Inelastic seismic response of diagrid structure under critical seismic zone due to bi-directional ground motion

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Abstract – *The innovative diagrid structural system has emerged with an aesthetic architectural view in the design of tall building structures. Nonlinear dynamic analysis is investigating the response of diagrid structural system under critical seismic zone owing to bi-directional excitation has been reported. Furthermore, in this study, the seismic performance of square and circular diagrid structures with different brace angles are compared to sustain the stability in critical seismic zone in India. Seismically operated asymmetric structures are more vulnerable than symmetric structures because of the coupling of lateral and torsional vibration. For this purpose, asymmetric system makes a challenging issue to determine the critical response of load resisting elements for serviceability. Structures are generally experienced on degradation matter of stiffness and strength in the event of strong seismic excitation. In that case, the structural deterioration occurs due to the external loads, clearly demonstrates that the elements have large amount of losses and fragility finitely. A broad conclusion presents in this study that to help the fine tune of the seismic code provisions.*

***Key Words*: Inelastic response, Seismic response, Bi-directional, Angle of brace, Near-fault, Critical zone.**

1. INTRODUCTION

Seismic analysis of R/C structure is necessary aspect in the recent past. Generally, diagrid structure is light weight structure compelling against gravity and also resisting the excess seismic loading, controlled as much as possible compared to other complex structures reasonably. The Diagrid structures are composed of triangulated sections which combat the seismic forces by axial action of diagonals provided on periphery. Structural design for diagrid system is governed by horizontal force due to lateral loads like earthquake, wind load etc. which resistible by the exterior and interior structural systems, usually braced frame, shear wall core etc. In the diagrid structural system structural patterns can be utilized to optimize the performance of structural members. Due to the rapid growth of population and increment of land values in all aspects, especially in urban and rural areas, it is the duty of a structural engineer to contrive the versatile performing structural systems. As a result, various structural systems have erupted over the years throughout the globe. The analysis of diagrid structure and its performance analysis at different angles has already been estimated by some researchers [1, 2]. The main veneration at which particular circumference the extended maximum stories are exploited and deflected in diagrid system owing to seismic loading. But in present system have paved the way for different methods of structural systems, the real challenges lie in procuring the system with high performance [3]. Whenever the soil in hilly region is stiffer or rocky, the inherent bond between soil and foundation is anemic; there is a divesting chance to collapse the structure against earth excitation in India [4, 41]. In conventional building there will be allocated number of vertical columns. But in case of diagrid vertical columns are put back by the inclined columns that are the diagonals. Diagrids are the array of triangles which has the combined ability to resist gravity and lateral loads both in a single action [5, 41-51]. The diagrid structures are stiffer, lighter in weight and have higher lateral seismic stability than the conventional system [5-9, 41-51]. Due to the diagonal or horizontal hollow supporting members and its triangulated arrangements, the lateral loads, vertical loads and distributions are easily countered [6-9]. We are not proclaiming that the extenuation of stories in this structural system at this aberrant and amorphous area against seismic load. Hence, we are looking forward for working the versatile seismic analysis. Diagrid is relatively a new structural system, the research work done or available is quite limited. The main source for any data available for diagrid is forming the diagrid buildings that have been constructed and there is only handful of them in the whole world [14-16]. A large number of studies have been made to address the issue of vulnerability of diagrid system under earthquake loading [14-18]. Even through few researchers have extensively studied this new system and put forth their findings, it is not enough to establish for seismic response of this type of structural system with secondary bracing system [11, 21]. The seismic response in a structural system is now essential parameter in recent design methodology. Generally, symmetric structures are found to be less vulnerable to seismic loading as compared to asymmetric counterparts. Structures are found to behave symmetrically under lateral loading causes of constraints owing to architectural and functional aspects. From the view of mechanics, symmetric occurs due to the coincidence of the center of mass (CM) and center of stiffness (CS). In every part of section of structure, stiffness is everywhere same and make same sense but the response of element is major differed. On the other hand, asymmetric setback is another major criterion to determine the seismic excitation of load resisting element of structure with the variation of CM and CS. This eccentric condition makes the critical response due to different parameters that create the ultimate response on MDOF system. The performance analysis of the diagrid structure is already made by some researchers but the literature regarding this in a critical seismic zone in India is still unknown. In this backdrop, this case study reckons to estimate the individual response in different stories diagrid structures. The study may provide a much better understanding of the vulnerability of such symmetric diagrid system also for asymmetric system. Several eminent examples of diagrid structures in world history are shown in Fig. 1. Dr. Kyoung Moon monitored the dynamic interrelationship between technology and architecture in tall buildings and assigned an initial step towards for diagrid structural system in 2007. Dr. Lenord studied the effect of shear leg in the diagrid buildings and developed on the work done by Moon in 2005. Researchers concluded that the performance of structure three times than the framed tube building in shear leg ratio and showed higher efficiency in carrying lateral load in high rise buildings [9-13]. Differentiate with conventional framed tubular structures without diagonals, diagrid structures are more virtual in minimizing shear deformation because they carry shear by axial action of the diagonal members [17], while conventional framed tubular structures carry shear by the bending of the vertical columns. The diagrid structures have significantly higher resistance against shear lag phenomenon than equivalent tubular structures [18]. Diagrid structure consisting of diagonal struts and ties in the periphery and an interior core with various complex shape [19, 20]. This type of structures is popular in many developed countries in the world but in India it is yet to gain importance. Researchers have estimated the seismic performance factor that is worthy way for using pushover analysis and IDA-based probabilistic approach comparison on diagrid tall structure. In that case IDA-based method gives significantly more rational value for reduction coefficient [22, 23, 47]. Very recent researchers scrutinized that hanging on the seismic reliability of multilevel response modification factor, for steel diagrid structure where steel is used 30-40% less than conventional structure that is more safety [24-26]. Last but not the least, combination of shear link to dissipate the earthquake energy with plastic design analysis model conclude that the shear link is excellently performed and adequate margin against collapse that is effective seismic force resisting system [27-30, 34, 39]. Significant amounts of work have been done in this case, but the aperture indicates the judgmental response of diagrid structure due to seismic synthetic bi-directional ground motions excitation, whether the structure of different stories for symmetric and asymmetric systems with different diagonal bracing angles in a critical seismic zone IV in India. Moreover, different parameters are considered and lie in a feasible range for diagrid response in the inelastic range. It is also intended to investigate the effect of incorporation of bidirectional interaction for both systems in terms of displacement of edge lateral load resisting elements. From this point of view, we can study the displacement and story drift demand due to seismic excitation in inelastic response for the satisfactory of this effectiveness in critical phase that should be useful for practical and design purposes and is believed to be new.

