

# Buckling of Perforated and Unperforated Stiffened Plate

Qasim H. Bader Al-Amar

Mohammed S. Hassan AL-Araji

Mechanical Engineering / University of Babylon

[drqsimbader@yahoo.com](mailto:drqsimbader@yahoo.com)

[mohammedsalih51@yahoo.com](mailto:mohammedsalih51@yahoo.com)

## Abstract

This paper focuses on the studied the structural instability caused by perforated and unperforated stiffened plate having all round simply supported boundary conditions subjected to in-plane uniaxial compressive load and also to the unperforated and perforated plate are reinforced with two stiffeners in (longitudinal, transverse and combined) directions. The aspect ratio, area ratios, and number and direction of stiffeners are the parameters considered. The analytical solutions are carry out by energy method. A finite element analysis is carry out by software Ansys. Results show that the presence of a three central circular perforations reason decreases in buckling load factor of plate and the stiffeners can be used to reduce this decreasing. It is also concluded effect of transverse stiffeners which is less than that of longitudinal stiffeners for both unperforated and perforated plate. Increase the cutout ratio to  $\eta=0.15$  at  $\delta=0.125$ ,  $\beta=1$  will lead to decrease the K (10, 21 and 10.6)% for SSSS2L3, SSSS2T3 and SSSS4C3 respectively at when compare with SSSS2L0, SSSS2T0 and SSSS4C0. The economical design of structures is likely by presenting stiffeners of optimum size.

Keywords: perforated and un perforated plate, buckling analysis, bucking load factor, stiffened and unstiffened plates.

## الخلاصة

هذا البحث ركز على دراسة عدم الاستقرار الهيكلي للصفائح المقواة المثقبة والغير مثقبة والتي تمتلك الشروط الحدودية ذات المساند البسيطة من جميع الجهات والمعرضة لحمل ضغط محوري وكذلك الصفائح المثقبة والغير مثقبة معززة باثنتان من المقويات في الاتجاه (الطولي. العرضي والجامع). المتغيرات التي تم اعتبارها هي نسبة طول الصفائح الى العرض، نسبة مساحة المقواة الى الصفائح عدد واتجاه المقواة. الحل التحليلي انجز بواسطة (نظرية الطاقة) الحل العددي انجز بواسطة برنامج (Ansys). النتائج اظهرت وجود ثلاثة ثقوب دائرية في مركز الصفائح يسبب انخفاض معامل الانبعاج ويمكن تعويض ذلك الانخفاض بواسطة استخدام المقويات وكذلك استنتج ان تأثير المقويات العرضية اقل فائدة من المقويات الطولية لكل من الصفائح المثقبة والغير مثقبة. كما ان زيادة نسبة القطع الى  $\eta=0.15$  سوف يؤدي الى اخفاض K حوالي (2.1, 13 and 2)% لصفائح المثقبة المقواة عند مقارنتها مع المقواة الغير مثقبة عند  $\delta=0.025$  و  $\beta=1$ . ان التصميم الاقتصادي للهياكل محتتمل بواسطة تقديم امثل حجم للمقويات.

الكلمات المفتاحية : الصفائح المثقبة والغير مثقبة، تحليل الانبعاج، معامل الانبعاج، الصفائح المقواة والغير مقواة.

## Nomenclature

$\beta$  = Aspect ratio

$\delta$  = Area ratio

$\eta$  = Cutout ratio

SSSS00 = unperforated plate with Simply support BC

SSSS2L0, SSSS2T0 and SSSS4C0 = unperforated plate with two (longitudinal, transverse and combined) stiffeners, with Simply support BC.

SSSS2L3, SSSS2T3 and SSSS4C3 = perforated plate with two (longitudinal, transverse and combined) stiffeners, with Simply support BC.

## 1. Introduction

plates widely uses in civil and mechanical industries . Generally, in plate cutouts are provided to decrease the self-weight, to provide service area and even aesthetics. When these plates are subject to loading, the presence of cutouts will effect on the redistribution of the stresses, consequently there will be effect in the buckling and

ultimate strength of the plate. The (shape ,number and location) of a cutout, the type of loading, different boundary conditions, thickness ratios of the plate and, these parameters effect on the mechanical behavior of plates(Jayashankarbabu, 2014). On the other hand, though the cutouts are provided to accomplishes certain structural advantages, it is worth to investigate here on the effect of hole in the stability of the plate in the form of buckling. If the perforated plate used then a design solution must use to increase the stability of perforated plate, This always can be achieved by increase thickness of plate but the design will not be economical because of increasing in the weight of material used. It is possible to design an effectively strong and rigid plate element by keeping its thickness as small as possible and employ stiffener to increase the stiffens(Timoshenko, 1963).

