Mansoura Engineering Journal

Volume 19 | Issue 2 Article 1

6-1-2021

Modelling Analysis of the Socket Connection.

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Mansoua University Journal (MEJ) Vol. 19, No. 2, June 1994.   C1

MODELLING ANALYSIS OF THE SOCKET CONNECTION

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تحليل نموزجي لوصلات الأعمدة المدفونة في الأعمدة ذات الجيب الخرساني

خلاصة :

كثيرا مايلجأ المهندس الانشائي الى استخدام الوصلات الأسهل في تنفيذها بالموقع والأقل تكلفة وبحيث تؤدى نفس الغرض الانشائي منها. ونظرا لقلة الأبحاث المنشورة لهذا النوع من الوصلات وكما أن هذا النوع من الوصلات يعتبر من أبسط وأسهل الأنواع تنفيذا في الموقع والأقل تكلفة. لذا تركزت هذه الدراسة على مايلي : ١- عمل طريقة جديدة لحساب عمق التثبيت لعمود الحديد بداخل العمود الخرساني. ٢- دراسة توزيع الاجهادات في الاتجاهات الثلاثة *(X,Y&Z)* على طول عمق التثبيت وكذلك في الاتجاه العرضي لفلنجة العمود الحديدى عند القطاعات المختلفة على نفس طول عمق التثبيت. ٣- الأخذ في الاعتبار تأثير البلاطات والكمرات الخرسانية في الاتجاهات الجانبية المختلفة على توزيع الاجهادات المختلفة وأيضا على حساب عمق التثبيت. ٤- توزيع الاجهادات على طول عمق التثبيت لحالات التحميل المختلفة. وقد أجريت هذه الدراسة باستخدام طريقة التحليل للعناصر المحددة باستخدام برنامج *SAP90*.

1. ABSTRACT

In this paper, a technique is developed for analyzing the socket connection. The aim is to determine the depth of fixation of a steel column which is embedded in a reinforced concrete column at any floor of the buildings. Also, the stress distribution in the longitudinal and transverse directions along the embedded length of the steel column is studied in the domain of X, Y and Z axes.

The effect of the reinforced concrete slab and beams on the stress distribution of the fixed depth of the steel column in two or three side directions are taken into consideration. Also, the different distributions of pressure along the embedded length of the steel column are investigated for the different cases of loading.

A static analysis of the socket connection is presented using the three dimensional brick element with 48 degrees of freedom in the domain of X, Y and Z axes (i.e. 6 degree of freedom at each node). The conclusion of this study is drawn out and some guide inducements are developed for design purposes.

2. INTRODUCTION

The design and detailing of connections is often as important as the design of members in structures. A good connection must be practical, economic, cheap and safe. It is not easy to satisfy these requi- rements simultaneously because the deformational response of joints under loading is very complex.

It is noticed from previous studies that the stress distribution along the embedded length of the steel column in a socket foundation is dependent on the case of loading at the face of the socket [1,2,3]. The elastic and plastic analyses for the socket foundation have been studied [2,3] without taking into account the side effects of reinforced concrete smells or beams and slab.

The research is extended to study the behaviour of the embedded length of the steel column inside the reinforced concrete socket. The objective of this study is to determine the stress distribution in the longitudinal and transverse directions along the embedded length of the steel column in socket connections along X, Y and Z axes. The effect of reinforced concrete slab and beams in two and three side directions on the stress distribution along the fixed depth of the steel column is taken into account. Also, a proposed technique is presented to analyze the socket connections under different cases of loading such as bending moment only, shearing force only and bending moment and shearing force acting together. The parameters used in this study are the depth of fixation, the effect of side restraints and the cases of loading.

3. FINITE ELEMENT MODELLING

An application using finite element program sap90 [5] to represent the socket connections with reinforced concrete slabs and beams in two and three side directions is shown in Fig.(1). The physical and real representation of the socket connection with the side reinforced concrete slab and beams is complicated as to obtain a closed form solution. Thus, the reinforced concrete slab and beams can be represented as beam element along X and Y axes in two and three side directions as shown in Fig.(2).

The problem is analyzed as a space stress problem with three dimensional analysis. In the finite element technique [5] two types of elements have been used to model this connection; (i) a beam element has been used to represent the R.C. slab and beams and (ii) a solid brick element has been used to represent the reinforced concrete and steel columns ,Fig.(1), which has been divided into 672 elements with 1522 nodes. Twenty one arrangement of the beam element to represent the reinforced concrete slab and beams in the socket connection in two and three directions are shown in Fig. (2).

4. DISCUSSION OF RESULTS.

*To study the structural behaviour of the embedded length of steel columns in socket connections and the effect of the reinforced concrete slab and beams (cases 1,2,3,4,5 & 6) on the stress distribution in X, Y and Z directions, the socket connection in Fig.(1) has been used. A fixed base R.C. column whose height and cross section dimensions equal 200cm and 45*45cm respectively is used. The clear height of the steel column is 200cm above the R.C. column. The column profile is assumed to be a B.F.I.B.No.200 and the depth of fixation is assumed to be 60.0cm. Twenty one different models for representating the R.C. slab and beams (cases A & B) have been considered.*

It has been assumed that 5.0ton lateral load is distributed uniformly on 14 nodes at the end cross section of the steel column through its web without the extremes of the flanges. Thus, the connection is subjected to combined shearing force and bending moment at the face of the socket.

