
Moment M=-10.03098
Thrust N=-129.1886

W=5# and P= 5 Strain in top gage= 222.981
Strain in bottom gage=-153.5909
Moment M=-14.70984
Thrust N=-130.1065

W=5# and P= 10 Strain in top gage= 365.2072
Strain in bottom gage=-305.0685
Moment M=-26.18264
Thrust N=-112.7602

W=0 and P= 1
Normalized Moment =-.5447999
Normalized Thrust =-2.284341

W=0 and P= 5
Normalized Moment =-1.044732
Normalized Thrust = .6404515

W=0 and P= 10
Normalized Moment =-1.669646
Normalized Thrust =-1.414404

Loads at loading point # 9

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 178.0604 | -99.28589 |
| C 2 | 9.151611 | -10.4693 |
| C 3 | 1.02813 | -1.073227 |

W=5# and P= 0 Strain in top gage= 178.0604
Strain in bottom gage=-99.28589
Moment M=-10.83384
Thrust N=-147.7023

W=5# and P= 1 Strain in top gage= 188.2402
Strain in bottom gage=-110.8284
Moment M=-11.68237
Thrust N=-145.1471

W=5# and P= 5 Strain in top gage= 249.5217
Strain in bottom gage=-178.4631
Moment M=-16.71816
Thrust N=-133.235

W=5# and P= 10 Strain in top gage= 372.3895
Strain in bottom gage=-311.3016
Moment M=-26.70668
Thrust N=-114.5399

W=0 and P= 1
Normalized Moment =-.8485264
Normalized Thrust =-2.555208

W=0 and P= 5
Normalized Moment =-1.176863
Normalized Thrust =-2.89345

W=0 and P= 10
Normalized Moment =-1.587284
Normalized Thrust =-3.31624

Loads at loading point # 10

Coefficients C1, C2 and C3 for equations of curve fitting

| | Top gages | Bot. gages |
|---|---|---|
| C 1 | 160.5643 | -80.66071 |
| C 2 | .4747315 | -1.163086 |
| C 3 | -4.375077E-02 | 8.616257E-02 |

W=5# and P= 0  Strain in top gage= 160.5643
Strain in bottom gage=-80.66071
Moment M=-9.422851
Thrust N=-149.8192

W=5# and P= 1  Strain in top gage= 160.9953
Strain in bottom gage=-81.73763
Moment M=-9.481753
Thrust N=-148.6081

W=5# and P= 5  Strain in top gage= 161.8442
Strain in bottom gage=-84.32207
Moment M=-9.615869
Thrust N=-145.3539

W=5# and P= 10  Strain in top gage= 160.9365
Strain in bottom gage=-83.67531
Moment M=-9.555149
Thrust N=-144.8648

W=0 and P= 1
Normalized Moment =-.0589025
Normalized Thrust =-1.211128

W=0 and P= 5
Normalized Moment =-3.860355E-02
Normalized Thrust =-.8930511

W=0 and P= 10
Normalized Moment =-1.322985E-02
Normalized Thrust =-.4954434

# EXPERIMENTAL AND THEORETICAL INVESTIGATION OF A SHALLOW FLEXIBLE ARCH

By

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This thesis presents a study of the experimental and theoretical investigation of a fixed ended flexible parabolic arch. The study is an attempt to test the applicability of a linearized deflection theory. The governing differential equation, based on the consideration of deflection of the arch, is derived and linearized for the construction of influence lines. A computer program in BASIC language, using the Runge-Kutta numerical integration method to construct the influence lines, through the technique of shooting method, is presented. Influence lines for the unit vertical force acting on the arch, for a given set of flexibility parameters, are constructed. The actual forces at the section of interest are then determined numerically, with the knowledge that the assumed and computed flexibility parameters must be equal. A series of experiments were conducted to verify the theoretical prediction. A model of steel arch, of span 60 inches and rise 8 inches, was built in the laboratory for this purpose. A comparison of the calculated stresses with the values obtained experimentally has been made at the end section as well as the central span section.