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Seismic Responses of Panelled Beams with Different Configurations Cover Large Circular Area

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Abstract: The big project requires special structures dive important of this project. The special architectural requirements for these projects need special structural design, for high performance in both dynamic and static cases. Panelled beams with circular edge beam has special behavior under seismic loads, with different panelled beams configurations with circular edge beam will be studied to make the most suitable panelled beams arrangement with acceptable performance under seismic loads. Six 3D panelled beams with circular edge beam with 6 stores with different panelled beams arrangements (skew panelled beams or perpendicular panelled beams configurations) studied to show the ideal performance of the structures subjected to earthquakes. Skew panelled beams supported on circular beams for angles 30^o, 45^o and 60^o are not suitable for those structures subjected to earthquakes with comparison with perpendicular panelled beams supported on circular beam which performed well under seismic loads, and the panelled beams supported on circular beam resist tensional forces results from earthquakes.
Keywords: gird system; panelled beams; circular beams; seismic performance; perpendicular panelled beams.

I. INTRODUCTION

Grid floor system is a conventional method of construction in which beams will be spaced at regular intervals in perpendicular directions and monolithic with slab. They are generally employed for architectural reasons for large spaces such as auditoriums, theatre halls, where column and free space is often the main requirement.

El-Shaer, 2014 studied laterally loaded static and dynamic performance and comparison between three types of slabs systems (flat slab, ribbed slab, and panelled beam slab) used in high rise buildings and concluded that ribbed slab performed well under later static and dynamic load, but in flat slab cases suffer from punching shear, and panelled beams system is with moderate response.

Tzevelekas and Kontoni, 2016, studied building with flat slab system with different configurations subjected to earthquake and concluded that the shear wall combined with this system may give stiff system that reduce the straining actions with the low or moderate building with flat slab covering system.

Mishra, *et al.*, 2015, studied HRB with different shear wall configurations subjected to earthquake and concluded that the interior position of shear is more effective in resistance earthquake effects.

Hossain and Famiyesin, 2001, developed an equations constitute the primary database of an intelligent computer-aided-design system for accurate on arbitrary slabs which is capable of generating a secondary database through systems of interpolation and can be used for design assistance purposes. Johnson D., 1995, developed the analysis of torsion ally isotopically and showed that method effective for the analysis of three slabs of varying complexity.

Zeng *et al.* 2015 investigated vibration of train slab Track Bridge under vibration of the moving train and the vibration of earthquakes.

Janghorban and Hoseini, 2018, studied post tensioned pre-stressed concrete edge columns connection slabs for long span and concluded that the method aids in constructing larger spans, more useful floor height, and reduces the total weight of the building and concluded that the addition of a shear cap increases the flexural capacity, further increases the shear strength and converts the failure mode of connections from shear rigidity to flexural ductility.

Xi et al. (2018) studied seismic behavior the beam column joints in different beam depths and concluded that the developed model was accurate to represent the eccentric joint to predict the shear and deformation of the eccentric column beam joints under seismic loads.

Turker and Gungor (2018) studied wide-beam and ribbed-slab low rise building system, subjected to earthquake and indicated that the predicted seismic performances were achieved for the low-rise (4-story) building with the high ductility requirements but the moment resisting frame with high ductility was not adequate for the medium-rise building and the sufficient amount of shear-walls to the system proved to be efficient way of providing the target performance of structure.

Guenaneche et al. (2019) evaluated plated RC beam and concluded that the interfacial stresses play a significant role in understanding this premature debonding failure of such repaired structures.

Ibraheem et al, (2014), analyzed L-shaped spandrel beams under eccentric concentrated load at mid-span to obtain a combined loading case: torsion, bending, and shear and concluded that the developed model can accurately predicted the loads and deflections for various types of reinforcements in spandrel beams, and captured the critical crack regions of these beams.

Rahmanian et al. (2014) summarized literatures on the optimization of reinforced concrete beams and suggested that nonlinear deterministic approaches can be efficiently employed to provide optimal design of RC beams.

Parrotta et al. (2014) studied the seismic behaviour of reinforced concrete beams experimentally and theoretically and concluded that the rheological effects can be important and must be accounted to understand the experimental results and the method of EC-2 tends to underestimate the tension-stiffening effects, leading to inaccuracies in the estimations of deflection and the results are agreement with the experimental results, showing the feasibility of the proposed modification.