The stresses distribution in the X, Y and Z directions along the depth of fixation of the steel column are shown in Fig.(3). Moreover, the effect of R.C. slab and beams (cases A & B) on the stress distribution along the fixed depth are taken into account and are shown in Fig.(3).

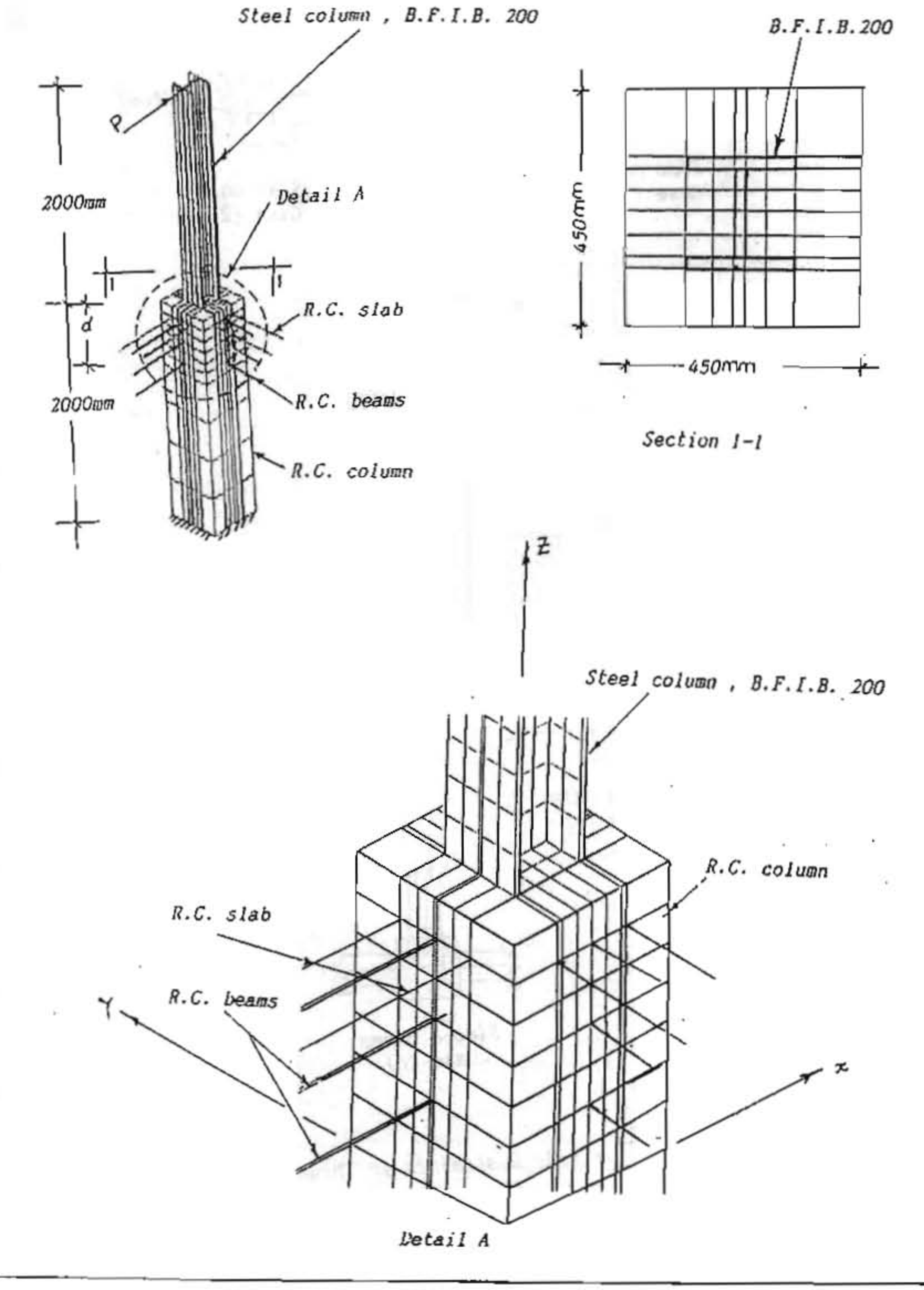


Fig.(1) : Finite element mesh for the socket connection.