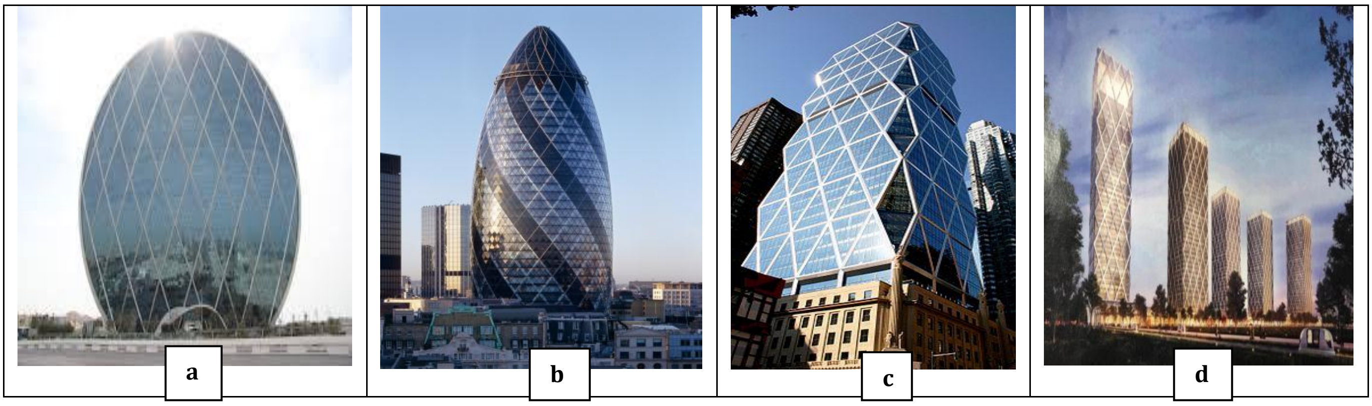


Fig. 1. Example of diagrid structures. (a) Alder Headquarters, Qatar (b) Swiss Re Building, London (c) Hearst Tower, New York (d) GOB Building, India.