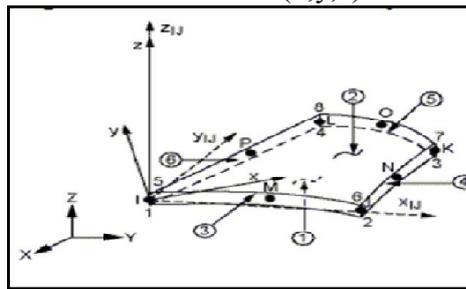
The stability of stiffened plate under various compressive loadings and boundary conditions has been the subject and studied by:

(Srivastava & DATTA ,2006) focused on effects of cutouts on the stability of square stiffened plates, it was contained on the longitudinal stiffener with square cutouts and subject to in plane biaxial load with various boundary condition ,used finite element method to determine the buckling load coefficient and modes shapes with square cutouts and various edge conditions.The result was showed the buckling load factor decrease with increase cutout size for simply and simply clamp boundary condition edge and increase with increase cutout for clamp. (Cheng and Zhao 2010) investigated the effect of stiffener on the perforated plate. There four types of stiffener investigated were flat ,ring ,longitudinal and transverse. the square plate subject to uniaxial compression load. The results show presence the stiffener in the perforated plate lead to improve the buckling load.(Nildem,Taysi; 2010) studied the effect stiffeners locations on critical buckling load of stiffened plates, have used finite strip method to select the buckling load. The optimize design variable was obtained by Sequential Quadratic Programming algorithm. ( Jawad,2012) have used finite difference method for linear buckling analysis of thin plates subjected to in-plane patch load.(Jayashankarbabua and Karisiddappa; 2014) analyzed Stability of Square Plate with Concentric Cutout, employed isotropic plate with (rectangular, square and circular) cutout, subject to in plane uniaxial and biaxial compression load ,the study performed by finite element analysis in the ANSYS package for various boundary condition.( Anupama and Jayashankarbabu; 2014) studied the effect of stiffener on the buckling of unperforated and perforated plates ,the boundary condition is simply support and subject to uniaxial load and plate contained stiffener in longitudinal and transverse directions ,finite element analysis is carried out in the ansys package.The two longitudinal stiffeners on either side of the central circular perforation increase the buckling load factor of the perforated plate .(Shruthi and Jayashankarbabu ; 2014) introduced the Analysis of Isotropic Perforated Stiffened Plate and examined the stability of structure ,subject in plane uniaxial compression load and boundary condition is simply support and clamped ,and used circular and square perforated plate, finite element analysis is carried out in the ansys package.The results showed that the presence of a central hole causes decreasing in buckling load factor and stiffeners can be employed to compensate this reduction. (Ashutosh kumar, *et.al.*,2015) studied buckling analysis of rectangular stiffened plate. These structures are subjected to uniaxial load with simply support boundary condition. Analytical solution is produced by Equilibrium method.

Finite element analysis is produced by Nastran program to select critical buckling load and corresponding buckling mode for stiffened and unstiffened plate. The results showed presencesimilar pattern with different modes for both case .The present study focused essentially on the linear buckling analysis of isotropic stiffened plate exposed to uniaxial load with simply support boundary condition (B.C). Analytical solution is produced by energy method. Finite element analysis is produced by Ansys program to select buckling load factor for stiffened plate, in addition to the parameters such as (aspect ratio, area ratio, andcutout ratio) are considered, its effect on the buckling load factor.The material of the plate is assumed to be homogeneous, isotropic with young's modulus  $E=210000N/mm^2$  and Poisson's ratio  $\nu= 0.3$ .

## 2. Finite Element Discretization

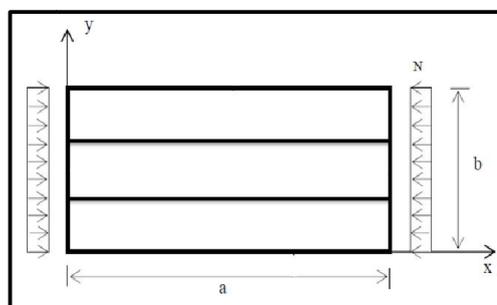
In latest years, finite element is widely used to analyze the structure. This method is the more powerful numerical technique, which produces an approximate solution to most pragmatic types of structures. The use of the computational tools has become common in design. More accurate results may be achieved in order to reaching safe and optimal design.In the present workelement type (shell-93) was selected, as shown in fig(1), which suitable for the analysis of thin structure, the element has 8- node and six degrees of freedom at each node translations and rotations in  $(x,y,z)$ .



Fig(1):Representation of shell 93 element

## 3. Buckling Analysis Of Stiffened Plate

Energy method can be used for buckling analysis of stiffened plate that depends on the strain energy and work done of structure,from this method can finding the relation ofcritical buckling stress and the cross-sectional dimensions. The present analysis of stiffened plate consists number of longitudinal stiffener that dividing the width of plate into parts the boundary conditions is simply support in all edges and subject to uniform uniaxial compression loads as illustrated in the Figure(2).



Fig(2):boundary condition of stiffened plate

The deflection surface of the buckled plate taken from the trigonometric series. (Eduard Ventsel, 2001)

$$w = \sum_{m=1}^{m=\infty} \sum_{n=1}^{n=\infty} a_{mn} \sin \frac{m\pi x}{a} \sin \frac{n\pi y}{b} \quad (1)$$

The expression of the strain energy of bending of plate can be represented. (Eduard Ventsel, 2001)

$$\Delta U = \frac{1}{2} D \int_0^a \int_0^b \left\{ \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right)^2 - 2(1-\nu) \left[ \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} - \left( \frac{\partial^2 w}{\partial x \partial y} \right)^2 \right] \right\} dx dy \quad (2)$$