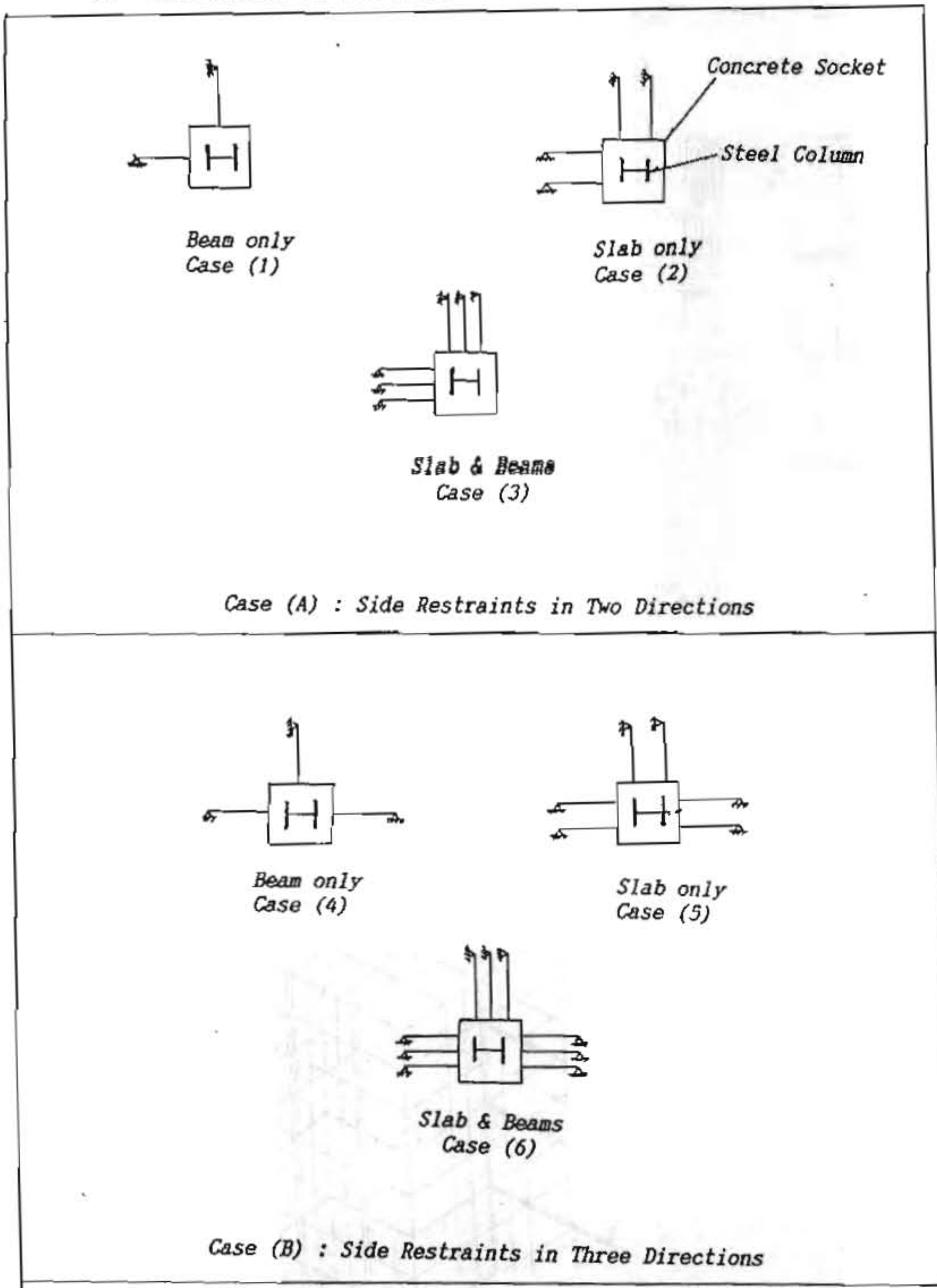


Fig.(2) : Representation of the R.C. slab and beamsas beam elements in socket connection with side restraints.

From Fig.(3), it is clear that the stress distribution in the Z-direction for all cases (with and without the the effect of R.C. slab and beams) increases from top at the face of the socket to bottom along the fixed depth. The maximum value of this stress occurs at the end of the fixed depth where the stress becomes 6.0 times its value at the face of the socket. The rate of reduction in the stress distribution in the Z-direction due to the effect of R.C. slab and beams (cases A & B) increases gradually from the end of the fixed depth to the top at the face of the socket and ranges from 9% to 43.5%. Also, the effect of R.C. slab and beams (cases 1,2,3,4,5 & 6) on the stress distribution in the Z-direction is constant along the depth of fixation.

It is noticed from Fig.(3) that the maximum value of the stress distribution in the Y-direction along the fixed depth lies at the bottom third. The stress distribution in the Y-direction along the fixed depth is highly affected by the R.C. slab and beams (case 3). The percentage decrease in this stress ranges between 40% and 96% along the upper half of the fixed depth whereas this rate ranges between 16.6% and 36% along the lower half. This stress is also affected by the R.C. slab only (case 2), the rate of reduction ranges from 23% to 50% along the upper half of the fixed depth and is negligable along its lower half. Also, this effect in case 6 is higher than that in case 4 along the upper half of the fixed depth. The rate of reduction in cases 4 & 6 is about 25% along the lower half of the fixed depth whereas this rate jumps to 50% (case 6) along the upper half of the fixed depth.

The effect of R.C. slab and beams (cases A & B) is discussed on the stress distribution in the X-direction along the fixed depth. This effect (cases 2,3,5 & 6) becomes insignificant on the stress distribution in the X-direction.

The stress distribution in X & Y-directions is highly affected by the R. C. beams only (cases 1 & 4). The rate of increase in the stress is about 2 to 3 times it's value for the case of free connection.

The stress distribution in the transverse direction on the steel column flange at different sections (d/6, d/2 and 5d/6 from the face of the socket) in the directions of X, Y and Z axes are shown in Figs.4, 5 and 6 respectively. It is clear from these Figs. that the distribution of stresses is nonlinear and this distribution is symmetrical about the center line of the steel column web.

From Fig.(4), it is clear that there is a reduction in the stress distribution in X, Y and Z directions. The rate of reduction in the stress distribution in the Z-direction due to the effect of R.C. slab and beams (cases A & B) ranges between 38% and 42%.

The reduction rate in the stress distribution in the Y-directions ranges from 24% to 65% and from 34% to 64% for cases 2,5 and 3,6 respectively. The reduction for case 4 increases gradually from 12% at the center line of the column flange to 66% at its extremes.

