STUDY OF BENDING BEHAVIOR OF REINFORCED CONCRETE SECTIONS UNDER CYCLIC LOADS

Dr. Bayar Jaafer Al sulayfani **Muna Mubarak Abdullah**

Professor **Ass. Lecturer**

Civil Engineering Dept.-Mosul University

ABSTRACT

This paper is concerned with the bending behavior of reinforced concrete sections subjected to cyclic loads, such as wind loads or earthquake loads. Previous studies have indicated that the cyclic loading of such kind can cause failure in the joints of a structure which subseguently put the structure into the state of insability or collapse.the papear also pays attention to the behavior of reinforced concrete beams and frames.

Modeling of the cyclic relationship between moment and curvature is presented for the reinforced concrete sections under effect of axial load and moment on the assumption of full bond between steel and concrete. The shear deformation however is sidestepped.

The stiffness method with the effective secant stiffness is used in the analysis of the structures for calculating displacement in each section and then getting the load-displacement curves, moreover, the recurrence method is used in the analysis of simple members in structures like reinforced concrete beams subjected to cyclic loads.

The current study presents a numerical model which is capable of predicting the behavior of a reinforced concrete beam, frame and joint subjected to cyclic loading. The effect of axial force on the structure is also considered.

The study concludes that the effect of axial force in the structural members is to decrease the energy absorption by these members and increases their failure loads. It also shows that the model used in the analysis of reinforced concrete sections has a good accuracy, it has ability to decrease the time of computer running compared with other methods, this makes it possible to depend on the analysis .The stiffness and recurrence method show good activity in the analysis from the obtained results.

KEYWORDS

Reinforced Concrete, Cyclic Loads, Beam-Column Connection, Bending Behavior, Nonlinear Analysis.

NOTATIONS

M represents moment

ϕ Stand for curvature

EI_{oo} and EI_{1o} are the slopes of the two lines (A-A′) and(C-L)

G a constant value

ξ represents the difference in curvature value

$a1, a2$ constant

M_Y is the yield moment

INTRODUCTION

The beam to column connection, as pointed out by Ahmed, J.D. and James, K.W. (1987) [1], is the portion of column with in the depth of farming beams depending on its location in the building, it may simply be a connection of two beams and a column, as in the corner joints of the uppermost story of a building frame .or it may be a complex as an interior joint with members framing in all four monolithically with floor beams.

In the past, structural failure under cyclic load has been seldom directly attributed to the failure of connections. Nevertheless, the behavior of connection under cyclic loads like earthquake concerns both the designers of multistory building and the researchers who are engaged in developing satisfactory design procedures .

REVIEW OF LITERATURE

The behavior of RC joint under cyclic loads like earthquake was first introduced by Hanson and Connor 1967 [2]; they also introduced the relationship between moment-curvature and load-deflection. They concluded that the cumulative ductility of a test specimens provide a measure of the ability of a structure to stand with seismic deformation.

A study by Robert Park, Kent, Sampson 1972 [3], concluded that the moment-curvature responded by using stress -strain curve of steel and concrete

Namia and Darwin 1986 [4]; also found that, for several cyclic loading, a decrease in the flexural reinforcement ratio reduces both the maximum shear and compressive stress in concrete and thus reduces the ratio of degradation.

Another study by Pilakoutas and Elnashai 1995 [5], present the Load-deflection curve and compared it with the theoretical results they found a good diversion between them.

In 2001 [6], a study by Hyo-Gyoung Kwak and Sun-Pil Kim concluded that the moment-curvature relationship of a reinforced concrete section can simulate the cyclic behavior of reinforced concrete beams

Finally, Mustafa and Eren 2002 [7] draw the load-deflection curves and found that using of SFRC (steel fiber reinforced concrete) tends to increase the strength of bending moment and shear force, and increasing the ductility.

MOMENT-CURVATURE RELATIONSHIP

Since the structure is composed of many structural members and a member is formed by the integration of each section, the nonlinear behavior of section causes nonlinear behavior in the structure .In the case of beams inelastic deformation occurs in the beam-column joint and/or at some sections near mid span .These regions have been defined as "critical" [8]. The stiffness at a critical region is defined as the slop of the moment-curvature relationship .So, the nonlinear analysis of reinforced concrete members can be conducted using moment-curvature relationship constructors by section analysis.

Under the cyclic loading, the shape of the moment-curvature relationship of reinforced concrete section is very much governed by the shape of stress -strain loop for the steel because the applied moment is carried very largely by the steel reinforcement placed in a section after the first yield excursion and a ccompanships the rounding and pinching in the moment-curvature loops [6] .This implies that there are generally assumed parallelogram of classical elastoplastic behavior.

BASIC ASSUMPTIONS:

This paper is based on three assumptions:

1- Neglecting the deformation caused by shear.
2- Assuming perfect bond between steel and concrete.
3- Neglecting concrete strength in tension.

DEFINITION OF HYSTRESTIC CURVE:

Region 1 (Linear Region): Initial elastic branch with stiffness $EI_{\circ\circ}$ path (O-A) and (O-A$'$) Fig (1).

The region characterizes elastic loading and unloading as the positive yielded moment $+M_Y$ and the negative yielding moment $-M_Y$ is not exceeded the relationship between moment-curvature is semi- linear.

Region 2 (Curved Region): path (A-B) Fig (1).

The case of section when the concrete begin to creak and loss large amount of its strength.

Region3 (Semi Linear Region): path (B-C) Fig (1).

This region can be defined as a semi-Linear Region where the section loses a large amount of concrete strength, and the sectional behavior will be under steel control.

The three regions can be expressed by this relation:

$$M^{*} = \lambda.\phi^{*} + (1-\lambda) * \phi^{*} / (1+\phi^{*G})^{1/G} \qquad \text{.......... (1)}$$

M represents moment

ϕ Stand for curvature

λ Can be defined from this relation:

$$\lambda = \frac{EI_{1o}}{EI_{oo}} \qquad \text{.......... (2)}$$

$$\phi^{*} = (\phi\ )/(\phi_{o}) \qquad \text{.......... (3)}$$

$$M^{*} = (M\ )/M_{o}) \qquad \text{.......... (4)}$$

EI_{oo} and EI_{1o} are the slopes of the two lines (A-A′) and(C-L) Fig(1), they will be explained later.

G a constant value will be explained later.

Region 4 (Unloading Region): path (C-F**)** Fig (1).

