



## Nonlinear Analysis of Bridge Girders Subjected to Lateral Impact Loading

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### ABSTRACT

This paper aims to investigate the nonlinear dynamic analysis of prestressed concrete bridge girders subjected to impact loading from collision with over-height vehicles.

Two cases with/without diaphragms are discussed. The FEM is used to model the prestressed bridge girders. It is assumed that vehicle load is to be in accordance to HS20 of AASHTO 2012 and its velocity is 40km/h. the impact load is modeled as horizontal forces applied at the lower edge of exterior girder at mid span.

The addition of diaphragms is found to decrease the lateral and vertical displacements in the girders by up to 86.8% and 84.3%, respectively. A decrease in the longitudinal and vertical stresses by up to 50.6% and 65.8%, respectively is also noted.

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## التحليل اللاخطي لعوارض الجسر المعرضة لتحميل صدمي جانبي

### الخلاصة

يهدف هذا البحث إلى دراسة التحليل الديناميكي اللاخطي لعوارض الجسور الخرسانية مسبقة الجهد المعرضة إلى التحميل الصدمي الناتج من تصادم المركبات ذات الارتفاع المفرط. تناولت الدراسة حالتين مع أو بدون الحواجز العرضية (diaphragms). استخدمت طريقة العناصر المحددة لتمثيل عوارض الجسور مسبقة الجهد. تم اعتبار ان حمل المركبة هو طبقاً للمواصفة HS20 وسرعتها 40 كم/ساعة. الحمل الصدمي تم تمثيله بقوة افقية مسلطة على الحافة السفلى للعارضة الخارجية في منتصف فضاءها. وجدت الدراسة ان إضافة الحواجز العرضية تؤدي إلى نقصان في الإزاحات الجانبية والعمودية في العوارض بمقدار 86.8% و 84.3% ، على التوالي. وان الاجهادات الطولية والعمودية تتناقص بمقدار 50.6% و 65.8% ، على التوالي.

### الكلمات المفتاحية

مفاتيح البحث: الحواجز العرضية في الجسور،  
التصادم الجانبي، العناصر المحددة

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**Introduction:**

In today’s transportation systems there are numerous prestressed concrete structures such as vehicle bridges that might be subjected to regarded or disregarded severe impact loadings. The effect of impact loading on structural response of prestressed structure is not very well studied [1].

The application of intermediate diaphragms to prestressed concrete girders may mend impact resistance of bridges. However, there are few studies in the literature addressing the effect of intermediate diaphragms on the impact damage of bridge girders. The role of intermediate diaphragms in mending the impact resistance is also not well defined [2].

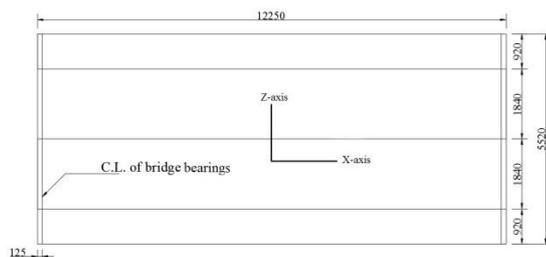
One of the main tasks of the diaphragm is to provide lateral support to the girders. In general, it is assumed that the interior diaphragms basically improve the transverse load distribution and stiffen the full structure with regard to vibration [3]. Fig. (1) shows the laterally impact load by the truck with bridge girder [4].



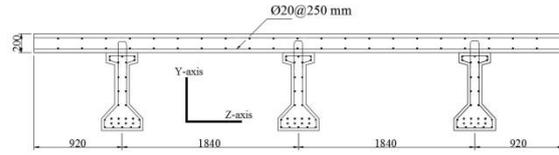
**Figure 1. The laterally impact load with bridge girders**

**Description of the Experimental Bridge Model**

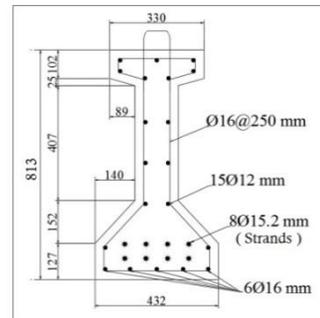
The bridge concrete model adopted for analysis in this study is previously tested by **Pizhong Qiao**, et al [5]. All spans are geometrically similar, having a deck with dimensions (5520\*12250\*200) mm as shown in Fig. (2). Three prestressed concrete girders (I-section) are supporting each simply supported span as (hinge-hinge). The details are shown in Fig. (3), and the size of I-girder with details of the reinforcement and prestressed tendons are shown in Fig. (4). Material properties and prestressing force value are listed in Table (1).