Xiao et al. (2017) studied dynamic behaviours RC beams in the laboratory and discover that the effects of loading rates on the failure model and load-displacement curve of RC beams and on the cracking, ultimate, yield and failure strengths and displacements, ductility and dissipated energy capability of RC beams these results compared with 3D FEM of RC beams, which showed a great match.

Sucharda and Konecny, (2018), carried non-linear analysis of reinforced-concrete beams involving the tensile strength of concrete, fracture energy and the modulus of elasticity to compare old and new specifications based on the series of experiments which involve a large number of reinforcement, cross-section and span variants, which subsequently enabled a wider verification and discussion of the usability of the non-linear analysis and constitutive concrete model selected.

Models of multi-storey circular structures with different diameters without columns in the middle that variable were taken, including the dimensions of the dimensions of the beams and the distances between the beams were changed (2 m - 3 m - 4 m). In order to get architectural designs in unique architectural designs such as (meeting rooms, theaters, wedding halls, hotels with spaces and large spaces without columns in the middle the effect of earthquakes on the circular structures in various forms was examined to find the exact behavior under seismic loads. The effect of earthquakes on the structures was taken by changing the angles of the beams from 30 degrees to 45 degrees and 60 degrees. On the substitutions, the two directions were changed in the direction X, Y, where 2 x 4 m was used in the vertical direction (90° angle) and 3 x 4 m was used in the perpendicular direction (90° angle). Four types of known earthquakes (El-Centro, Chi Chi, Hollister, and Loma Prieta earthquakes) were used.

II. MODEL DESCRIPTION

To find the effect of the earthquake on the response of grid beams with circular edge beam different cases of grid beams were studied with different configurations. To improve the effect of the earthquakes on the grid beams different configurations of panelled beams with circular edge beam studied but the internal divided like the different angles between x and y directions grid beams three different angles used 30^o, 45^o and 60^o (Fig. 1-a, 1-b and 1-c), and perpendicular grid beams with different portions distances 2x4m, 3x4m and 4x4m (Fig. 1-d, 1-e and 1-f). The columns also represented as frame elements with constant square cross sections 700x700m (to ignore the unsymmetrical effect) distributed on the perimeter of the circular edge beams of the models at central angles 36^o(elven columns) each column direction rotated with its central angle.

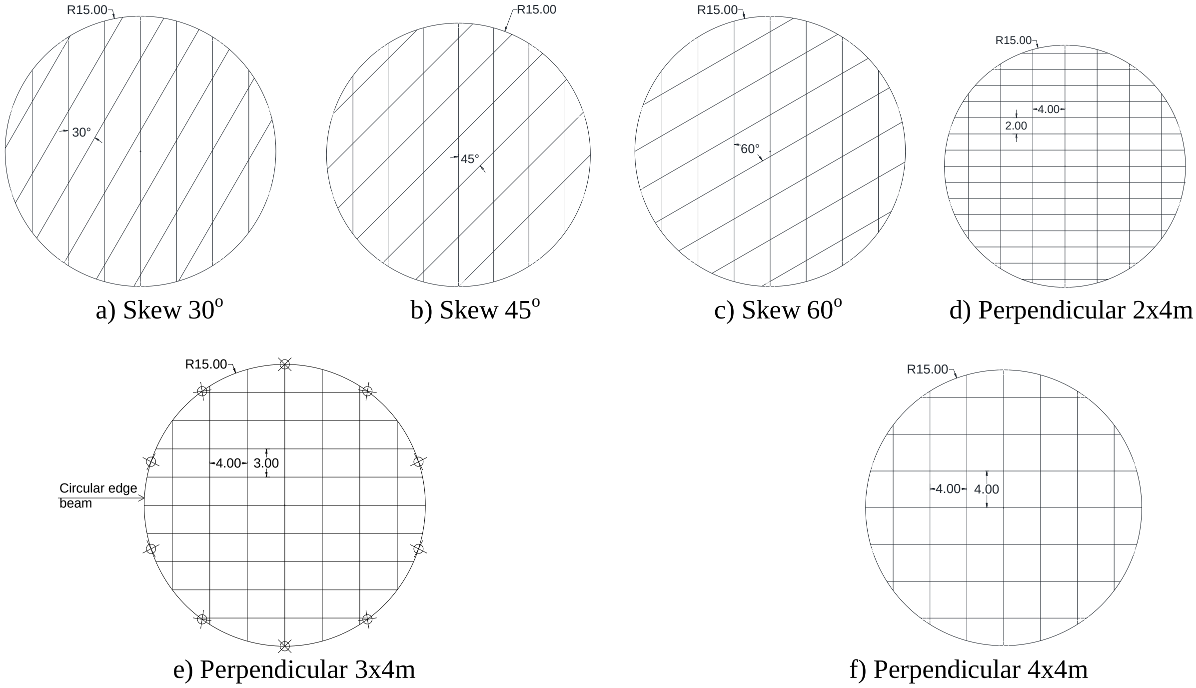


Fig. 1: planes of the tested models.