The curve of this region is curved along the straight line (c-t) with slope EI◦◦ .The moment-curvature response of a section initiates a shape very similar to that of the stress -strain of steel [9] , and this trend continue during closing of crack because the behavior in this region is dominantly affected by the amount of longitudinal tension and compression reinforcement. This phenomenon makes it possible to define the moment-curvature relationship based on the hysteretic curve of steel Menegotto and Pinto, (1973).

Region 5 (Reloading Region): from point (F-v**)** Fig (1).

The curve of this region is curved along the straight line (f-z) with slop EI◦◦ . The moment-curvature response of a section initiates a shape very similar to that of the stress -strain of steel .The behavior in this region is dominantly affected by the amount of longitudinal tension and compression reinforcement.

The two regions (4 and 5) can be expressed by this equations:

$$M^* = \lambda.\phi^* + (1-\lambda) * \phi^* / (1+\phi^{*G})^{1/G} \qquad (5)$$

$$\phi^* = (\phi - \phi_r)/(\phi_\circ - \phi_r) \qquad (6)$$

$$M^* = (M - M_\circ)/(M_\circ - M_r) \qquad (7)$$

The stiffness $EI_{\circ\circ}$ represents the slope of line (O-S), and the stiffness $EI_{1\circ}$ represents the slope of the line (D-a) .The two points S_2, S and the stiffness $EI_{\circ\circ}$, $EI_{1\circ}$ can be calculated from the analysis of the reinforced concrete section , assuming that the concrete strain changed from (0-0.003) and then the location of neutral axis can be calculated in every time the strain changed by the equilibriums of the interior force see Fig. (2)

$$N_{C1} + N_{C2} = N_T \qquad (8)$$

In this way the value of moment and curvature can be found for every location of neutral axis .The value of the negative moment and curvature can be found by the same way by changing the section from compression to tension.

After that we can draw the relation between moment and curvature as in Fig. (3) Below.

From the curve in Fig.(3), we can get the slope of the two straight lines(H_1-H_2) ,(H-L) and point of intersection (H),and straight lines (L_1-L_2)), (H-L) and point of intersection (L) as well. In this way, the value of $EI_{\circ\circ}$,$EI_{1\circ}$ and the two point S,S_2 will be known for the proposed model.

The two points (C and F) represent the last curvature reversal with a moment of equal sign as in Fig (1).the change in stiffness caused by the cracked section cannot sustain the moment of an uncracked section due to the presence of open cracks in the compression region. The two points (ϕ_r, M_r) and ($\phi_\circ$,$M_\circ$) are updated after each curvature reversal.

Moreover, a critical issue in the curved hysteretic loop is the determination of parameter G in eq.(1) since it influences the shape of transition curve even though the influences of the G value may not be great in the structural behavior. The G value in eq.(1) cannot be easily determined because the shape of the transition curve depends on many variables such as the amount of compression and tensile of steel and its relative ratio, amount of effective strain hardening, moment to shear ratio, and shape of the cross section.

To calculate the value of G we can depend on this relation.

$$G(\xi) = G_o - a1.\xi / a2 + \xi \quad \text{.....} \quad (9)$$

The value of ξ represents the difference in curvature value at any step ϕ_i و ϕ_i', the value of ξ($\phi_\circ$,$M_\circ$) will be updated after each curvature reversal. See Fig. (4)

The value of each constant $a1, a2$ can be calculated from these relations:

$$a1 = \frac{E_s}{E_c} \quad \text{.....} \quad (10)$$

$$a2 = \frac{(As + As') * f_y}{W * H * fc'} \quad \text{......} (11)$$

The relations (9 and 10) give a good diversion between the experimental and theoretical values. Also the constant G◦ can be calculated to give a good diversion between the experimental and theoretical values from this relation:

$$G_\circ = -2E - 05 * M_Y^{\ 2} + 0.0315 * M_Y - 0.3851 \quad \text{......} (12)$$

Where M_Y is the yield moment in the reinforced concrete section, see Fig. (5).

The equation (12) calculated by analysis group of reinforced concrete section differed in dimensions and reinforcement.

During unloading and reloading from an inelastic region a signification reduction in stiffness occurs as the number of a ternating loading cycle's increases.

Accordingly, neglecting loss of stiffness may lead to an over estimating of the energy absorption capacity of the structure and also to a reduction of the constitutive of moment -curvature relationship propose

NUMERICAL APPLICATIONS

To establish the applicability of the proposed hysteretic moment-curvature relationship, a reinforced concrete beam and frame are investigated and discussed

BEAM ANALYSIS

Beam P1

The geometric and cross -section dimension of the specimen Beam P1are presented in Fig. (6) [10], and table (1) shows the details of the longitudinal sections for beam p1, and Fig. (7) Shows the chart of applied load on the beam p1

Fig (8) compares the moment-curvature relationship obtained by the proposed model with the experimental results of beam P1. Very satisfactory agreement between analysis and experimental is observed. Fig. (9) shows the load-deflection Relationship of beam P1.

Also the curves of moment-curvature and load-deflection under partial reversal and repeated cyclic loads were drawn as shown in these figers.

FRAME ANALYSIS:

We have two cases of frame analysis as shown in Fig. (14) and table (2) shows the details of the longitudinal sections for frame under analysis [11].

First case:

The geometric and cross -section dimensions of the frame are presented in Fig (15). Fig. (16) show the chart of applied load on the frame (first case).

Fig (17) show the moment-curvature relationship obtained by the proposed model and Fig (18) show the load-deflection Relationship of the frame (first case).

Second case:

The geometric and cross -section dimensions of the frame are presented in Fig. (19)

Fig. (20) Show the chart of applied load on the frame (second case).

Fig. (21) Shows the moment-curvature relationship obtained by the proposed model, and Fig. (22) Shows the load-deflection Relationship of the frame (second case).

CONCLUSIONS

From the analytical obtained from this study, it can be conclude that:

1. The proposed model for the nonlinear analysis of the reinforced concrete section shows a good efficiency for the analysis through the good representation of the moment-curvature relationship for reinforced concrete section under cyclic load.

2. The proposed model can be effectively used to predict structural response under cyclic loading, and its application can be extended to the dynamic analysis of frame structure.