**Figure (2) Plan view of the bridge tested [2]**



**Figure 3: Cross-section view of the bridge tested**



**Figure 4: Details of reinforcement of the prestressed concrete I-girder**

**Table (1) Properties of bridge model**

The property	Value
Modulus of elasticity for concrete (MPa)	20000
Poisson's ratio for concrete	0.2
Compressive strength for prestressed concrete I-girder (MPa)	42
Compressive strength for concrete deck (MPa)	30
Modulus of elasticity for reinforcement (MPa)	200000
Poisson's ratio for reinforcement	0.3
Jacking force / Pretensioned system (kN)	180
Tensile strength of prestressed tendons (MPa)	1860

**Modeling of Impact Forces:**

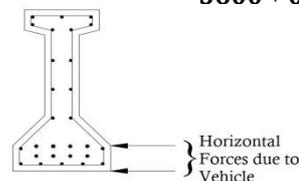
The load simulated in ANSYS model is taken as concentrated loads, applied at some points at the side of bottom flange of girder as shown in Fig. (5). For horizontal forces, the load decreases linearly from 725747.78 N to 0 (the total force at points of application).

The value of forces are calculated as follows:

$$F = M * a, \quad a = \frac{V_0 - V_1}{t}$$

$$V_0 = \frac{40km}{hr}, \quad V_1 = 0, \quad t = 0.5 \text{ sec}, \quad M = 32658.65kg$$

$$F = 32658.65 * \frac{40 * 1000}{3600 * 0.5} = 725747.78 \text{ N}$$



**Figure 5: Details of applied loads from impact on the girder**

**Applications:**

**Bridge girders with / without diaphragms:**

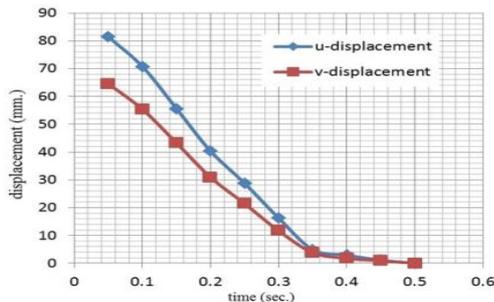
In the first case, girders without diaphragms are considered. The load is applied over a width of 500 mm. The impact load is from a collision of HS20 truck weighted 32658.65 kg with initial velocity 40 km/hr. It is located at mid span to give maximum effect. Total horizontal load is 725747.78 N located at six nodes, each node has decreases linearly from 120957.96 N to 0, and total time period of impact loading is 0.5 sec. The impact load with time period is obtained as shown in Table (2).

**Table (2) the impact load with the time period**

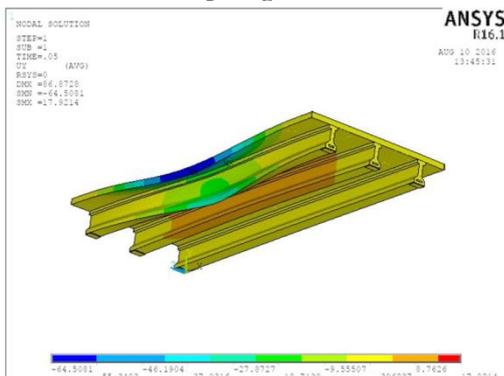
Time at end period (sec.)	Horizontal force (N)
0.05	120957.96
0.10	107518.19
0.15	94078.41
0.20	80638.64
0.25	67198.87
0.30	53759.09
0.35	40319.32
0.4	26879.55
0.45	13439.77
0.50	0.00

**Results of the Analysis of Application**

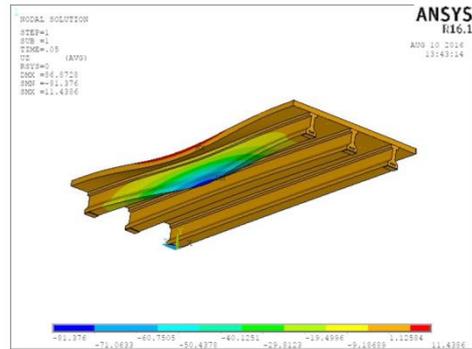
The maximum value of displacement at time step in bridge without diaphragms is shown in Fig. (6), and also the maximum displacements in y and z-axes are shown in Figs. (7) and (8), respectively.