Figure 2 represented the 3D models of the tested models used in SAP2000. In SAP2000 grid beams represented by from elements (these elements response to moments in y directions, normal force, shear force and torsion force), and so the circular edge beams which the grid beams supported on them, the shell elements used to represent the slabs, the height of each floor 3m for all 7 floors model.

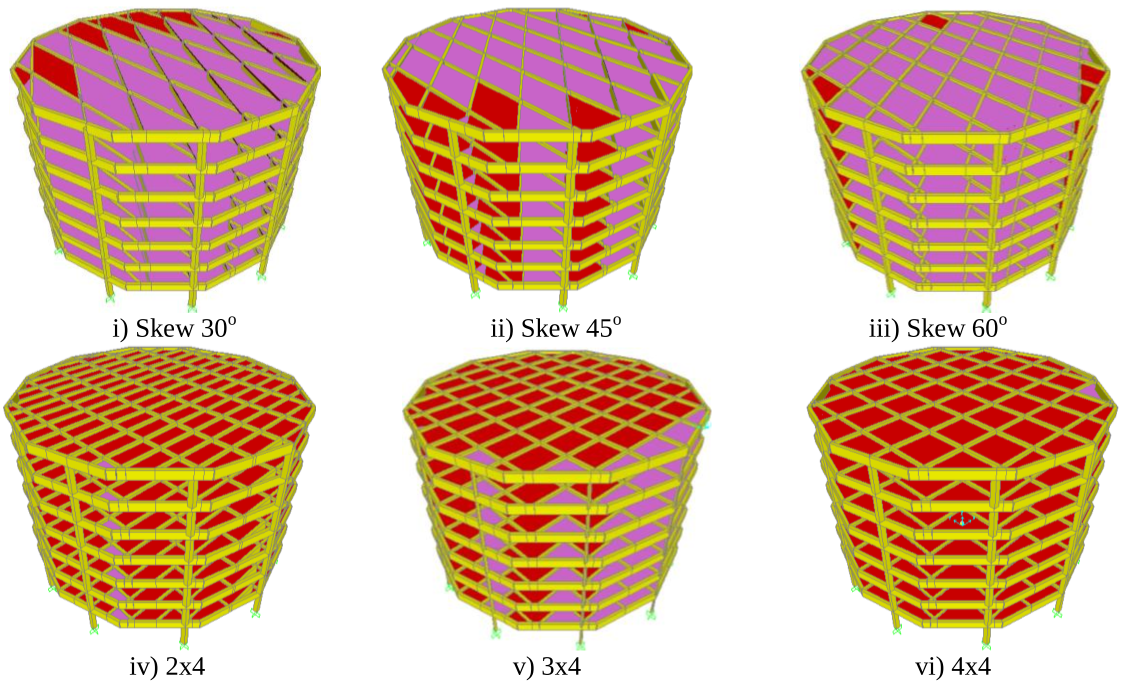
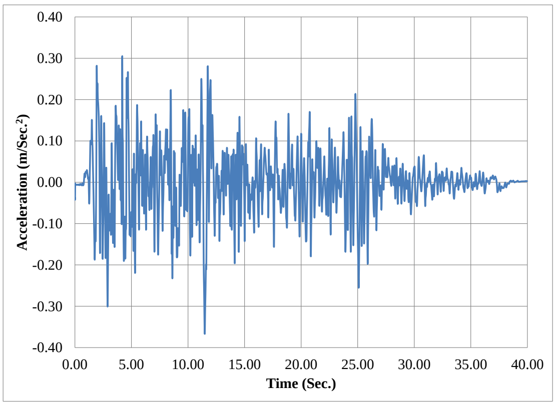


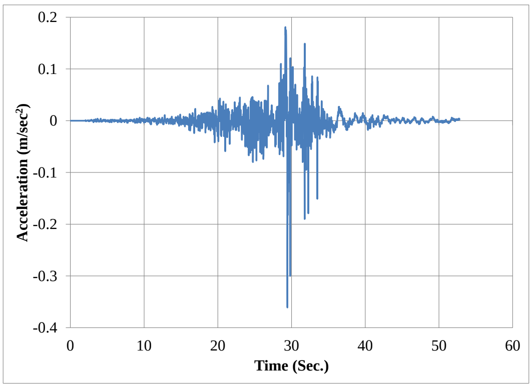
Fig. 2: 3D models represented in SAP2000.