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Table (1) Details of the longitudinal sections for Beam P1

f_y (Mpa)	f_c' (Mpa)′	Area of reinforcement (mm^2)	Sectional hight (mm)	Sectional width (mm)
573	23	402	400	200
		402		

Table (2) Details of the longitudinal sections for frame under analysis.

f_y (Mpa)	f_c' (Mpa)′	Area of reinforcement (mm)^2	Sectional hight (mm)	Sectional width (mm)	member	case
585	25	1000	300	300	column	First and second
		1000				
585	25	764	400	300	beam	
		764				

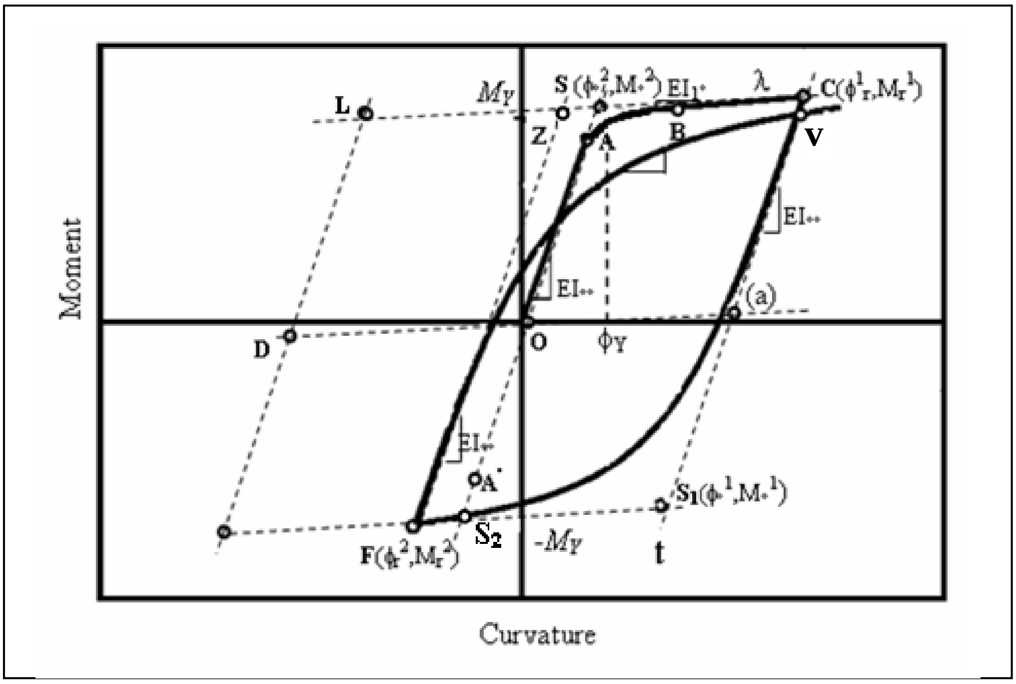


Fig.(1) Details of the mode used in this study .

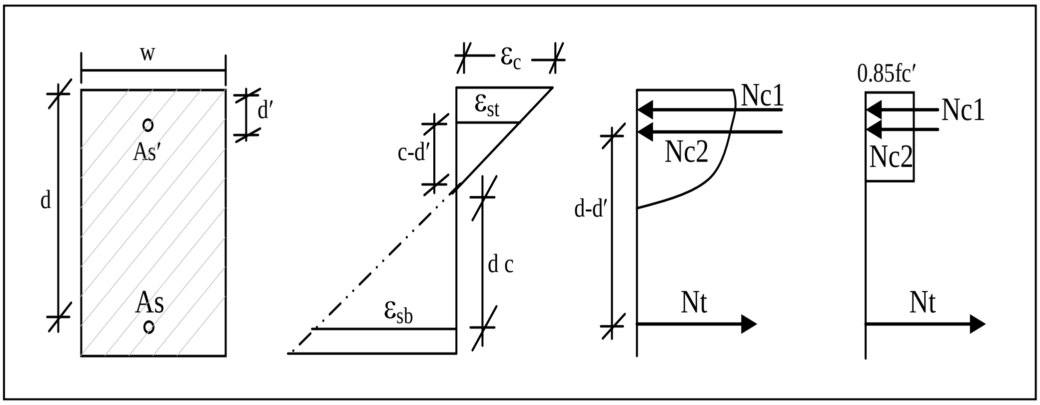


Fig. (2) Analysis of reinforced concrete section

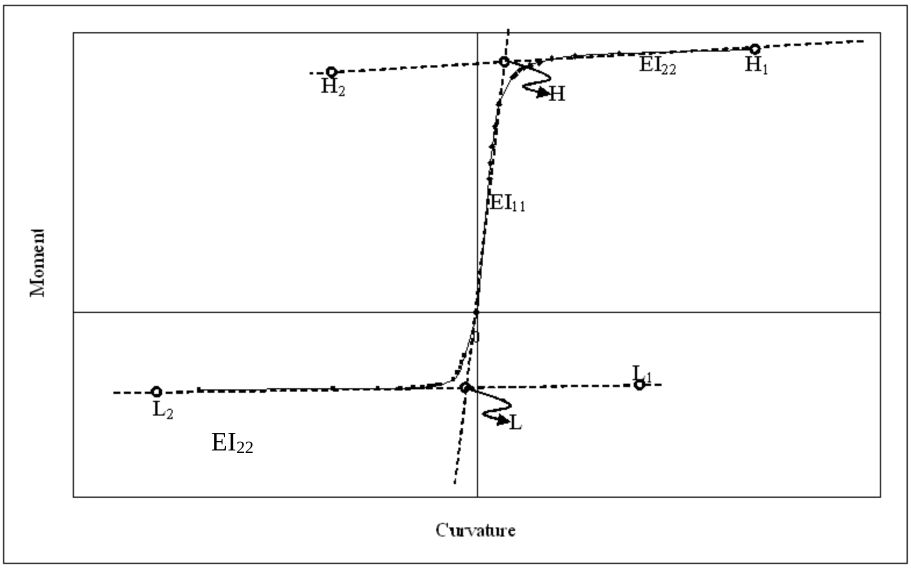
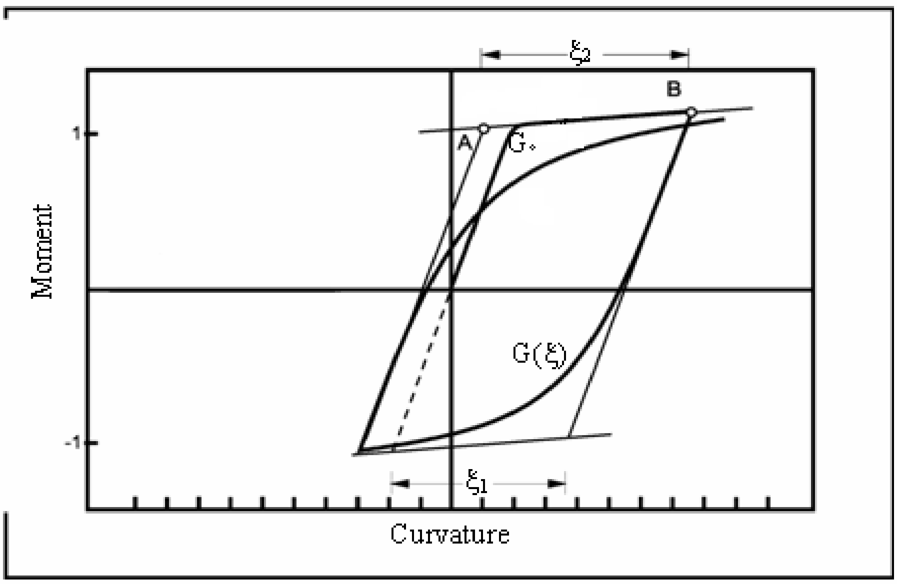