The strain energy of stiffener when buckled together with plate. (Eduard Ventsel, 2001)

$$\Delta U_i = \frac{EI_i}{2} \int_0^a \left( \frac{\partial^2 w}{\partial w^2} \right)_{y=c_i}^2 dx \quad (3)$$

where  $EI_i$  represented flexural rigidity of stiffener at distance  $C_i$  from edge  $y=b/2$

General equation of work of the forces influence on the middle plane of plate can be represented in the following. (Eduard Ventsel, 2001)

$$\Delta T = -\frac{1}{2} \iint \left[ N_x \left( \frac{\partial w}{\partial x} \right)^2 + N_y \left( \frac{\partial w}{\partial y} \right)^2 + 2N_{xy} \frac{\partial w}{\partial x} \frac{\partial w}{\partial y} \right] dx dy \quad (4)$$

The work which his done is caused by applied load acting on the plate according to boundary condition .

$$\Delta T = \frac{1}{2} \int_0^a \int_0^b N_x \left( \frac{\partial w}{\partial x} \right)^2 dx dy \quad (5)$$

The work done caused by applied load acting on the stiffener .

$$\Delta T_i = \frac{P_i}{2} \int_0^a \left( \frac{\partial w}{\partial x} \right)_{y=c_i}^2 dx \quad (6)$$

The critical buckling stress can be calculated by general equation. (Timoshenko, 1963)

$$\Delta U + \Delta \sum_i U_i = \Delta T + \Delta \sum_i T_i \quad (7)$$

The summation of above equation must be extended overall the stiffener . Use the following equations for simplification .

$$\beta = \frac{a}{b} \gamma = \frac{EI_i}{bD} \delta = \frac{P_i}{bN_x} = \frac{A_i}{bh} \quad (8)$$

where

$bh$ -represents cross-section area of plate.

$A_i$  - represents cross-section area of one stiffener .

By substitute the equations (2),(3),(5)and(6) in the equation (7) and after simplification .

$$\sigma_{cr} = \frac{\pi^2 D}{b^2 h \beta^2} \left[ \frac{\sum_{m=1}^{m=\infty} \sum_{n=1}^{n=\infty} a_{mn}^2 (m^2 + n^2 \beta^2)^2}{\sum_{m=1}^{m=\infty} \sum_{n=1}^{n=\infty} m^2 a_{mn}^2 + 2 \sum_i \sum_{m=1}^{m=\infty} m^2 \left( \sum_{n=1}^{n=\infty} a_{mn} \sin \frac{n\pi c_i}{b} \right)^2} + \frac{\sum_i \gamma_i \sum_{m=1}^{m=\infty} m^4 \left( \sum_{n=1}^{n=\infty} a_{mn} \sin \frac{n\pi c_i}{b} \right)^2}{\sum_{m=1}^{m=\infty} \sum_{n=1}^{n=\infty} m^2 a_{mn}^2 + 2 \sum_i \sum_{m=1}^{m=\infty} m^2 \left( \sum_{n=1}^{n=\infty} a_{mn} \sin \frac{n\pi c_i}{b} \right)^2} \right] \quad (9)$$

By derivatives the above equation with respect to  $a_{mm}$  and equating to zero will obtain a system of homogeneous linear equations .

$$\frac{\pi^2 D}{b^2 h} \left[ a_{mn} (m^2 + n^2 \beta^2)^2 + 2 \sum_i \gamma_i \sin \frac{n\pi c_i}{b} m^2 \sum_{p=1}^{p=\infty} a_{mp} \sin \frac{n\pi c_i}{b} \right] - \beta^2 \sigma_{cr} \left( m^2 a_{mn} + 2 \sum_i \delta_i \sin \frac{n\pi c_i}{b} m^2 \sum_{p=1}^{p=\infty} a_{mp} \sin \frac{p\pi c_i}{b} \right) = 0 \quad (10)$$

Where  $\sigma_{cr}$ -can be found by equating the determining factor of this equation to zero. We can assume the stiffened plate buckles into one half -wave , therefore we take  $m=1$  and substitute in equation (10), after simplification.

$$\frac{\pi^2 D}{b^2 h \beta^2} [a_1 (1 + \beta^2)^2 + 2\gamma(a_1 - a_2 + a_3 - \dots)] - \sigma_{cr} [a_1 + 2\delta(a_1 - a_2 + a_3 - \dots)] = 0 \quad (11)$$

when the plate stiffened by two equal longitudinal stiffener dividing the width of plate into three equal parts. assume the buckling form is symmetrical about the middle axis at  $(y = b/2)$ . The first approximation of critical buckling stress obtaining after substitute the  $c_i = b/3$  ,and  $m = 1$  , in the equation (10) and after simplification the equation we obtained .

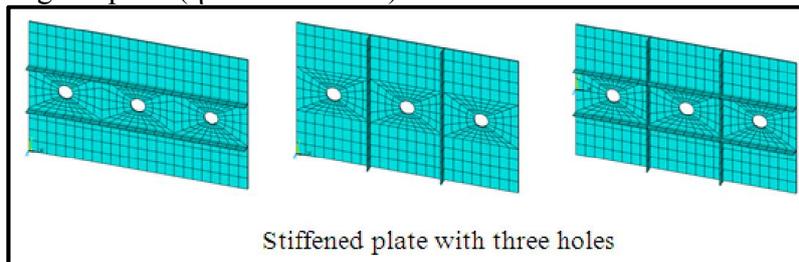
$$\sigma_{cr} = \frac{\pi^2 D (1 + \beta^2)^2 + 3\gamma}{b^2 h \beta^2 (1 + 3\delta)} \quad (12)$$

#### 4. Geometrical Modeling

In general, the model is a stiffened plate with two stiffeners in (longitudinal, transverse and combined).as shown in fig(3) The plate dimensions are 840mm in length, 840mm in width, and 8mm in thickness. Thickness of Stiffeners is 6mm and 56mm in height.