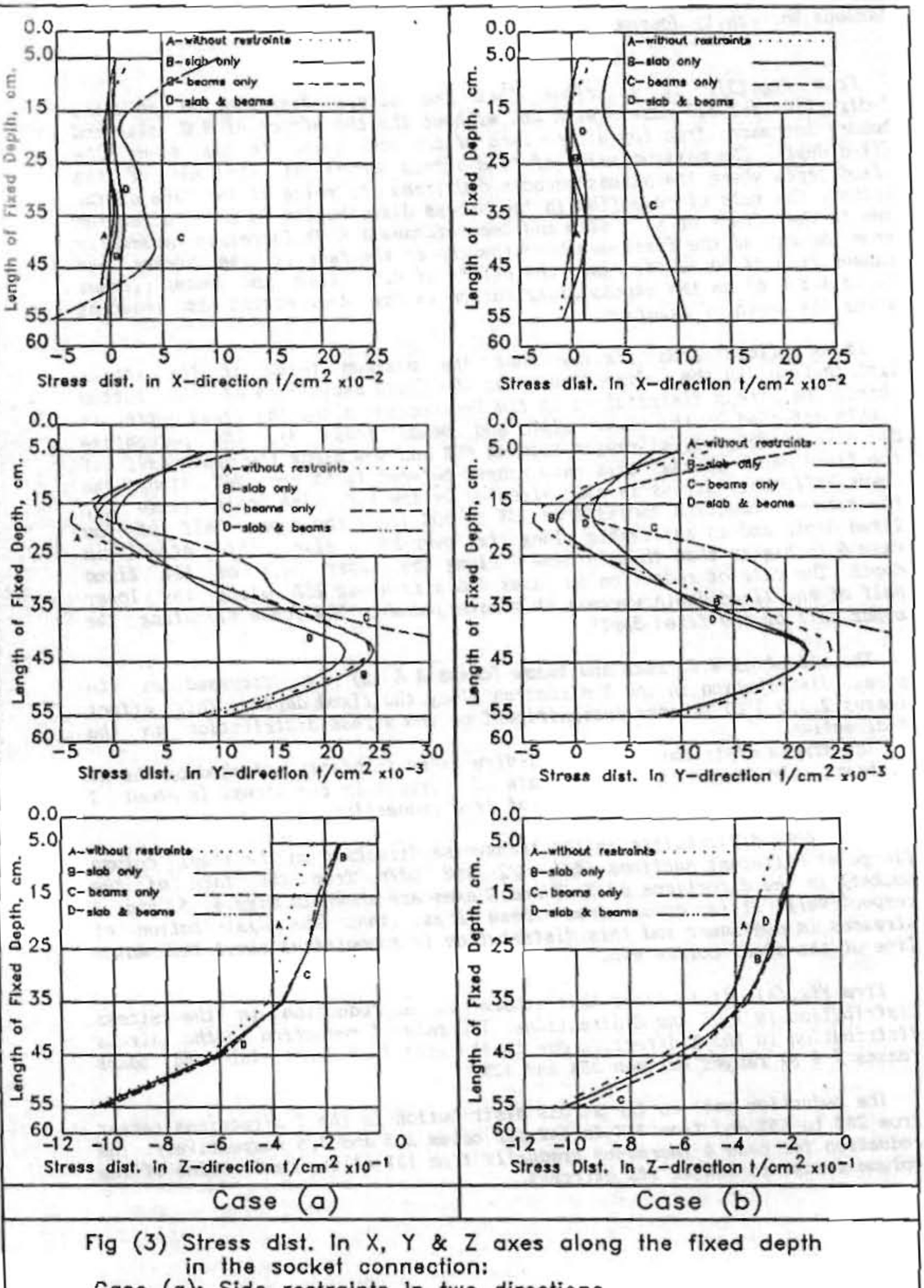


Fig (3) Stress dist. in X, Y & Z axes along the fixed depth in the socket connection:
Case (a): Side restraints in two directions
Cbse (b): Side restraints in three directions