Fig. (3) Relationship between moment-curvature from sectional analysis



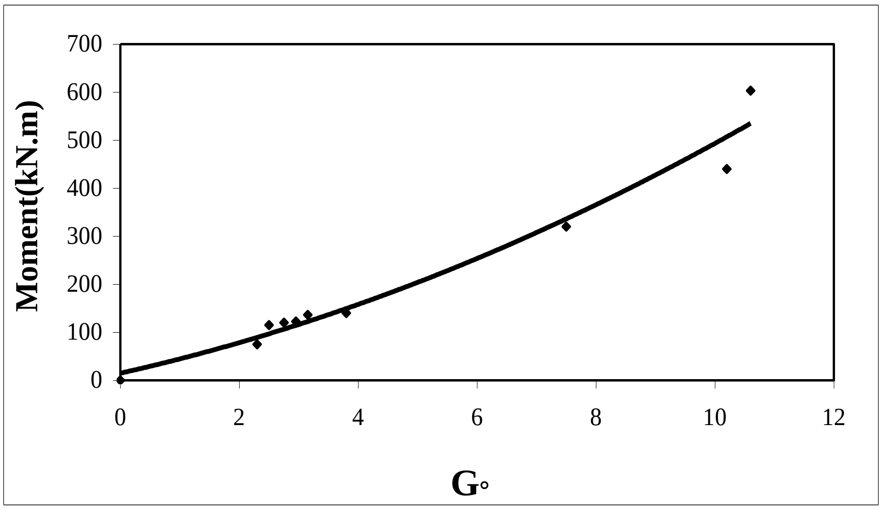


Fig (5) Relation between moment and G∘

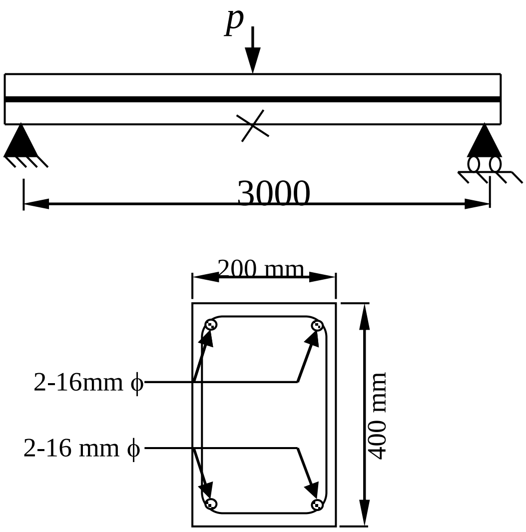


Fig (6) Details of Beam P1

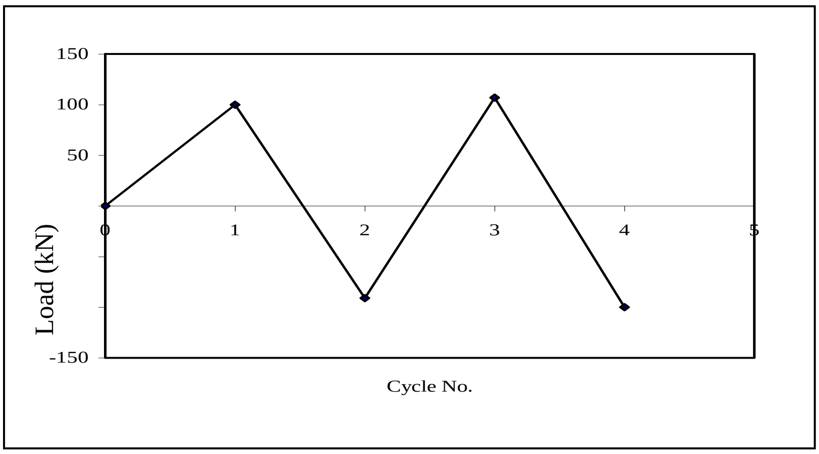


Fig. (7) Chart of applied load on the beam p1

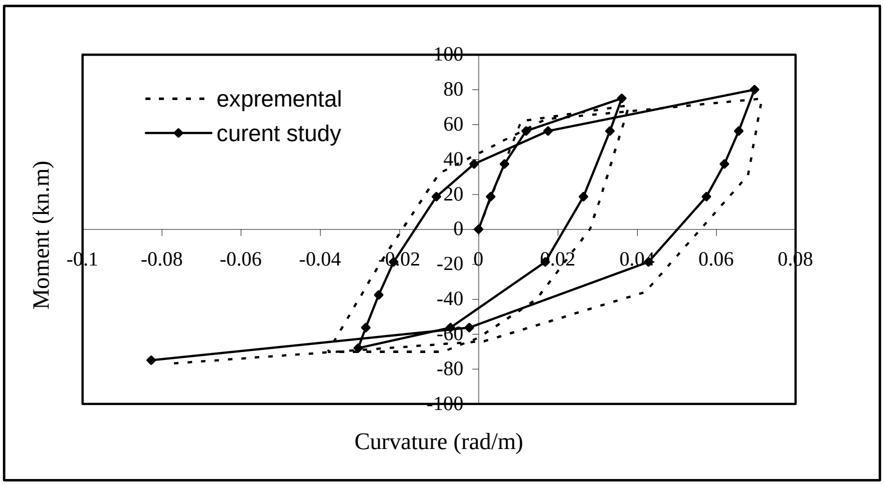


Fig. (8) Moment-curvature Relationship of Beam P1