The following parameters are considered.

- 1-Aspect ratio of the plate ( $\beta = a/b=0.5$  to  $2.5$ )
- 2-Area ratio of the stiffener and plate ( $\delta = 0.025$  to  $0.15$ )
- 3- Plate enhanced with three holes with ratio of diameter of the circular cutout to the side of the rectangular plate ( $\eta = 0.10$  to  $0.25$ ).



Fig(3):Finite elements modeling

#### 5. Results and Discussions

The results of buckling load factor  $k$  with respect to direction of stiffener, aspect ratios cutout ratio, area ratios and boundary condition are present in this section.

##### 5.1 Comparative studies

The results obtained from the analytical and numerical solution have been presented in Table (1 and 2).

**Table 1**

Comparison of buckling load factor (k) for different Aspect ratio for SSSS isotropic unperforated plate with two longitudinal stiffener subjected to in-plane uniaxial compression loading. ( $\delta=0.05; \gamma = 8.9; C_i=b/3$ ).

$\beta$	K-analytical	K –numerical	error 100%
1	26.74	25.42	4.93
1.5	14.42	14.86	3.051
2	11.25	11.91	5.86
2.5	11.06	11.83	6.96
3	12.25	13.2	7.75

**Table 2**

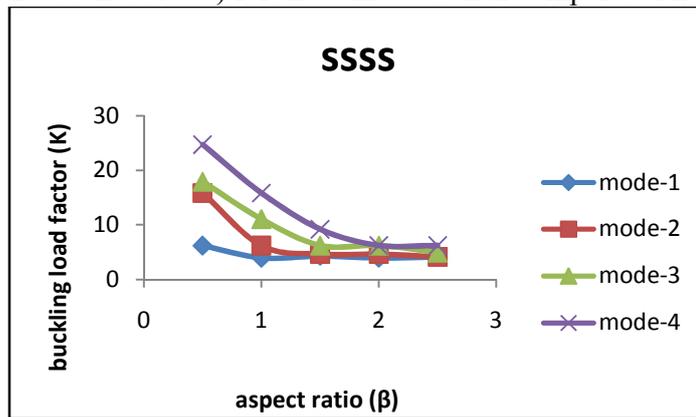
Comparison of buckling load factor (k) for different Aspect ratio for SSSS isotropic unperforated plate with two transverse stiffener subjected to inplane uniaxial compression loading. ( $\delta=0.05; \gamma$ -take from table of (Timoshenko,1963).

B	K-analytical	K –numerical	error 100%
0.9	9.26169	8.415916	9.131962
1	6.379901	6.250944	2.021306
1.2	5.004415	5.133663	-2.58267
1.414	4.500145	4.491432	0.193623

**5.2 Unperforated plate :**

**5.2.1:- Effect of mode number :**

Fig(4) is shown the Buckling load factor versus Aspect ratio(0.5-2.5) for SSSS00, for four modes. From result are concluding, the increase  $\beta$  will lead to decrease the K for different modes, due to decrease in stiffness of plate. The maximum decrease in K at  $\beta=2.5$  (33%, 73%, 72.6% and 74.8%) for these modes when compare with  $\beta=0.5$ .



**Fig(4): uniaxial compressive buckling load factor (K)with different mode number for SSSS boundary conditions.**

**5.3 Unperforated stiffened plate:**

**5.3.1-Effect of aspect ratio:**

Fig. [(5),(6)and(7)] present simply support rectangular plate reinforce with stiffeners in (longitudinal, transverse and combined) and subject to uniaxial compressive load.