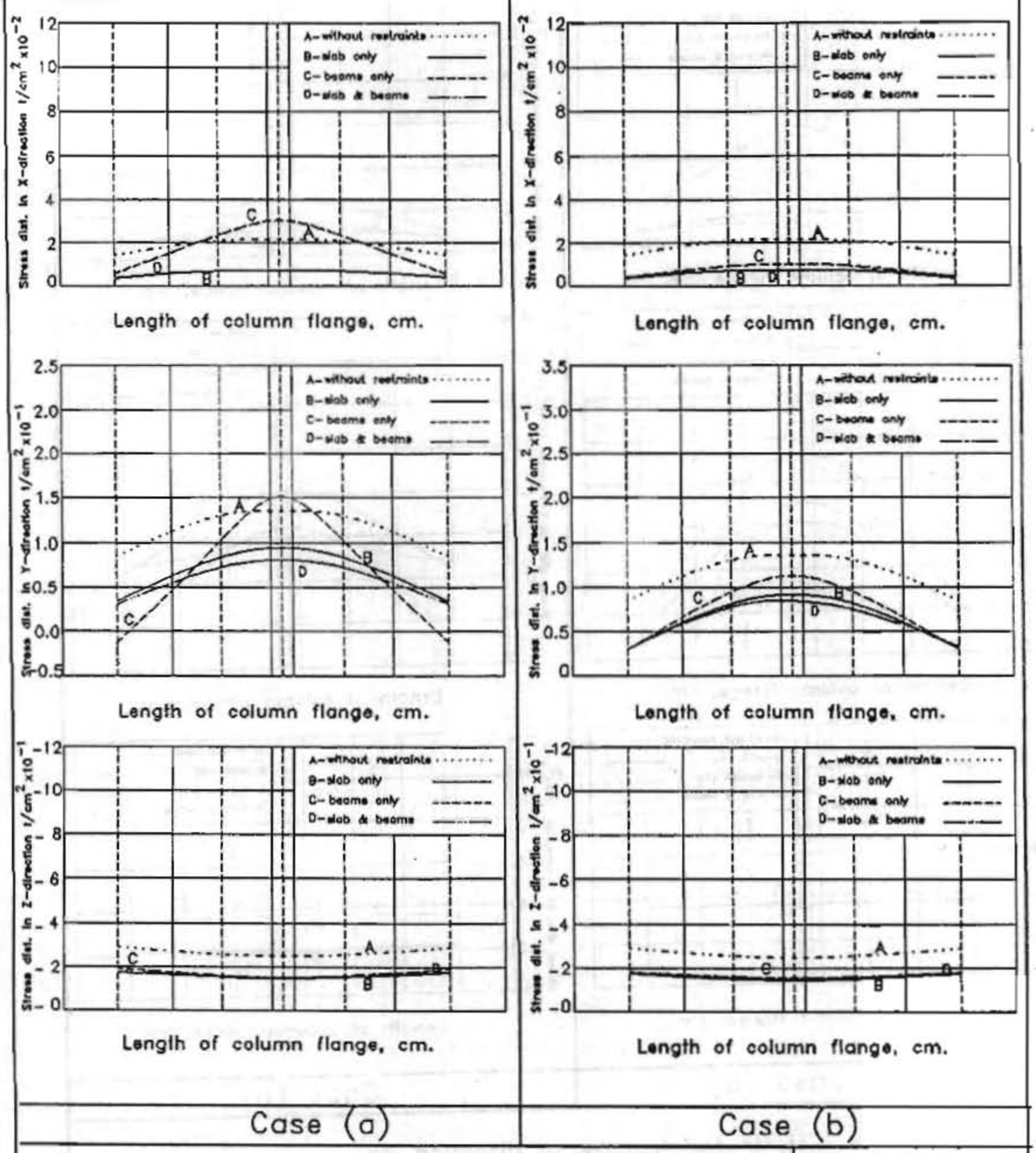
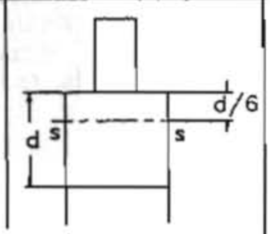
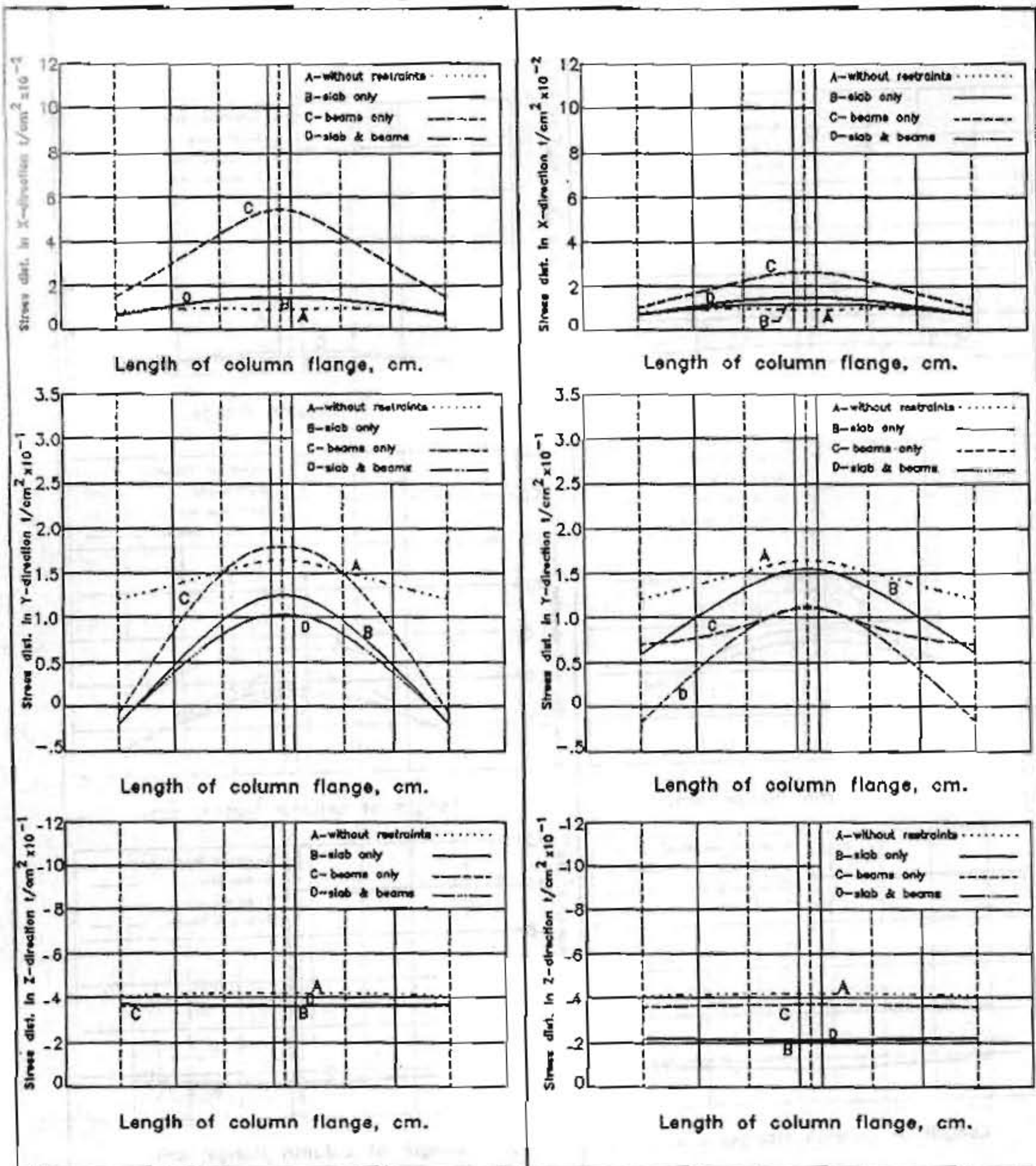