**Figure 6: The displacements with time in bridge model without diaphragms**

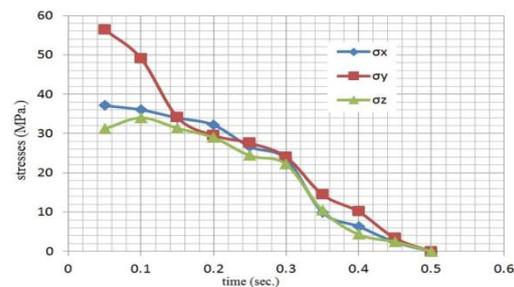


**Figure 7: Maximum displacement (mm) in x-direction for bridge without diaphragms**

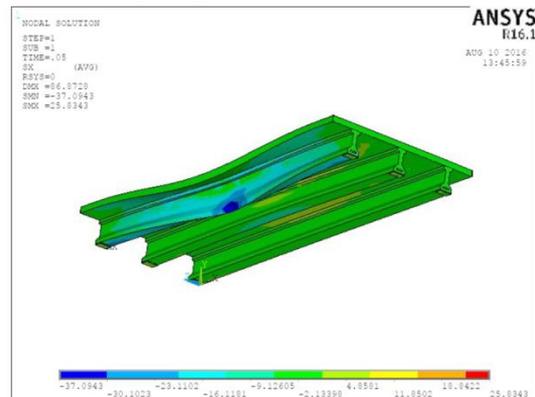


**Figure 8: Maximum displacement (mm) in z-direction for bridge without diaphragms**

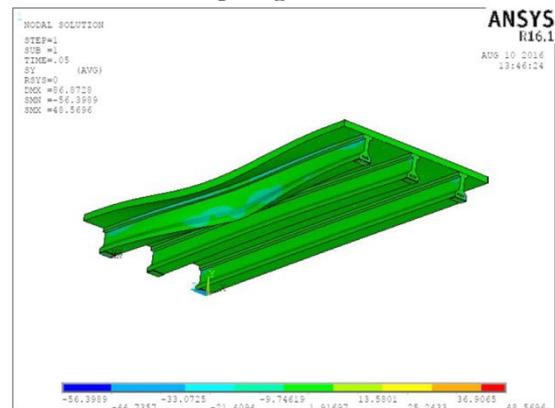
The maximum value of stress at each time step in bridge model B8 is shown in Fig. (9), and also the maximum stresses in x, y and z-axes are shown in Figs. (10), (11) and (12), respectively.



**Figure 9: The stresses with time in bridge model without diaphragms**



**Figure 10: Maximum stress (MPa) in x-direction for model without diaphragms**



**Figure 11: Maximum stress (MPa) in y-direction for model without diaphragms**

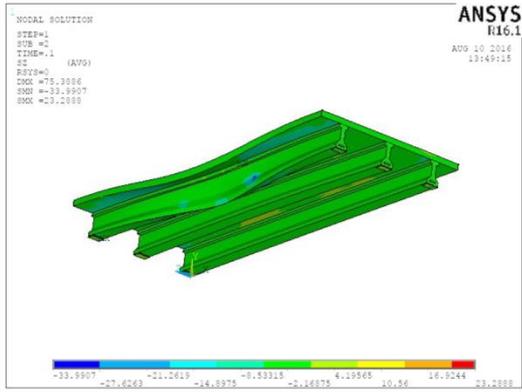


Figure12: Maximum stress (MPa) in z-direction for model without diaphragms

The maximum value of shear stress at each time step in bridge model without diaphragms is shown in Fig.(13), and also the maximum shear stresses in xy, yz- and xz-planes are shown in Figs. (14), (15) and (16), respectively.