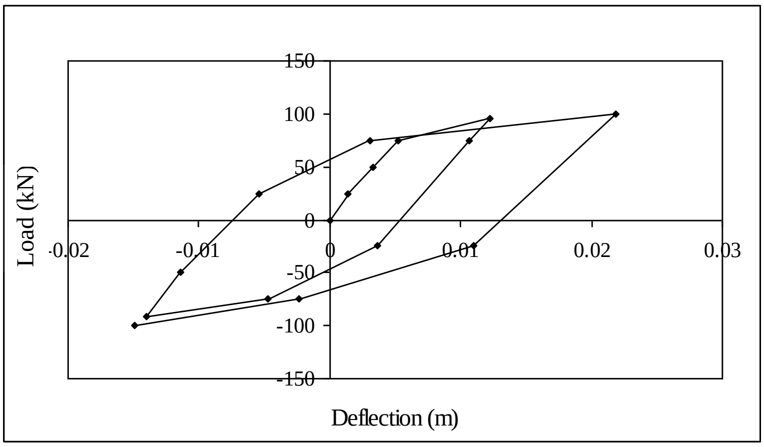


Fig. (9) Load-deflection Relationship of Beam P1

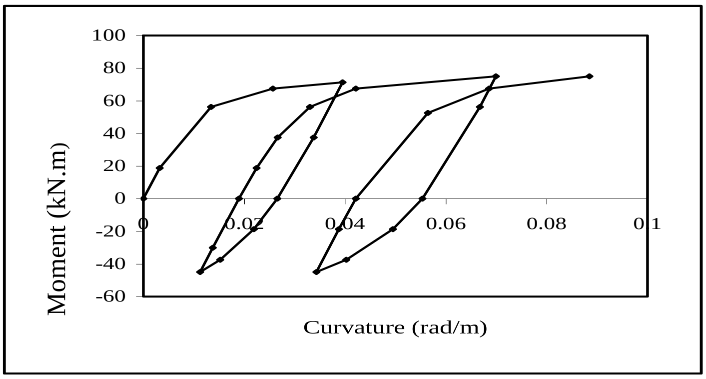


Fig. (10) Moment-curvature relationship of beam P1 under partial reversal loads

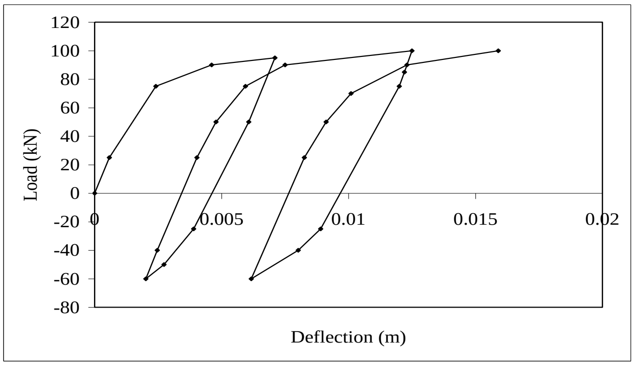


Fig. (11) Load-deflection Relationship of Beam P1 under partial reversal loads

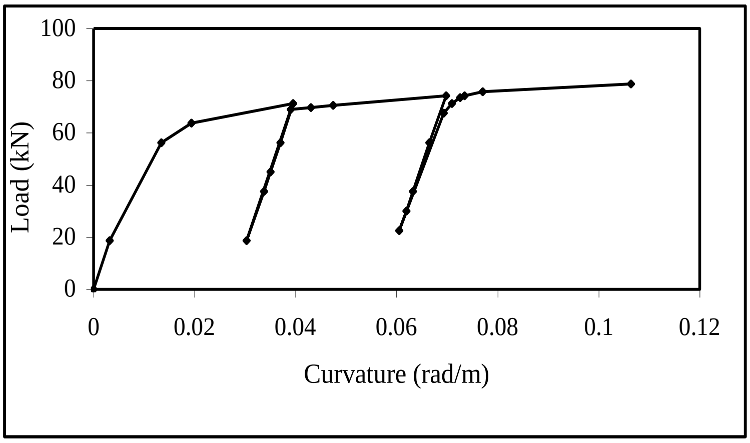


Fig. (12) Moment-curvature relationship of beam P1 under partial repeated loa