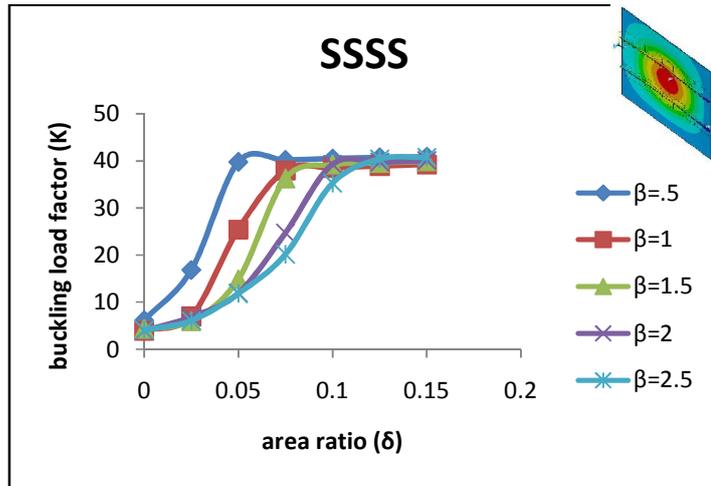


Fig (5): buckling load factor versus area ratio and aspect ratio for SSSS2L0

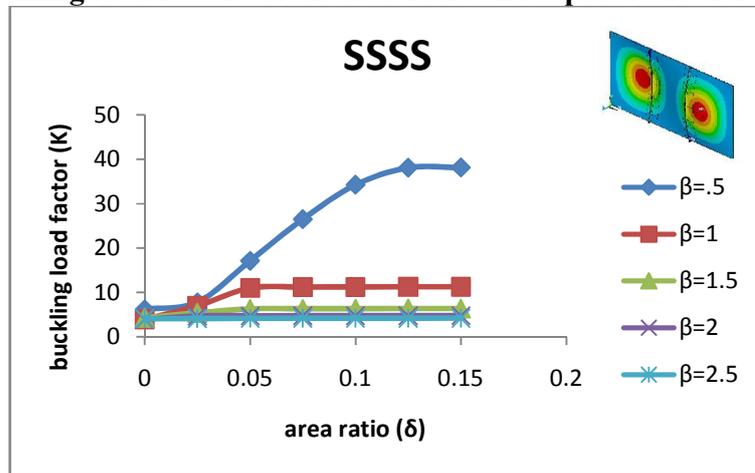


Fig (6): buckling load factor versus area ratio and aspect ratio for SSSS2T0.

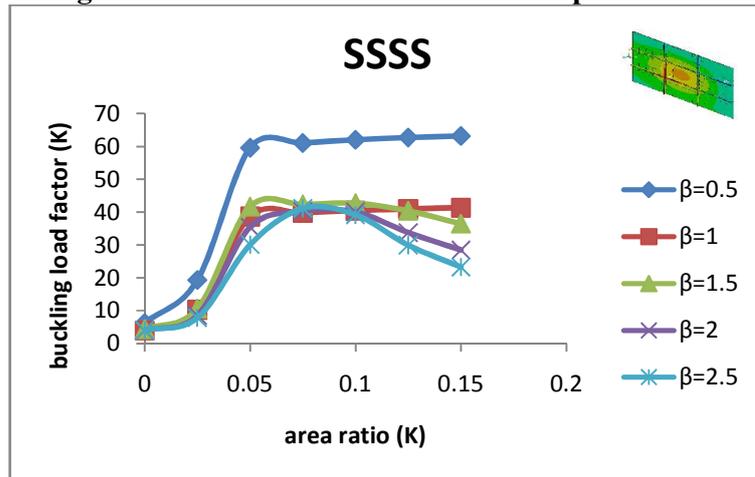


Fig (7): buckling load factor versus area ratio and aspect ratio for SSSS4C0.

Fig.(5) is shows SSSS2L0, the buckling load factor increase with increase area ratio for all aspect ratio due to increase in moment of inertia of stiffeners. From results in

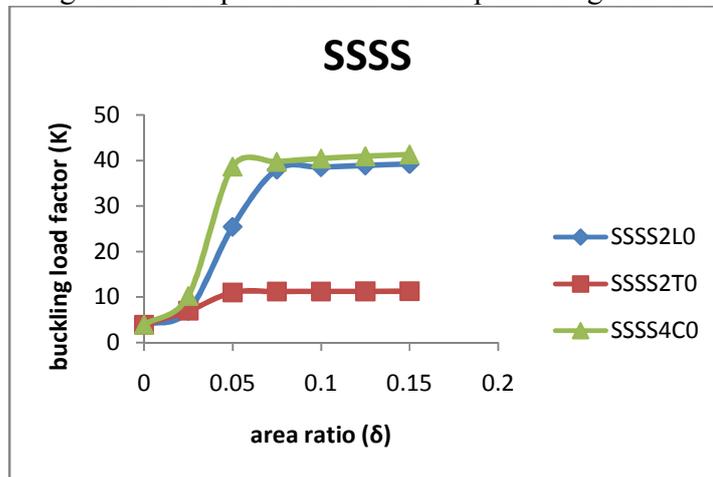
fig.(5) conclude the SSSS2L0 gives best increasing in stiffness that leads to increase buckling load factor. For  $\beta=0.5$  the optimum increase in  $k=5.49$ , at  $\delta=0.05$ , for  $\beta=(1,1.5)$  the optimum increase in  $k=(8.6, 7.4)$  respectively at  $\delta=0.075$ , for  $\beta=(2,2.5)$  the optimum increase in  $k=(8.9, 7.6)$  respectively at  $\delta=0.1$  when compare with SSSS00.

Fig.(6) is shows SSSS2T0 plate. From results are conclude the behavior the stiffened plate at  $\beta=0.5$  varies from  $\beta>0.5$ , for  $\beta=0.5$  the optimum value of  $k$  at  $\delta=0.125$ , for  $\beta>1$  the optimum value of  $k$  at  $\delta=0.05$ , increase in  $k$  very small after  $\delta=0.05$ . Therefore small increase in stiffness insufficient to access for local buckling modes, because of location of stiffeners ineffective

Fig.(7) is shown SSSS4C0 plate. From results are conclude the value of  $K$  increase with increase  $\delta$  due to increase in moment of inertia of stiffeners. For  $\beta=0.5$  the optimum increase in  $K=8.6$  times, at  $\delta=0.05$  when compare with SSSS00. For  $\beta>0.5$  the optimum increase in  $K$  about (6.34 to 9)times at  $\delta$  limited between (0.05-0.075) when compare with SSSS00. when  $\beta$  increase the influence of  $\delta$  become small for this range of  $\delta$ . In SSSS4C0 consider benefit for provides high stiffness can be obtaining local buckling modes. From results in fig. [(5), (6) and (7)] will conclude, for  $\beta \geq 1$  the maximum increase in buckling load factor ( $K$ ) for SSSS4C0 more than SSSS2L0 and SSSS2T0, use the SSSS2T0 is ineffectual because of small increase in stiffness of structure.