III. RESULTS AND DISCUSSION

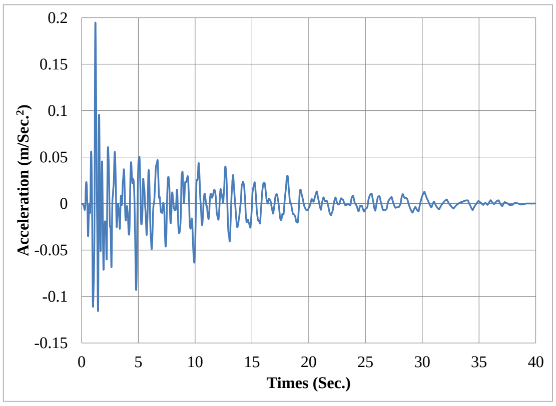
Five models were represented to show the seismic response of grid beams with circular edge beam, the FEA with SA2000 program was used the most effective program in time history analysis. The loads used are dead loads (own weight of the structural elements of the system) and the earthquake loads which get from four famous earthquakes (El-Centro, Chi Chi, Hollister, and Loma Prieta earthquakes), Fig. 3 shows the earthquake waves. The responses of the five models were measured for torsion, normal force, bending moment and lateral displacements.



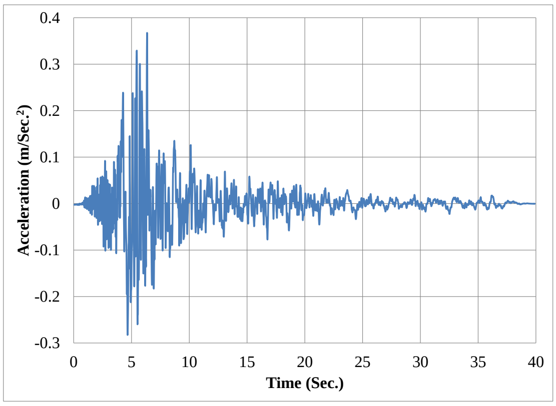
i) El-Centro Earthquake wave



ii) Chi Chi Earthquake wave



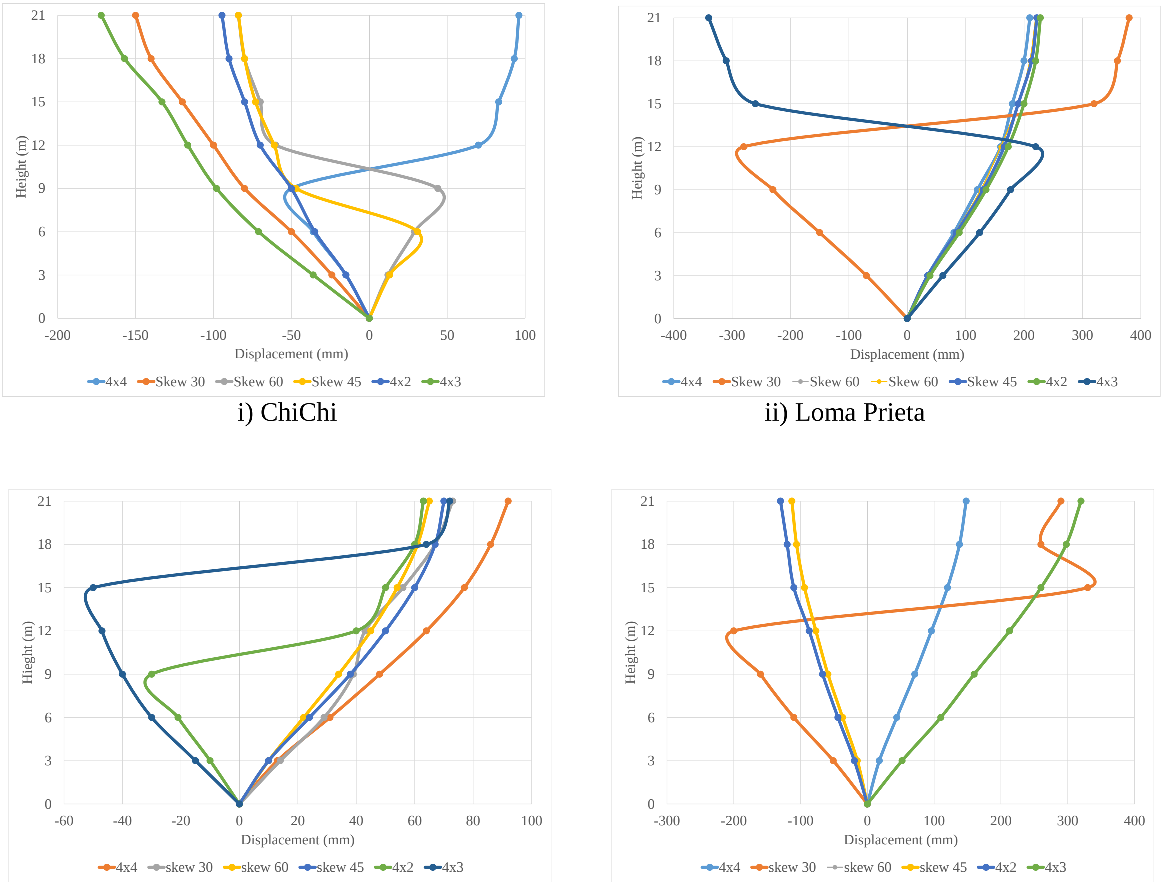
iii) Hollister Earthquake wave



iv) Loma Prieta Earthquake wave

Fig. 3: Earthquakes waves.

Figure 4 show the lateral displacements of the five models under different of earthquakes with different grid beams configurations. Fig. 4-i show the lateral displacements of different models subjected to Chi Chi earthquake the reference case (perpendicular panelled beams with division 4x4m) is used to compare all cases, the most displacements values are for skew 30 and 4x3 cases (nearly bigger than control case by 1.5 times), the 4x4 control case nearly equals to 4x2, skew 45 and skew 60 panelled beams rest on circular beam cases. Fig.4-ii represents the lateral displacements of the models subjected to Loma Prieta earthquake skew 30 case record the high values of lateral displacements and it is high than the control, skew 60, skew 45, and 4x2 cases by neatly 2 times, but 4x3 case record 1.5 times more than the control case. Fig.4-iii shows the lateral displacements of the models subjected to Hollister earthquake, skew 30 and 4x3 cases show distortions in the displacements in the height of the models, but for the control case (4x4) and skew 60, skew 45, and 4x2 shows a conversion behavior for the displacements in all heights. Fig. 4-iv show the lateral displacements of the models subjected to El-Centro earthquake, the