2. IDEALIZED MODEL STRUCTURES

In this paper, model structures are represented for symmetric systems in eleven, twenty-one and thirty-one stories of diagrid structures with various slopes (35°, 45° and 55°) of the external braces and also an eleven-story asymmetric system with a 55° brace angle respectively. The idealized structures have a 30 m × 30 m for square plane system and a diameter of 35 m for circular plane systems, as shown in Fig. 2, for preparing the response comparison respectively also 35 m × 40 m for asymmetric plane system shown in Fig. 3 is considered. The height of each floor is 3.5 m. In this system, rigid floor diaphragm is considered for both cases having three degree of freedom that is two translational degree of freedom along two principal direction and one rotational in plane. In diagrid structures, a pair of braces are located at 6 m spacing for circular model and external columns are spaced at 3 m for square and rectangular diagrid structure along the perimeter. The given model is assumed to have two lateral load resisting elements for both structural systems for outer and inner sides. In mid position, column is satisfied as an element and as another element slab of floors is considered. Fig. 4 depicts the side elevation of the different brace angles model structures. These inclined members i.e., diagonal braces are placed on a fixed support at earth level to height of story levels that resist the shear-bending. Due to inclined brace members, lateral loads are countered by axial exertion of the brace tubes. The internal frames are designed for gravity load and thus dispense the pin-joint connection.

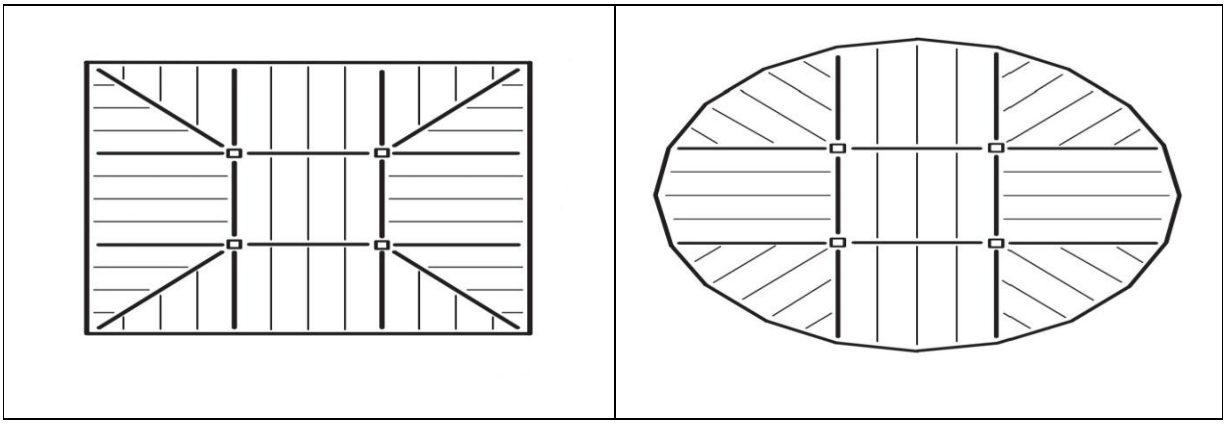


Fig. 2. Plan elevation of idealized symmetric structural system.