### 5.3.2-Effect of area ratio:

Fig.(8) is shown  $K$  for SSSS2L0, SSSS2T0, SSSS4C0 for  $\beta=1$  versus  $\delta$ . From results is conclude. The optimum increase in  $K$  and weight for SSSS2L0 (8.6 times, 15%) at  $\delta= 0.075$  when compare with SSSS00, the optimum increase in  $K$  and weigh for SSSS2T0 (1.78 times, 10%) at  $\delta= 0.05$  when compare with SSSS00, the optimum increase in  $K$  and weigh for SSSS4C0 (8.77 times, 20%) at  $\delta= 0.05$  when compare with SSSS00, fig.(8) presents buckling load for unperforated stiffened plate for global and local range.



**Fig (8): buckling load factor versus area ratio and type of stiffeners to unperforated plate  $\beta=1$**

Table (3) presents the magnitude increase in weight of plate at increase area ratio for two (longitudinal & transverse and combined) stiffeners, at aspect ratio  $\beta=1$ . This results can be use with other figure to discuss the relation between optimum  $K$  and  $\delta$ .

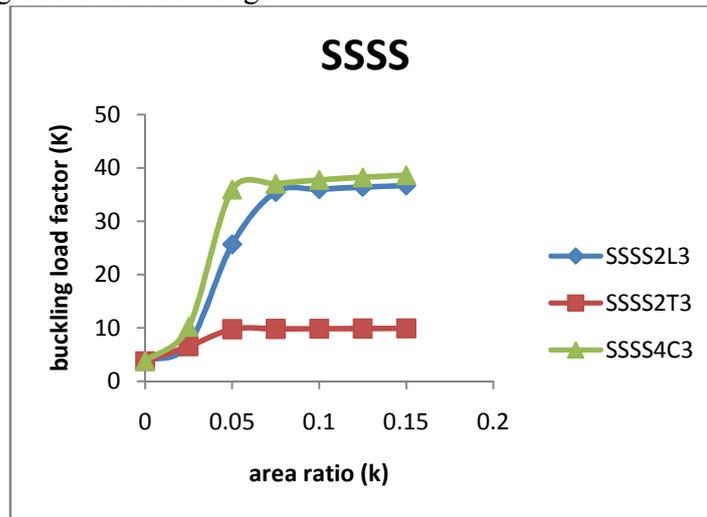
area ratio	total increase in weight		
$\delta$	SSSS2L0%	SSSS2T0 %	SSSS4C0 %
0.025	5	5	10
0.05	10	10	20
0.075	15	15	30
0.1	20	20	40

**Table (3): area ratio versus increase in weight stiffener type at  $\beta=1$ .**

### 5.4.Stiffened plate perforated with three hole

#### 5.4.1-Effect of area ratio:

Fig.(9) is shown buckling load factor for SSSS2L3, SSSS2T3, SSSS4C3 for square plate  $\beta=1$  versus  $\delta$  at  $\eta=0.1$  subject to uniaxial compressive load. From results in fig.(9) are conclude. The optimum increase in K for SSSS2L3 (8.37 times) at  $\delta= 0.075$  when compare with SSSS03, the optimum increase in K for SSSS2T3( 1.58 times) at  $\delta= 0.05$  when compare with SSSS03, the optimum increase in K for SSSS4C3 (8.5 times) at  $\delta= 0.05$  when compare with SSSS03, fig.(9) presents elastic buckling stress for perforated stiffened plate for global and local range.



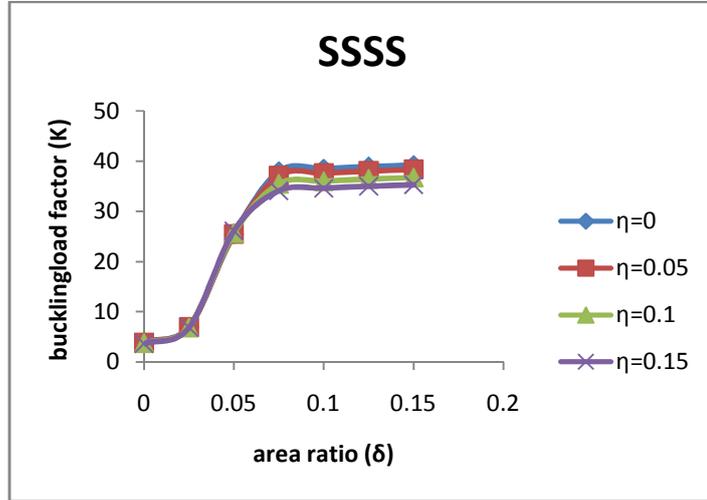
**Fig (9): buckling load factor versus area ratio type of stiffener at  $\eta=0.1$  and  $\beta=1$ .**