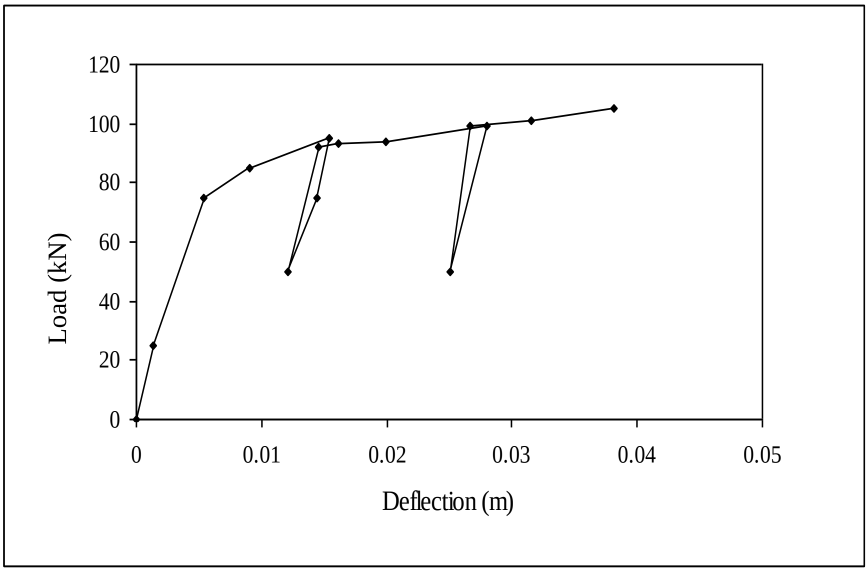


Fig. (13) Load-deflection Relationship of Beam P1 under partial rep

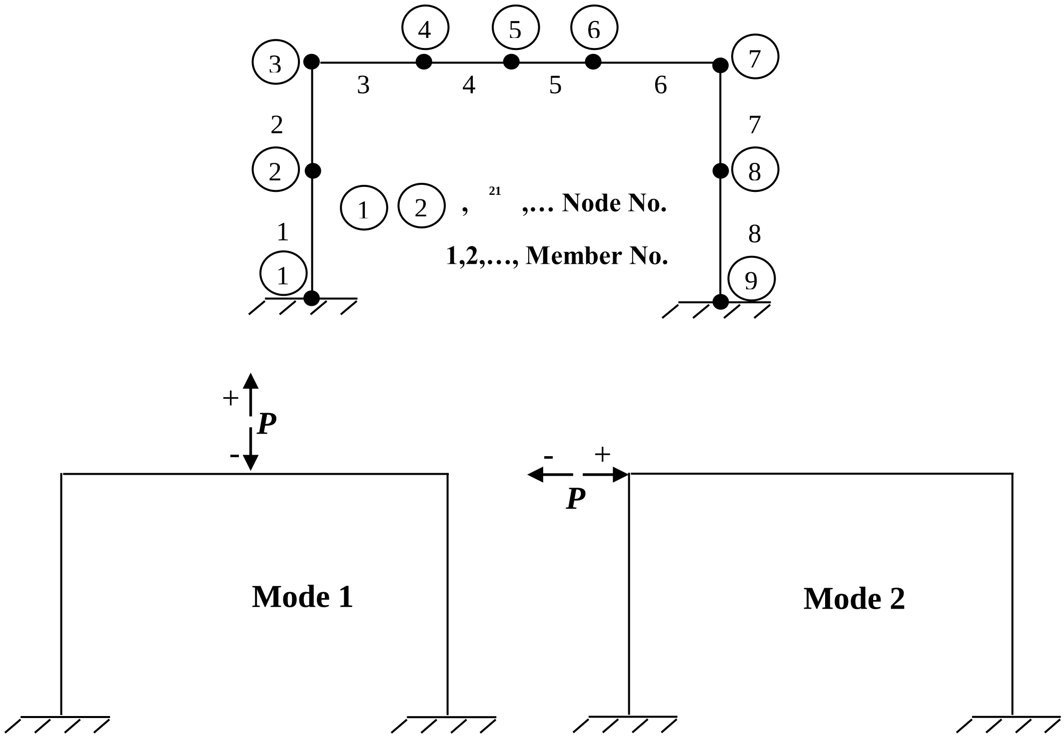


Fig. (14) Cases of frame under analysis

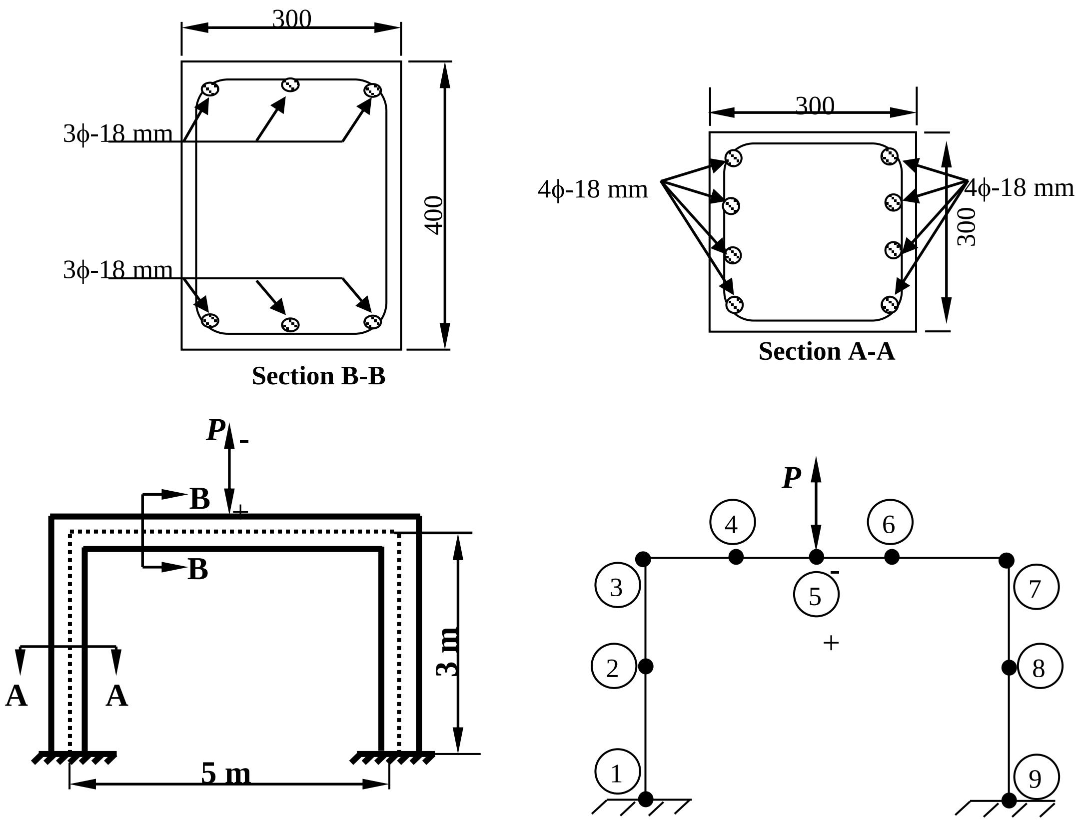


Fig (15). Geometric and cross -section dimensions of the frame (first case)

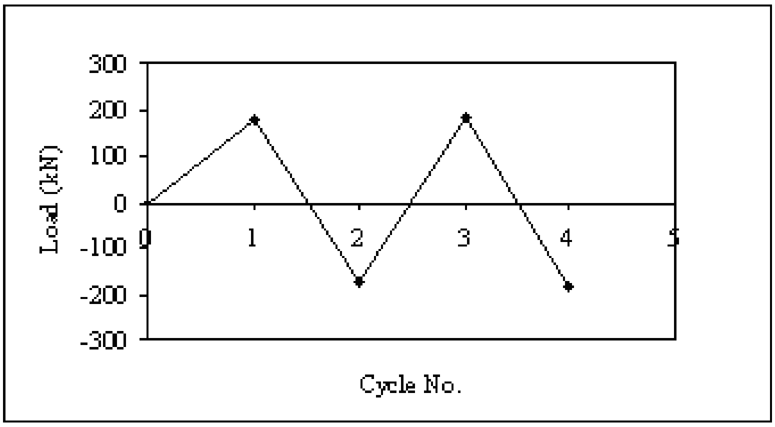


Fig (16) Chart of applied load on the frame (first case).