lateral displacements, 4x4, skew 60, skew 45 and 4x2 models show similar behavior for the values and normalize, but 4x3 and skew 30 show a distortion behavior in the displacements all over the height of the models and a high value in the displacements with respect to the corresponding values of the control case (4x4) (more than control case by nearly 2 times).



i) ChiChi ii) Loma Prieta

iii) Hollister iv) El-Centro

Fig. 4: Displacements due to different kinds of earthquakes and different panelled beam configurations.

Table 1 represents and defines the symbols used in the next part.

Table 1: Definitions of symbols used in the next curves.

Symbol	Definition	Symbol	Definition
chi chi4	control case subjected to Chi Chi earthquake	chi chi S45	Skew 45 case subjected to Chi Chi earthquake
Loma Prieta4	control case subjected to Loma Prieta earthquake	Loma PrietaS45	Skew 45 case subjected to Loma Prieta earthquake
hollister4	control case subjected to Hollister earthquake	Hollister S45	Skew 45 case subjected to Hollister earthquake
El-centro4	control case subjected to El-Centro earthquake	El-centro S45	Skew 45 case subjected to El-Centro earthquake
chi chi S30	Skew 30 case subjected to Chi Chi earthquake	chi CHI 2	4x2 case subjected to Chi Chi earthquake
Loma Prieta S30	Skew30 case subjected to Loma Prietaearthquake	Loma rieta2	4x2 case subjected to Loma Prieta earthquake
Hollister S30	Skew 30 case subjected to Hollister earthquake	Hollister 2	4x2 case subjected to Hollister earthquake
El-centro S30	Skew 30 case subjected to El-Centro earthquake	El-centro 2	4x2 case subjected to El-Centro earthquake
chi chi S60	Skew 60 case subjected to Chi Chi earthquake	chi chi 3	4x3 case subjected to Chi Chi earthquake
Loma PrietaS60	Skew60 case subjected to Loma Prietaearthquake	Loma Prieta 3	4x3 case subjected to Loma Prieta earthquake
Hollister S60	Skew 60 case subjected to Hollister earthquake	Hollister 3	4x3 case subjected to Hollister earthquake
El-centro S60	Skew 60 case subjected to El-Centro earthquake	El-centro 3	4x3 case subjected to El-Centro earthquake