#### 5.4.2- Effect of cutout ratio:

Fig.(10) is shown K for SSSS2L0, SSSS2L3 at  $\beta=1$ . From results is conclude, for  $\eta \geq 0$  the optimum value of K at  $\delta=0.085$ , this point presents changeover start from global buckling mode to local buckling modes. for SSSS2L3 at  $\delta=0.085$  the maximum decrease K about (2.5%, 7.1% and 11.2%) for  $\eta$  (0.05, 0.1 and 0.15) respectively when compare with SSSS2L0. On the other hand the presence holes will lead to redistribution stresses and decreasing strength of structure. but these reduction consider small compare without stiffeners.

Fig.(11) is shown buckling load factor for SSSS2T0, SSSS2T3 at  $\beta=1$ . From results are conclude, for  $\eta \geq 0$  the best value of K at  $\delta=0.05$ . the maximum increase in K= 1.78 times for SSSS2T0 when compare with SSSS00. For  $\eta > 0$  the maximum increase in K about (1.42-1.73) times for SSSS2T0 when compare with SSSS03 at  $\delta=0.05$ . on the other hand increase the  $\eta$  from( 0 to 0.15) for SSSS2T3 will lead to decrease the K about (2.6%-

20.2%) for  $\eta \geq 0.05$  and  $\delta = 0.05$  when compare with SSSS2T0. This means the presence holes will effect on the redistribution stresses and strength of structure, so that the transverse stiffeners ineffective in this case.



Fig(10): buckling load factor versus area ratio and cutout ratio for SSSS2L3.

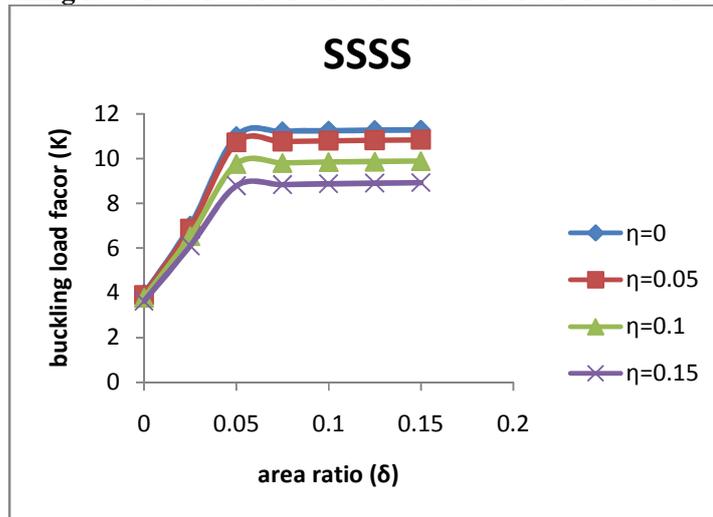
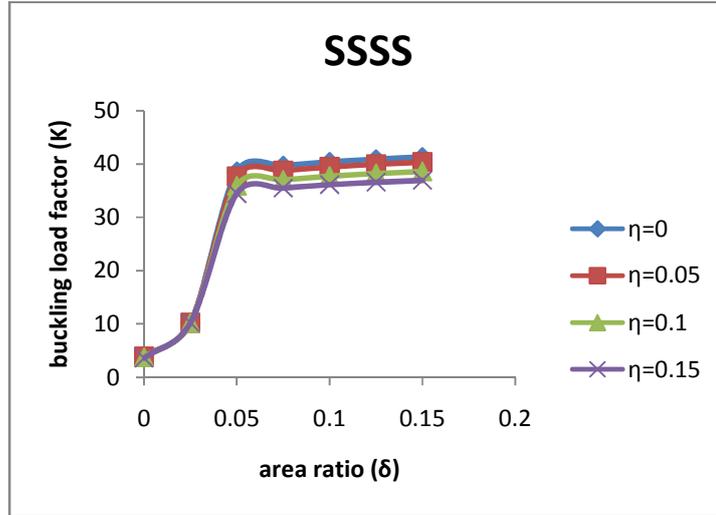


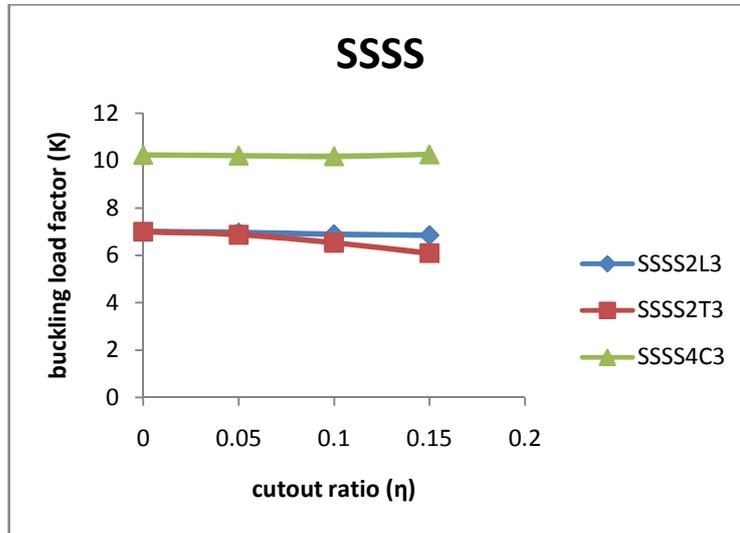
Fig (11): buckling load factor versus area ratio and cutout ratio for SSSS2T3.