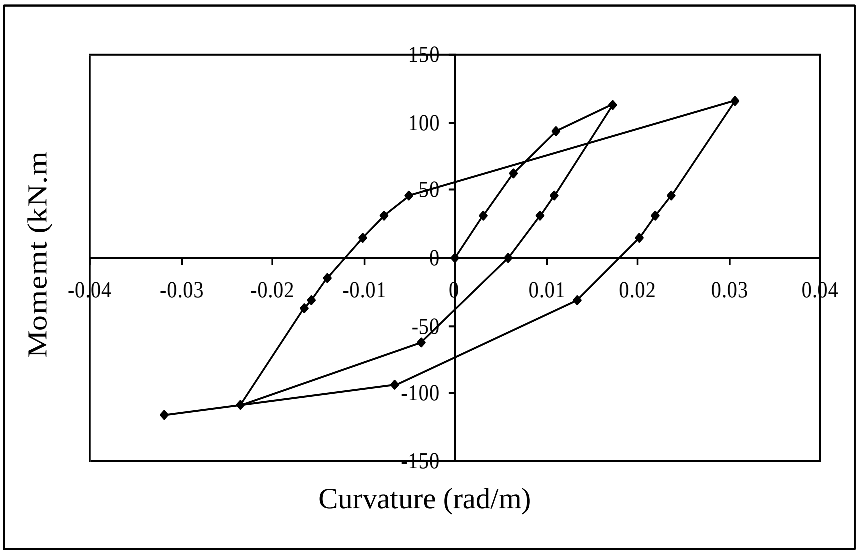


Fig. (17) The (moment-curvature) relationship

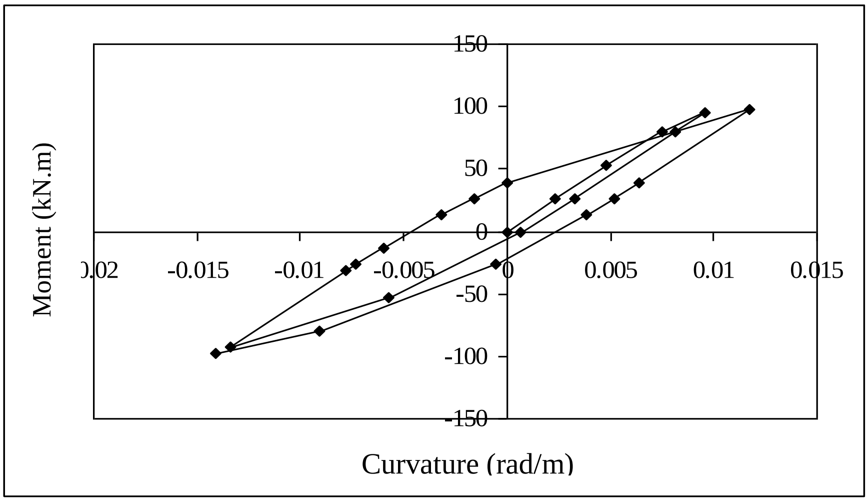


Fig. (18) (Load-deflection) Relationship of the frame (first case).

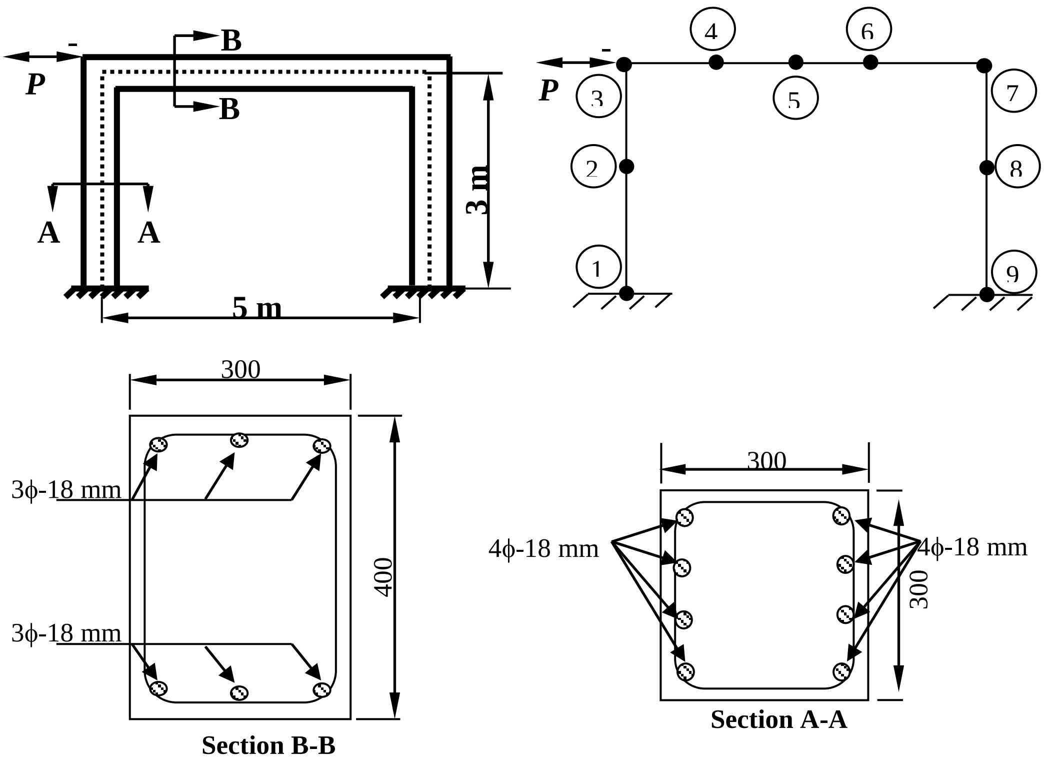


Fig. (19) Geometric and cross -section dimensions of the frame (first case)

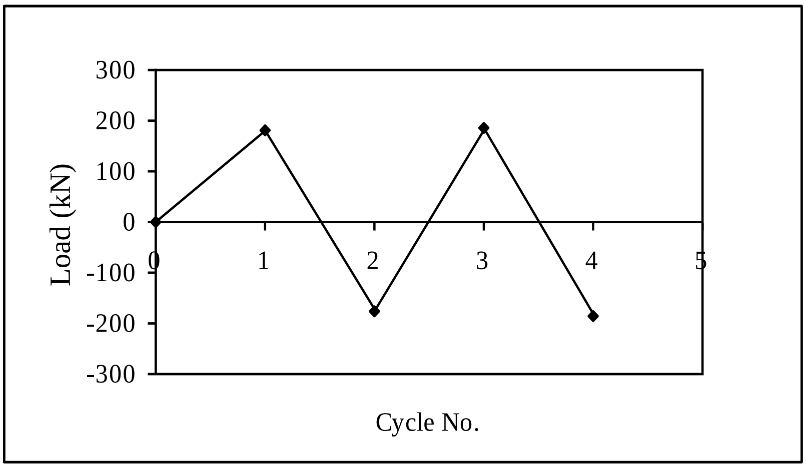


Fig. (20) Chart of applied load on the frame (second case).