Figure 5 shows the base shear of the models subjected to different earthquakes and with different grid beams configurations, the response of the models show the values of each model to carry base shear under different earthquake kinds for skew30 and 4x3 cases look to carry more than the rest cases the control case and the rest cases carry small values of base shear with respect to skew30 and 4x3 cases.

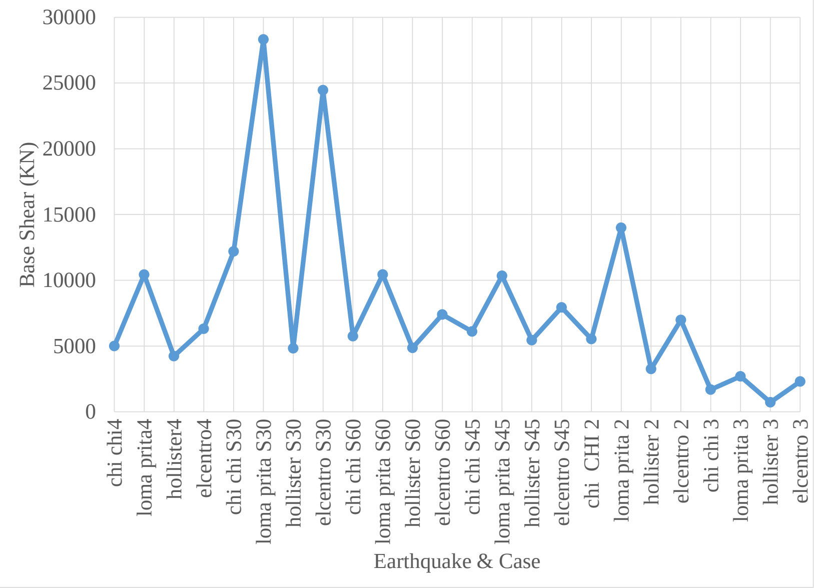


Fig. 5: Base shear under earthquakes loads with different panelled beam configurations.

Figure 6 represents the base moments of the panelled beams with different configurations supported on circular edge beam subjected to different of earthquakes, all models carry nearly the same values of base moments except the skew 30 case with 2 times bigger than all cases.

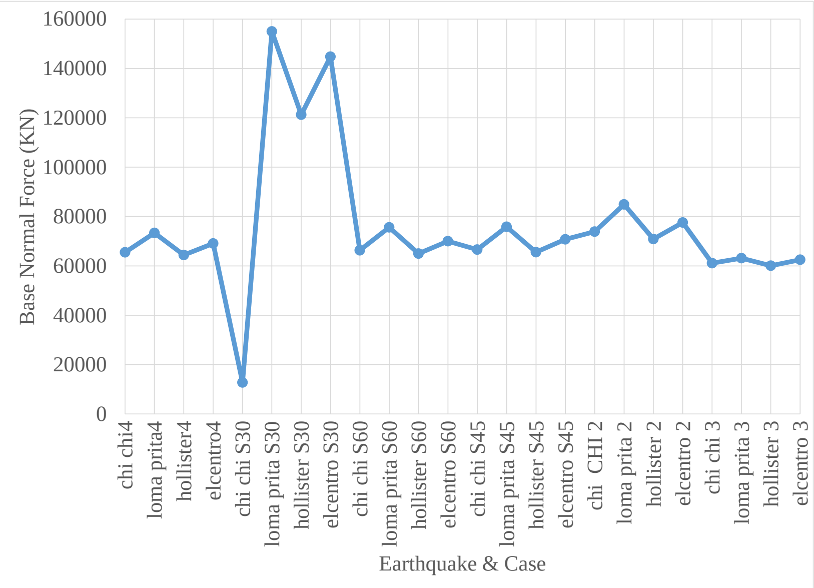


Fig. 6: Base Normal under earthquake loads and different panelled beam configurations.