Fig (4) Stress dist. in the transverse direction on the steel column flange at section S-S in the in the X, Y & Z directions
Case (a): Side restraints in two directions
Cbse (b): Side restraints in three directions



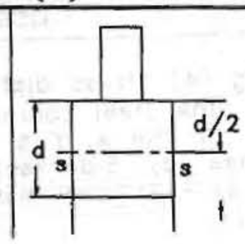


Case (a) Case (b)

Fig (5) Stress dist. in the transverse direction on the steel column flange at section S–S in the X, Y & Z directions

Case (a): Side restraints in two directions

Cbse (b): Side restraints in three directions



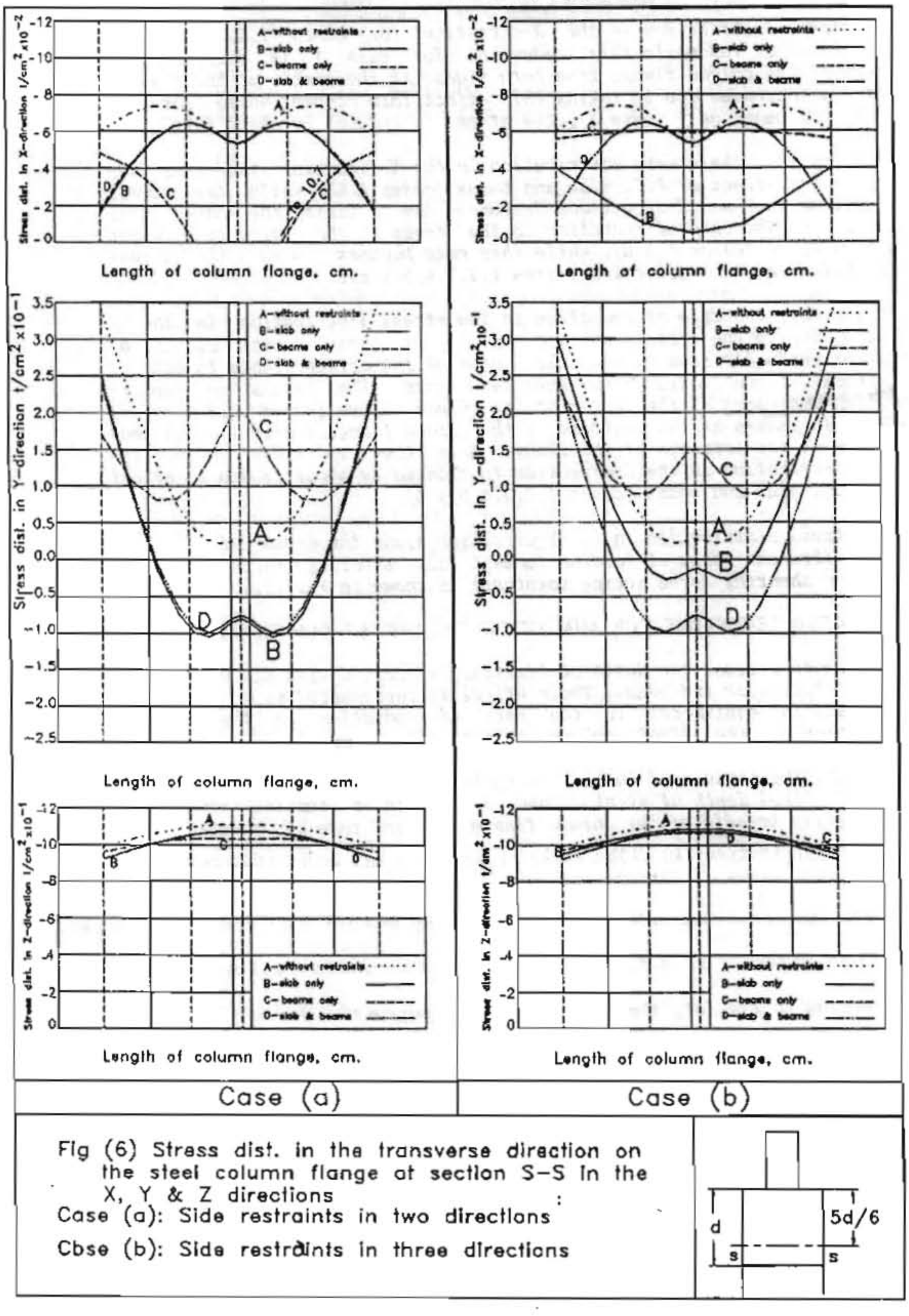


Fig (6) Stress dist. in the transverse direction on the steel column flange at section S-S in the X, Y & Z directions :
Case (a): Side restraints in two directions
Cbse (b): Side restraints in three directions

The stress distribution in the X-direction for cases 2,3,5 & 6 is reduced by about 70% while this reduction for case 1 is only at the extremes of the column flange from both sides. At the center of the flange, the stress increases due to taking this effect into account while for the case of R.C. beams only (case 4), the stress is reduced by about 50%.