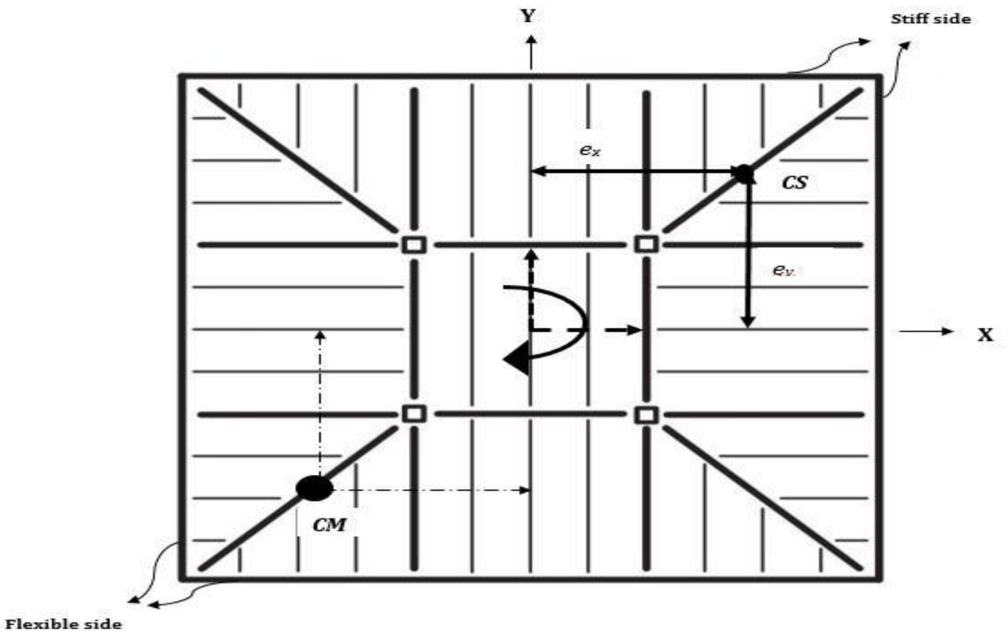


Fig. 3. Plan elevation of idealized asymmetric structural system.

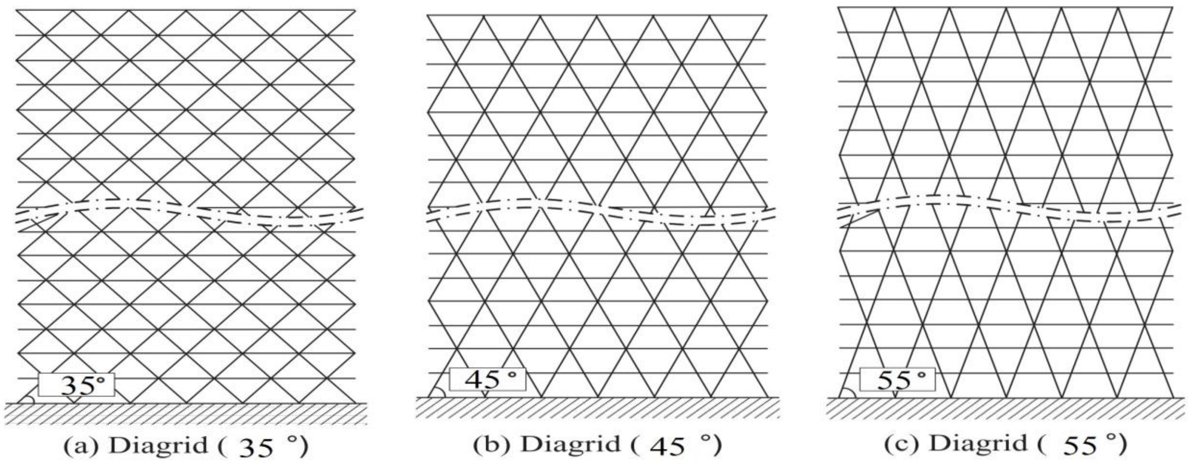


Fig. 4. Diagrid model structures for different braces angle.

The mass of such elements is assumed to be zero and denoted by m. The lateral period (T_l), mass (m) and lateral stiffness (k) of all elements for both systems were calculated using eq. 1., Where, m is lumped mass of story, K_l is the total lateral stiffness