Figure 7 shows the total axial forces carry out by the models subjected to different earthquakes waves and different panelled beams configurations, skew30 case is bigger than control case by nearly 2.5 times, the rest of cases show a convergent behavior in the values of the base axial force, the values of total axial force carry by models are different because of the different response of each model which is respect to the different configurations of grid beams.

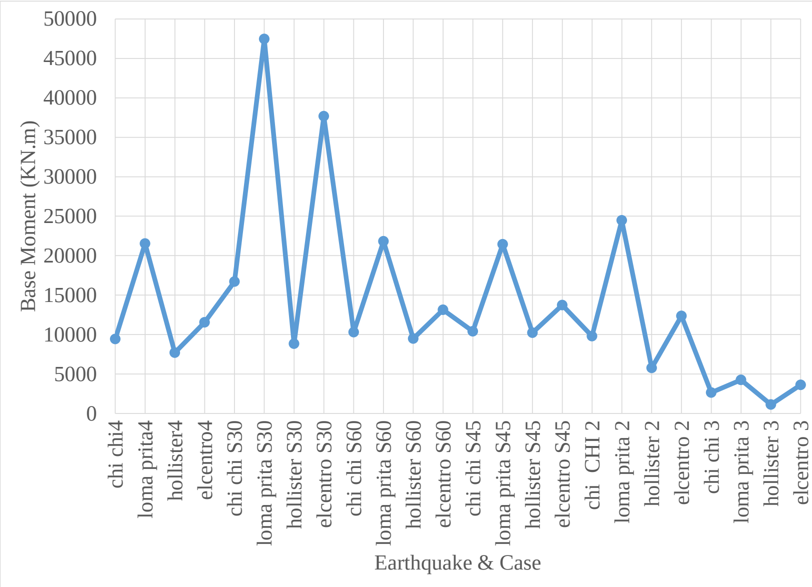
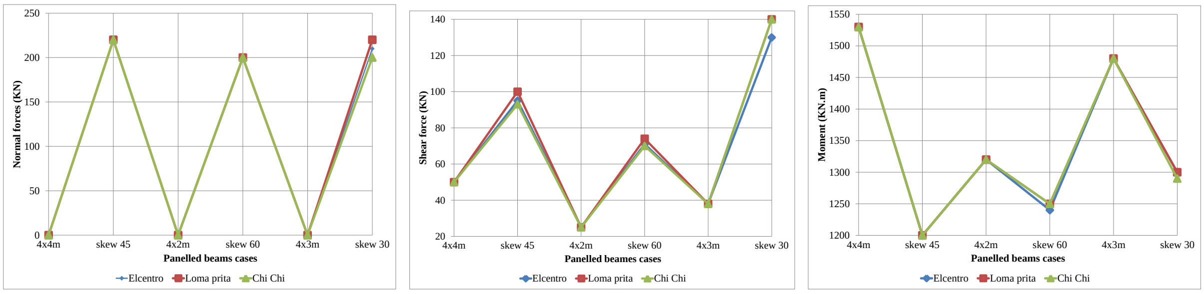


Fig. 7: Base moment under earthquake loads and different panelled beams configurations.

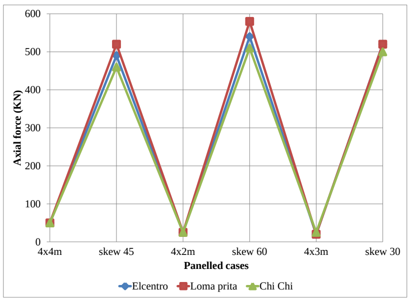
Figure 8 shows maximum forces in panelled beams with different configurations under seismic load, Fig. 8-a shows the maximum normal forces in the panelled beams it is clear that the perpendicular panelled beams supported on circular beam the normal forces nearly equals to zero but for skew panelled beams supported on circular beams the axial forces nearly equals to a specific value for the three different used earthquakes. Fig. 8-b represents the maximum shear force in panelled beams, the perpendicular panelled beams supported on circular beam recorded the minimum shear force compared with the corresponding cases of the skew panelled beams, all earthquakes used are show the same behavior, the maximum shear force are recoded in skew 30 panelled beams and the following case is skew 45 panelled beams. Fig. 8-c shows the maximum bending moment in different panelled beams configurations and different earthquakes, the maximum bending moments recorded in a perpendicular 4x4 then 4x3m and 4x2m panelled beams.