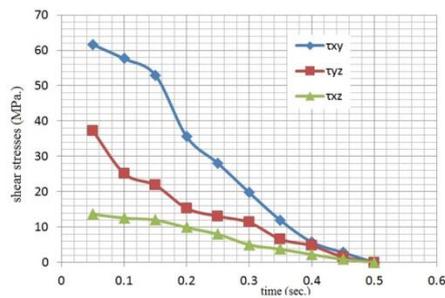


Figure 13: The shear stress with time in bridge model without diaphragms

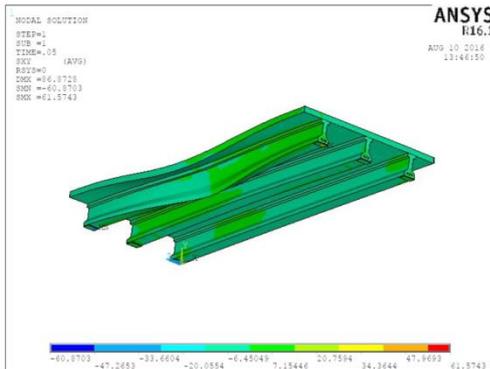


Figure 14: Maximum shear stress (MPa) in xy-plane for model without diaphragms

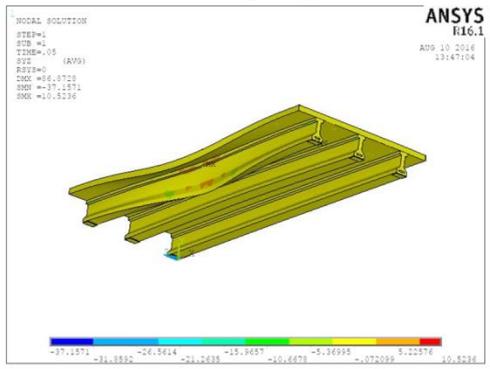


Figure 15: Maximum shear stress (MPa) in yz-plane for model without diaphragms

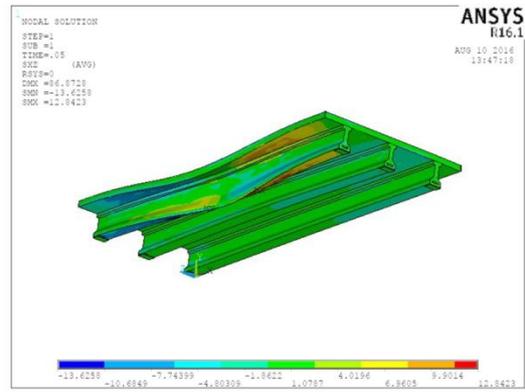


Figure 16: Maximum shear stress (MPa) in xz-plane for model without diaphragms

The maximum value of displacement at each time step in bridge model with three diaphragms is shown in Fig. (17), and also the maximum displacements in y and z-axes are shown in Figs. (18) and (19), respectively.

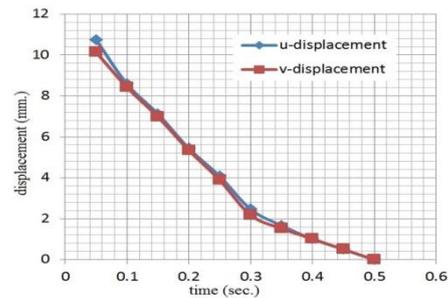


Figure 17: The displacement with time in bridge model with three diaphragms

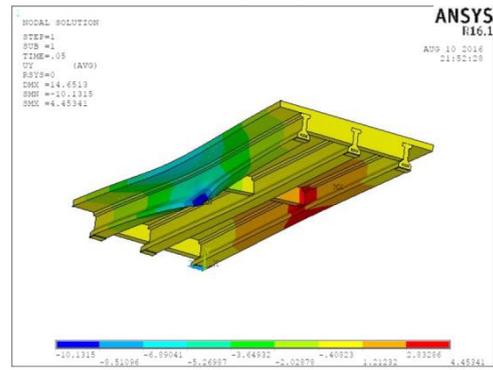


Figure 18: Maximum displacement (mm) in y-direction for model with three diaphragms

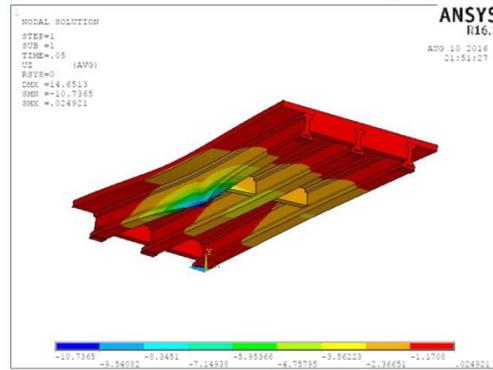


Figure 19: Maximum displacement (mm) in z-direction for model with three diaphragms

The maximum value of stress at each time step in bridge model with three diaphragms is shown in Fig. (20), and also the maximum stresses in x, y and z-axes are shown in Figs. (21), (22) and (23), respectively.