$$T_l = 2\Pi\sqrt{m / k_l} \qquad ......[1]$$

in any principal directions = 4k, k is the stiffness of element in any directions for both cases. The degree of freedom of rigid diaphragm is varied with different rigid floors. For the reference symmetric system, the location of CM and CS are initially the same. Besides that, keep in touch on the lateral load resisting edge elements of bi-directionally asymmetric system eccentricity is initiated by increasing the stiffness of one edge element and decreasing that of the element at the opposite edge. The lateral load-resisting edge elements with less stiffness were considered like flexible elements and the opposite edge elements having greater stiffness were represented to as stiff elements. In this system, the location of the CM and CS recline at the different eccentric location and assume on a same axial section. In such bi-directionally asymmetric systems eccentricities are symbolized by e_x and e_y that lies between the distance of CM and CS with respect to principal axis of system. Distribution of eccentric condition is balanced for both eccentricities' e_x and e_y with the positive sense where CS and CM lies in the first quadrant. Another observation shows that the negative eccentric sense that is e_x and $-e_y$ where CM and CS lies in the second quadrant of the principal axis of the system. Such this study gives an idea about the nature of eccentricity makes any difference or not in the behavior. The stiffness and mass of all floors in different stories is varied, where mass of different floors generated by several parameters. A range of symmetric and asymmetric systems with an otherwise same fundamental parameter has been studied.

3. METHODOLOGY

The non-linear equation of motion show in eq. 2. is numerically solved in time domain using Newmark's β-γ method and by the by modified Newton-Raphson technique is used for iteration. The Newmark's parameters are chosen as $\gamma = 0.5$ and $\beta = 0.25$ [31, 33, 37-40]. The results are computed with various sizes of time step given by T_x/N, where T_x is the uncoupled lateral period and N is an integer number which is gradually increased by doubling it to obtain the results with better accuracy. For this purpose, we considered time step of $T_x/400$ for appropriate determination of values [31, 33, 37]. Seismosignal V. 5.1.0 – A computer program that constitutes an easy and efficient way for signal processing of strong-motion data [online]; 2018, ed: available from URL: (http://www.seismosoft.com) and by the by added the essential parameters that is moment magnitude, closest site-to-fault-rapture distance, shear wave velocity, mean time period [32]. Using this essential software investigating the ultimate characteristic of ground acceleration motion capacity that has been acted on the structural diagrid members as well as the different angle of braces that lies in joint connection. Where, r is the radius of gyration of mass of rigid deck; c is the damping matrix; u_x, u_y, θ are the translations of CM along the x and y axis and rotation of CM is horizontal plane respectively and $\ddot{u}_{gx}$ and $\ddot{u}_{gy}$ are ground accelerations along two perpendicular principal axes respectively.

$$\begin{bmatrix} m & 0 & 0 \\ 0 & mr^2 & 0 \\ 0 & 0 & m \end{bmatrix} \begin{Bmatrix} \ddot{u}_x \\ \ddot{\theta} \\ \ddot{u}_y \end{Bmatrix} + [C] \begin{Bmatrix} \dot{u}_x \\ \dot{\theta} \\ \dot{u}_y \end{Bmatrix} + \{f_s\} = -\begin{bmatrix} m & 0 & 0 \\ 0 & mr^2 & 0 \\ 0 & 0 & m \end{bmatrix} \begin{Bmatrix} \ddot{u}_{gx}(t) \\ 0 \\ \ddot{u}_{gy}(t) \end{Bmatrix} \quad ....[2]$$

For symmetric system the uncoupled torsional effect is negligible.

4. GROUND MOTION

For the diagrid structural model an enhanced nonlinear dynamic analysis has been used which is capable to capture progressive seismic damage of structures. As scaled near-fault (NF) ground motions are considered from Pacific Earthquake Engineering Research(http://peer.berkeley.edu) Center for the performance analysis [37]. The ground motion is generated on a structural system like a vector formation, often oriented in north-south (N-S) and east-west (E-W) directions whereas the strong motion database for horizontal components of motions are generally available along orientations of recording which are often arbitrary. This recorded component is applied along two principal axes of the structure with the shearing brace effect. Thus, it is often deduced that the arbitrarily placed recording sensors are aligned with the principal axes of structure. In this way, overall structural response of the MDOF diagrid system is estimated owing to bi-directional NF synthetic ground motion history under critical zone IV. The case studies in this paper are investigated for a set of fifteen bi-directional synthetic ground motions to resist any variability arising subjected to the particular characteristic of any specific ground motion. Details of the ground motions are shown in Table 1. We select ground motions in terms of geophysical parameters, viz., magnitude-distance-soil conditions triads. Selected motions are scaled appropriately to introduce a uniform level of inelastic action. For each component of a motion, this scale factor is decided observing the spectral acceleration of each original record component at the fundamental period of vibration of element in relation to the element capacity. Scale factors of two components of a record so computed are compared and the average factor is applied to the components.