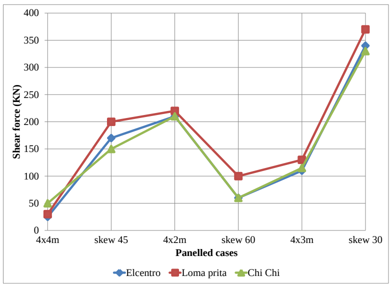
a) Normal Force b) shear Force c) bending moment

Fig. 8: Maximum forces in panelled beams

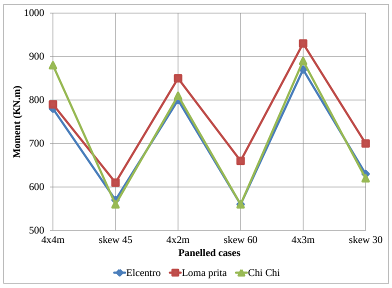
Figure 9 shows maximum forces in circular edge beam with different configurations of paneled beams under seismic load, Fig. 9-a shows the maximum normal forces in circular beam, the perpendicular panelled beams supported on circular beam the normal forces nearly equals to zero but for skew panelled beams supported on circular beams rise the axial forces in circular beam nearly equals to a specific value for the three different used earthquakes. Fig. 9-b represents the maximum shear force in the circular beam, for the perpendicular panelled beams supported on circular beam, the minimum shear force recorded in 4x4m and skew 60, but the maximum shear force in circular beam recorded in skew 30 case, generally skew panelled beams recorded the maximum shear forces in the circular edge beam. Fig. 9-c shows the maximum bending moment with different panelled beams configurations and different earthquakes in circular edge beam, the maximum bending moments recorded in a perpendicular 4x4 then 4x3m and 4x2m panelled beams, bending moment in circular beam in skew panelled beams equals to nearly 0.75 the corresponding cases in the perpendicular panelled beams. Fig. 9-d shows the maximum torsion in circular beam with different panelled beams configurations and different earthquakes, the maximum torsion recorded in skew 30 panelled beams.



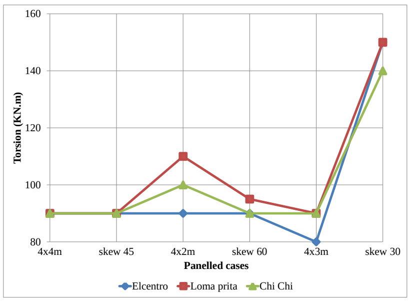
a) Normal Force



b) shear Force



c) bending moment



d) bending moment

Fig. 9: Maximum forces in circular beam

IV. CONCLUSIONS

The grid beams supported on circular beam behave different from these supported on straight edge beams. Six models 4x4 (control case). Skew 30, skew 45, skew 60, 4x2 and 4x3 analyzed under different kind of earthquakes to show the different behavior of each panelled beams configurations, the response of each models was measured by lateral displacements, base shear, base axial force, and base moments, from the time history analysis of each model under four different kinds of earthquakes the following conclusions can be drown out:

- The displacements in the same plane of 4x4, 4x3 and 4x2 models are constant for all earthquakes.
- The displacements for skew30, skew45 and skew60 in the same floor are not equals due to the inclinations of panelled beams in different direction with connection with circular edge beams.
- The displacements over the height of the models are nearly equals with smoothly interval, except for skew30 and 4x3 cases which increased by nearly 1.3 to 1.5 times than control case with distortion in the models with height.
- The base shear increase twice times for skew30 than control case and nearly for the rest of models either.
- Base axial force for skew30 is bigger than control case by nearly 2 times all cases show a conversion values with the control case.
- A base moment for skew30 case is bigger than control case by 2.5 times all cases show oscillatory values but also low than skew30 case.
- The skew30 case with circular edge beam show a destructive behavior for both lateral displacements and forces, but 4x3 model show destructive behavior for lateral displacements.
- Maximum axial force and shear force in panelled beams occur in skew panelled beams case.
- Maximum bending moment in panelled beams occurs in perpendicular panelled beams case.
- Maximum axial force and shear force in circular edge beam occur in skew panelled beams case.
- Maximum bending moment in circular edge beam occurs in perpendicular panelled beams case.
- Maximum torsion in circular edge beam occurs in skew 30 panelled beams case.
- Circular edge beam for panelled beams may improve the behavior of such structure spatially those subjected to earthquakes, the configurations of panelled beams may be affect as a very important factor to survive such structures under earthquakes loads.

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