From Fig.(5), the stress distribution in the X-direction increases due to taking the effect of R.C. slab and beams (cases A &B) while the stress distribution in Y and Z-directions decreases due to taking the above effect into account. The rate of reduction in the stress in the Z-direction ranges from 3.9% to 9% (cases A & B), while this rate becomes 20% in the stress distribution in the Y-direction (cases 1,2,3,4,5 & 6).

In Fig.(6), the rate of reduction in the stress distribution in the X direction due to the effect of R.C. slab and beams (cases 2,3 & 6) increases gradually from zero at the center of the column flange to 66% at the extreme of the flange from the two sides. The stress in the Y-direction increases at the center of the column flange (cases 2,3,5 & 6) while it increases at the centroid of the column flange (cases 1 & 4) and decreases at the extremes of the flange from the two sides. Also, the stress distribution in the Z-direction is reduced by about 7% due to effect of the R.C. slab and beams (cases 1,2,3,4,5 & 6).

The stress distribution in the Y-direction along the depth of fixation for the different cases of loading (moment only, shearing force only and moment and shearing force acting together) is shown in Fig.(7).

5. PROPOSED TECHNIQUE FOR ANALYZING THE SOCKET CONNECTION.

In this technique, the depth of fixation is derived with and without the effect of R.C. slab and beams. Their effect is represented as a side beam element and is equivalent to the rate of reduction in the pressure distribution on the steel column flange along the fixed depth. The connection is subjected to bending moment and shearing force at the face of the socket. The items used in this analysis are the force due to a beam action ,R, fixed depth of steel column ,d, stregth of contact concrete , σ_c, effective breadth of the column flange ,b_f, and rate of reduction in pressure distribution (k) . The socket connection has been analyzed under the following cases of loading :

Case 1 : Connections subjected to bending moment and shearing force .

A) : Side effects of R.C. beams taken into consideration:

Referring to Fig.(8), the upper and lower compressive forces (C_U& C_L) may be expressed as;

$C_U = C_{U1} + R$ Then; $C_{U1} = C_U - R$

Where :

C_U = upper comp. force without side effect $= 0.8X\ b_f\ \sigma_c$ (1a)

C_{U1} = upper comp. force with side effect $= 0.8X\ b_f\ \sigma_c (1-k)$ (1b)

R = effect of side restraints $= 0.8X\ b_f\ \sigma_c (k)$ (1c)

and;

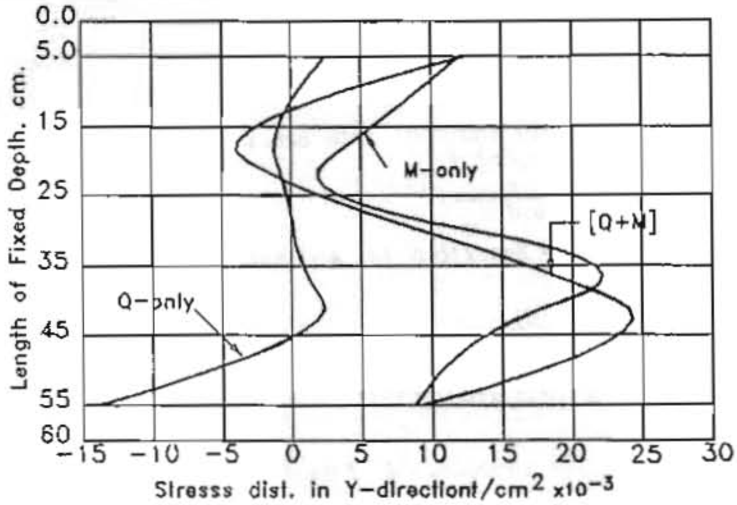


Fig.(7) : Stress dist. in Y-direction along the fixed depth when the connection is subjected to (i) Q-only, (ii) M-only and (iii) Q + M .