Fig.(12) is shown K for SSSS4C0, SSSS4C3 for  $\beta=1$ . From results are conclude, the optimum value of  $K=8.77$  times at  $\delta=0.05$  for SSSS4C0 for compare with SSSS00, for  $\eta \geq 0.05$  the optimum value of K about (8.4-8.6) times for SSSS4C3 for compare with SSSS00 at  $\delta=0.05$ . on the other hand the increase the  $\eta$  from 0 to 0.15 will lead to decrease K about (2.4, 6.9 and 10.7)% at  $\delta=0.05$  for  $\eta$  (0.05, 0.1 and 0.15) when compare with SSSS4C0. this means the presence holes will lead to decrease the strength of structure. Employ the SSSS4C0, SSSS4C3 are benefit because of can be obtaining on local buckling modes.



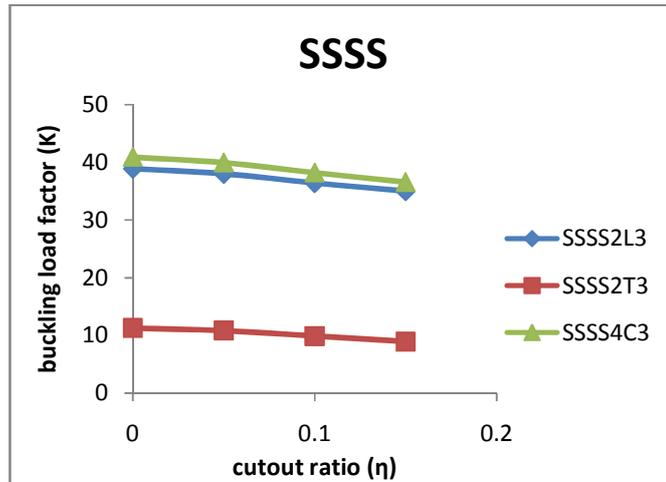
**Fig.(12): buckling load factor versus area ratio and cutout ratio for SSSS4C3.**

Fig.(13) is shown buckling load factor for SSSS2L3, SSSS2T3, SSSS4C3 versus  $\eta$  for  $\beta=1$  at global buckling modes  $\delta=0.025$ . From results are conclude increase  $\eta$  from 0 to 0.15 will lead to decrease of K about (2.1%, 13% and 2%) for (SSSS2L3, SSSS2T3 and SSSS4C3) respectively at  $\eta=0.15$  when compare with SSSS2L0, SSSS2T0, SSSS4C0 respectively. this mean the SSSS2T0 more than effect by holes.presence the holes in(SSSS2L3 and SSSS4C3) have small effect on K because of redistribution stress in plate and stiffener.



**Fig (13): buckling load factor versus aspect cutout ratio for stiffened plate at  $\delta=0.025$  and  $\beta=1$ .**

Fig.(14) is shown K for SSSS2L3, SSSS2T3, SSSS4C3 versus  $\eta$  for  $\beta=1$  at local buckling modes  $\delta=0.125$ , from results are conclude the increase the  $\eta$  from 0 to 0.15 will lead to decrease the K (10, 21 and 10.6)% for SSSS2L3, SSSS2T3 and SSSS4C3 respectively at  $\eta=0.15$  when compare with SSSS2L0, SSSS2T0 and SSSS4C0. presence the holes lead to redistribution stress in plate and stiffener and reduction the stiffness of stiffeners.



**Fig.(14): buckling load factor versus cutout ratio for stiffened plate at  $\delta=0.125$ .**

### Conclusions:

Based on the results obtained in the present study, several conclusions may be drawn. These may be summarized as follows:

- 1-The finite element method by (ansys) is very appropriate for programming and sufficiently accurate for buckling analysis of square stiffened plate with cutout area, as it tends to a convergent solution with analytical solution.
- 2-This investigation shows that the influence of transverse stiffeners on unperforated plate is less when compared to longitudinal stiffeners.
- 3-In case of SSSS2L0 & SSSS4C0 and  $\beta=1$ , the optimum increase in area ratio lead to increase the buckling load factor and weight about (8.6,8.77) times, (15 , 20)% respectively.
- 4-Increase the area ratio will lead to convert the global buckling to local buckling that give more stability to structure.
- 5- Increase the cutout ratio at  $\delta=0.025$   $\beta=1$  will lead to decrease the K (2.1, 13 and 2)% for SSSS2L3, SSSS2T3 and SSSS4C3, respectively at  $\eta=0.15$  when compare with SSSS2L0, SSSS2T0 and SSSS4C0.
- 6-Increase the cutout ratio at  $\delta=0.125$   $\beta=1$  will lead to decrease the K (10, 21 and 10.6)% for SSSS2L3, SSSS2T3 and SSSS4C3 respectively at  $\eta=0.15$  when compare with SSSS2L0, SSSS2T0 and SSSS4C0.

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