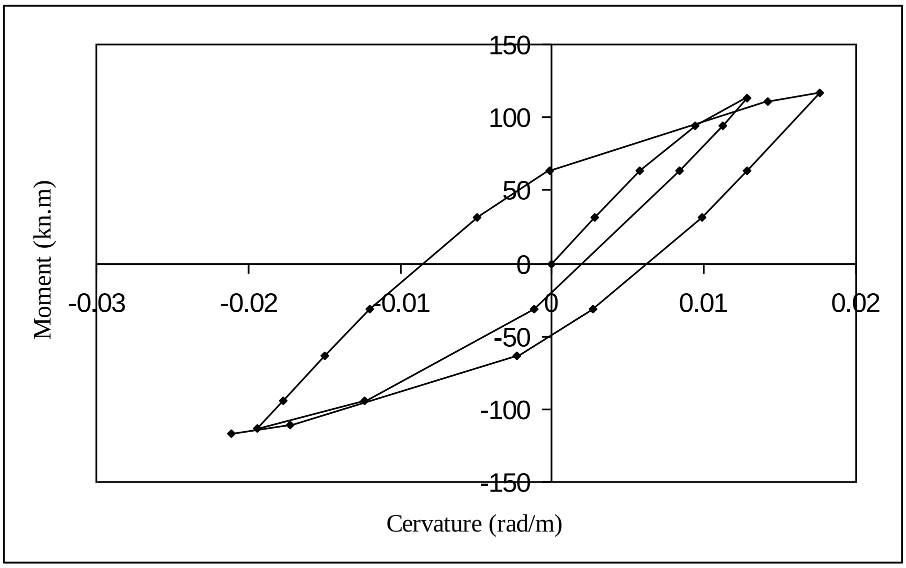


Fig. (21) Moment-curvature relationship

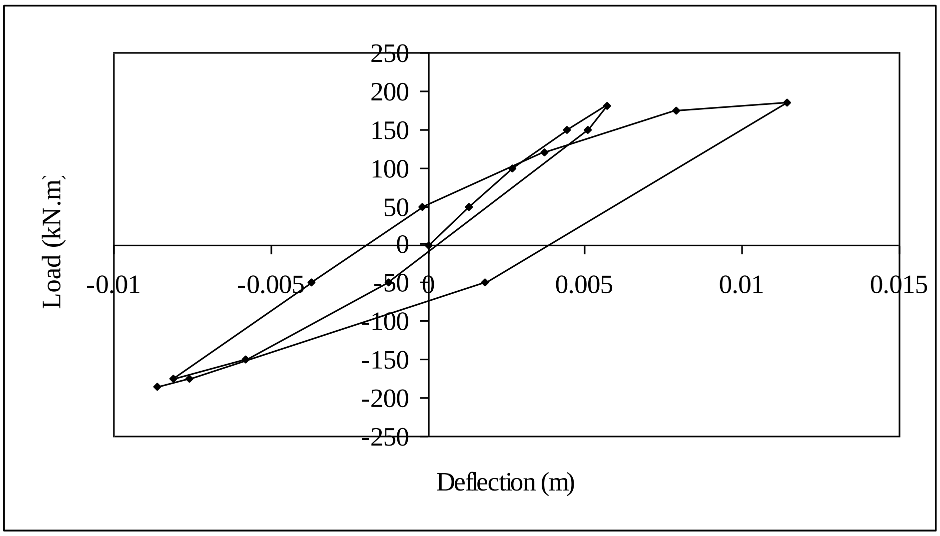


Fig. (22) Load-deflection Relationship of the frame (Second case).

دراسة سلوك الانحناء للمقاطع الخرسانية المسلحة تحت تاثير الاحمال الدورية

د. بيار جعفر السليفاني منى مبارك عبدالله
استاذ مدرس مساعد
قسم الهندسة المدنية–جامعة الموصل

الخلاصة

في هذا البحث تم دراسة سلوكية الانحناء في المقاطع الخرسانية المسلحة المعرضة إلى أحمال دورية كأحمال الرياح أو الهزات الأرضية وذلك لما تشكله من أهمية في استقرارية أو فشل المنشات , إذ لوحظ من خلال البحوث والدراسات أن الفشل يحدث في المنشات بعد أن تفشل المفاصل فيها ويطلق عليها اسم المناطق الحرجة. كما تطرق البحث إلى دراسة سلوك الهياكل والعتبات الخرسانية المسلحة.

ويقدم البحث نموذجاً رياضياً يتكهن بسلوك العتبات والهياكل والمفاصل الخرسانية المسلحة الواقعة تحت تأثير الأحمال الدورية.

وتم في هذه الدراسة نمذجة العلاقة الدورية بين العزم والتقوس للمقطع الخرساني المسلح تحت تأثير قوى العزم والضغط المحوريين مقترحين وجود ترابط تام بين الخرسانة وحديد التسليح مهملين تأثير التشوه الناتج من قوى القص .

كما تمت الإفادة من طريقة الجساءة والجساءة القطاعية المؤثرة في تحليل المنشات وحساب العزوم الازاحات في كل مقطع وبالتالي الحصول على علاقة (الحمل–الإزاحة) , فضلاً عن استخدام طريقة التكامل في تحليل الأعضاء البسيطة من المنشأ كالعتبات الخرسانية المسلحة المعرضة للأحمال الدورية.

وتم في الدراسة ادخال تاثير القوى المحورية على هذه المنشات ايضاً.

خلصت الدراسة الى ان القوة المحورية المؤثرة على الأعضاء الإنشائية أسهمت في اختزال قابلية هذه الأعضاء على امتصاص الطاقة آلا أنها آدت الى

زيادة حمل الفشل لهذه الأعضاء فأظهرت الدراسة ان النموذج المستخدم في تحليل المقطع الخرساني المسلح عمل بكفاءة لابأس بها وسرعة في عملية التنفيذ مقارنة مع الطرائق الأخرى تجعل في الإمكان الاعتماد عليه في عملية التحليل . كما بينت طريقتي الجساءة والتكامل كفاءة جيدة في عملية التحليل وذلك من خلال النتائج التي تم الحصول عليها.

الكلمات الدالة

الخرسانة المسلحة،الاحمال الدورية،الارتباط بين الاعمدة و العوارض.