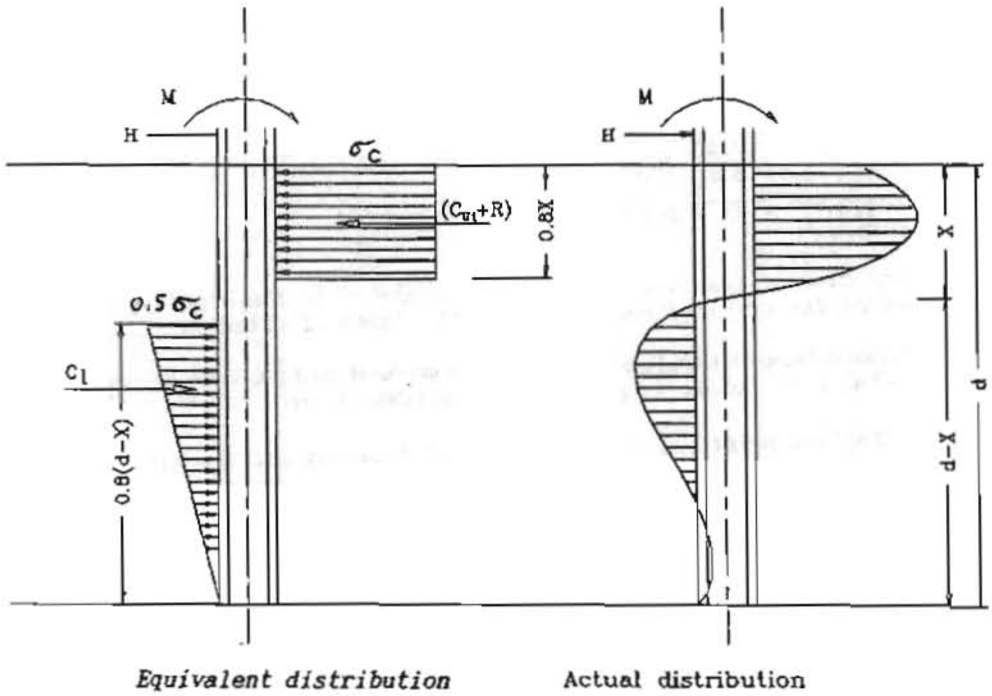


Fig.(8):Pressure distribution of the concrete socket on the column flange along the depth of fixation.

$$C_L = 0.2(d-X)b_f\sigma_c \tag{1d}$$

$\Sigma H = 0.0$

$$C_{U1} = C_L + H \tag{2}$$

Substituting of Eqns. (1b) and (1d) into Eqn.(2) to obtain the value for the distance of inflection point X

$$X = \frac{d}{(1-0.8k)}\left[0.2 + \frac{H}{b\,d\,\sigma_c}\right] \tag{3}$$

By substituting Eq.(3) into Eqs.(1b & 1d) and putting $k'=(1-k)/(1-0.8k)$ *then;*

$$C_{U1} = 0.8k'(0.2b_f d\,\sigma_c + H) \tag{4}$$

and;

$$C_L = [0.16b_f d\,\sigma_c\,k' - [0.2/(1-0.8k)]] \tag{5}$$

Taking moment about C_L*, the embedded "d" length is given by :*

$$d = \left[\frac{3M - 0.4X(C_{U1} - 4H)}{1.4\,(C_{U1} - H)}\right] \tag{6}$$

B) : Side effects of R.C. beams or slabs neglected :

The inflection point and the depth of fixation are given by the following equations :

$$X = d\left[0.2 + \frac{H}{b_f\,d\,\sigma_c}\right] \tag{7}$$

and;

$$d = \left[\frac{3M - \frac{0.4H}{b\,\sigma_c}(C_U + 4H)}{1.4(C_U - H) - 0.8\,(C_U + 4H)}\right] \tag{8}$$

For each case of loading, the stresses produced in the steel column must be checked at the critical section along the depth of fixation [1,5].

Case 2 : Connections subject to bending moment only (Side effects of R.C. slabs or beams taken into consideration).

The inflection point ,X, and the depth of fixation ,d, are given by the following equations :

$$X = \left[\frac{0.2d}{(\ -0.8k)}\right] \tag{9}$$

and;

$$d = \left[\frac{3M}{1.32C_{U1}\left(\frac{1-0.85k}{1-0.80k}\right)}\right] \tag{10}$$

Case 3 : Connections subject to shearing force only (Side effects of R.C. slabs or beams taken into account).

The inflection point ,X, and the depth of fixation ,d, are given by the following equations :

$$X = \frac{d}{(1-0.8k)} [0.2 + \frac{H}{b\ d\ \sigma_c}] \qquad (11)$$

and;

$$d = \frac{0.4X}{1.4} [\frac{(C_{u1} - 4H)}{(H - C_{u1})}] \qquad (12)$$

6. CONCLUSIONS.

The behaviour of the socket connection with the effect of R.C. slab and beams as side restraints in two and three directions has been studied. From the present study the results lead to the following conclusions:

1- The normal stress in the embedded length of steel column (Z-direction) increases from top to bottom and its maximum value occurs at the end of the fixed depth.
2- The normal stress (Z-direction) along the fixed depth is reduced due to the effect of the side restraints in two and three directions.
3- The maximum values for the shear stress (Y-direction) along the fixed depth lie along it's bottom third. This stress is highly affected by the side restraints in two or three directions along the fixed depth.
4- The shear stress (X-direction) is not affected by the side restraints in two and three directions along the fixed depth.
5- The stress distribution in the Z-direction for the steel column flange at various cross sections along the fixed depth is reduced due to the side effects in two or three directions.
6- The stresses distribution in the X and Y directions for the column flange is highly affected by the side restraints (cases 2,3,5 & 6).
7- A proposed technique is presented for analyzing the socket connection taking the effect of the R.C. slab and beams into consideration for different cases of loading.

7. REFERENCES.

1- Kahlmeyer, H. "Steel Structures" Werner Verlag, West Germany 1989.
2- M. Swelem, S. Abd-Rabou and M. Elnggar "Plastic Modelling of steel socket foundation" First Conf. Alex. Dec 1990 Str. Eng. pp.751-767.
3- S. Abd-Rabou "Socket foundation of steel column" Ph.D. 1990 Mansoura university Str. Eng. Depart.
4- Wilson, E. L. and Habibullah, A. "Sap90 Structural Analysis Programs" Computer & Structures Inc., Warkly, California 1990.
5- Christain Petersen "Steel Structures" Muenchen, Ernest and Sohn Verlag W. Germany 1988.