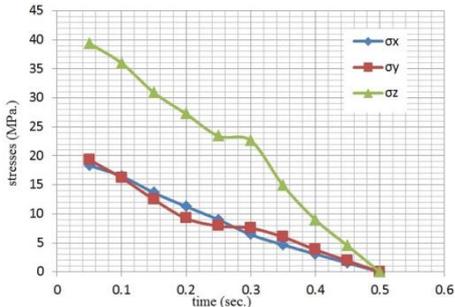


Figure 20: The stress with time in bridge model with three diaphragms

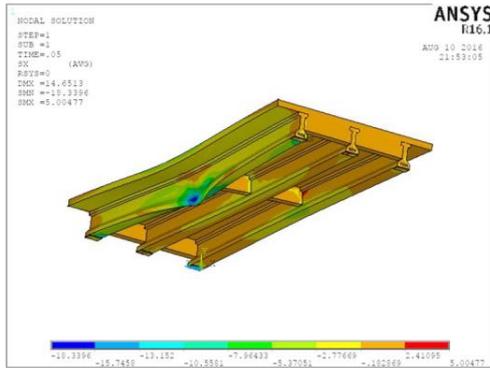


Figure 21: Maximum stress (MPa) in x-direction for model with three diaphragms

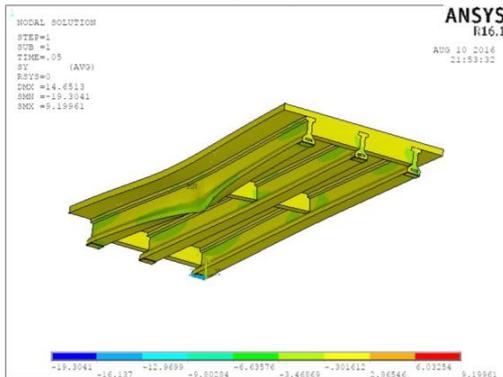


Figure 22: Maximum stress (MPa) in y-direction for model with three diaphragms

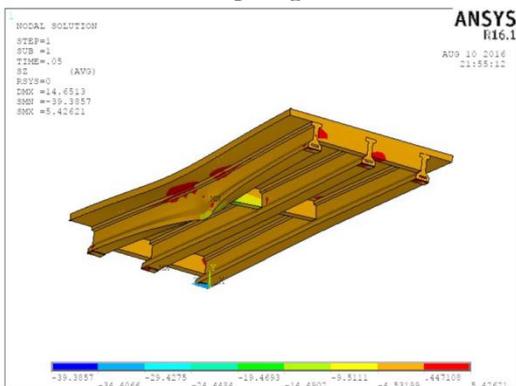


Figure 23: Maximum stress (MPa) in z-direction for model with three diaphragms

The maximum value of shear stress at each time step in bridge model with three diaphragms is shown in Fig. (24), and also the maximum shear stresses in xy, yz and xz-planes are shown in Figs. (25), (26) and (27), respectively.

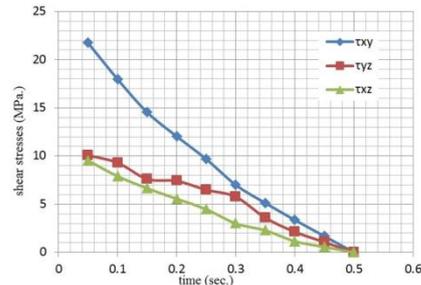


Figure 24: The shear stress with time in bridge model with three diaphragms

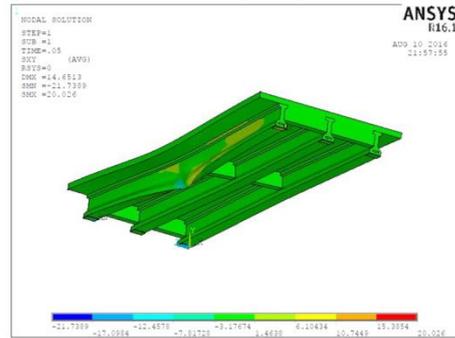


Figure 25: Maximum shear stress (MPa) in xy-plane for model with three diaphragms

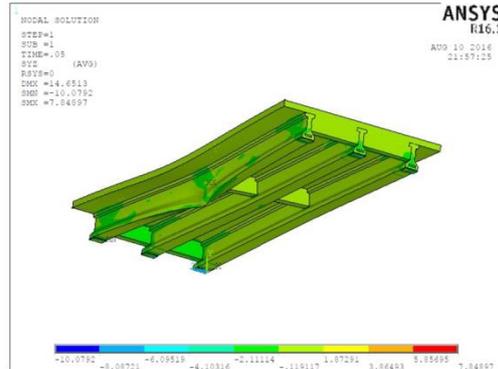


Figure 26: Maximum shear stress (MPa) in yz-plane for model with three diaphragms

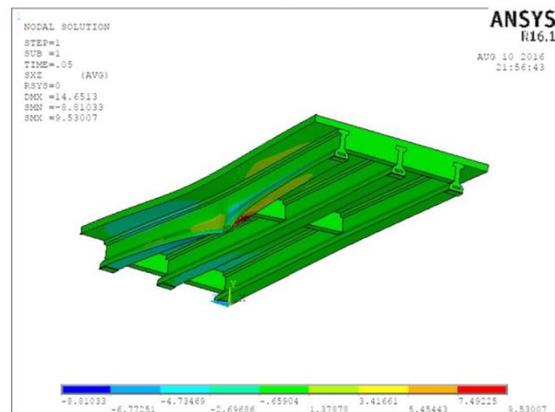
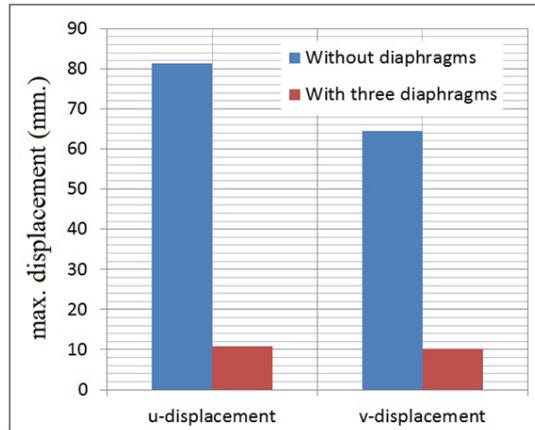


Figure 27: Maximum shear stress (MPa) in xz-plane for model with three diaphragms

### Comparison of the Results of Application

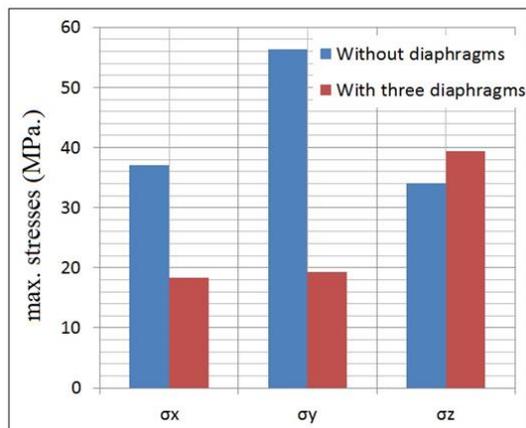
The results of the two last models above, the results with/without diaphragms, observe the changes value taking place in the following states:

- a) The relationship of maximum values of displacement with/without diaphragms is shown in Fig. (28).



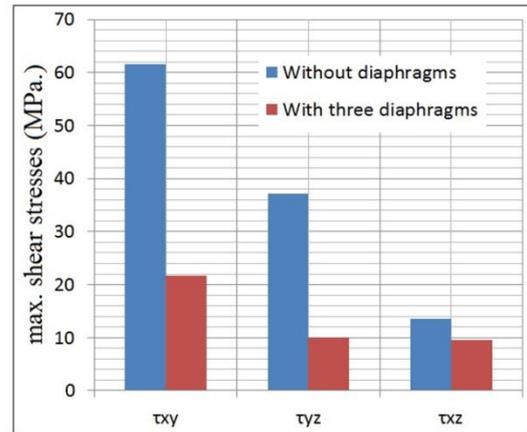
**Figure 28: Effect of diaphragms on the maximum values of displacement**

- b) The relationship of maximum values of stresses with/without diaphragms is shown in Fig. (29).



**Figure 29: Effect of diaphragms on the maximum values of stresses**

- c) The relationship of maximum values of shear stresses with/without diaphragms is shown in Fig. (30).



**Figure 30: Effect of diaphragms on the maximum values of shear stresses**

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