Table 1: Details of ground motions (NF) used.

Serial no.	Event (Year)	Station	Record ID	Moment magnitude (M_w)	r(km)	Vs30(m/s)	PGA(m/s²)		T_m(s)	
							X - Component	Y - Component	X -Direction	Y- Direction
1.	Corinth_ Greece, 1981	Corinth	RSN313	6.6	10.27	361.4	2.32	2.90	0.17	0.14
2.	Landers, 1992	Joshua Tree	RSN864	7.3	11.03	379.32	2.68	2.78	0.73	0.78
3.	Landers, 1992	Morongo Valley Fire Station	RSN881	7.3	17.36	396.41	2.19	1.61	0.69	0.88
4.	Manjil_ Iran,1990	Abbar	RSN1633	7.4	12.55	723.95	5.04	4.87	0.32	0.33
5.	Tottori_ Japan,2000	OKY004	RSN3907	6.7	19.72	475.8	8.08	5.28	0.20	0.18
6.	Chuetsu-oki_ Japan,2007	Yoshikawak u Joetsu City	RSN4850	6.8	16.86	561.59	4.44	3.08	0.79	0.83
7.	Iwate_ Japan,2008	MYG005	RSN5664	6.9	13.47	361.24	5.25	4.37	0.78	1.76
8.	Iwate_ Japan,2008	Kurihara City	RSN5818	6.9	12.85	512.26	6.89	4.14	0.39	0.42
9.	Chi-chi_Taiwan-03_1999	TCU 129	RSN1023	6.2	10.9	511	9.85	6.12	0.35	0.34
10.	Imperial valley-1979	El centro Array#4	RSN179	6.5	7.1	209	4.75	3.63	0.68	1.29

11.	Imperial valley-06_1979	El centro Array#6	RSN181	6.5	1.4	203	5.19	3.76	0.66	1.22
12.	Imperial valley-06_1979	El centro Array#10	RSN173	6.5	8.6	203	5.19	3.76	0.66	1.22
13.	Kocaeli, Turkey_1999	Duzce	RSN1158	7.5	13.5	282	3.06	3.57	0.87	0.50
14.	Loma Prieta_1989	Los Gatos - Lexington Dam	RSN3548	6.9	5.5	1070	4.34	4.04	0.89	0.98
15.	Denali, Alaska_2002	TAPS Pump Station#10	RSN2114	7.9	2.7	329	3.26	2.92	1.52	1.19

5. SYSTEM PARAMETERS

The variation of maximum displacement response may be influenced by several system parameters as well as loading considerations for valuable conclusions. These primarily considerable two dynamic control parameters namely the lateral natural period (T_x) and the uncoupled torsional-to-lateral period ratio (τ). This lateral periods (T_x) considered for symmetric systems lies between 0.25 to 2.0 sec and for asymmetric system it considered 0.25 sec, 0.5 sec, 1.0sec and 2.0sec in short, medium and long period ranges respectively. On the other hand, for most real buildings, the values of uncoupled torsional-to-lateral period ratio (τ) are varied within the range of 0.25-2.0 with an interval of 0.05 also used in previous research [31, 33, 37]. Influence the torsional effect for asymmetric system eccentricity is important criteria to observe the critical response of structural elements with respect on τ. Further, the present study attempts to incorporate the analysis of the bi-directional asymmetric system into a feasible range of eccentric variation. In this case study, the three typical eccentric parameters of this system are classified in terms of small, intermediate and large eccentric systems as represented as e/D = 0.05, 0.1 and 0.2 used in previous literature [33, 37]. Hence, six combinations of eccentricity are considered along two principal directions in this paper, as listed in Table 2. Asymmetric systems with stiffness and mass eccentricities are considered in this present study. The four different values of ductility reduction factor (R_μ) = 2, 4 and 6 are chosen only for symmetric structure whereas standard reduction factor R_μ = 4 select for asymmetric system only. These values are highly recommended by the different codes, such as ASCE 7-05 [36] and NEHRP [35].

Table 2: Combinations of eccentricity considered along two principal directions.

Sl. No.	e_x/D	e_y/D
1.	0.05	0.1
2.	0.05	0.2
3.	0.05	0.05
4.	0.2	0.2
5.	0.1	0.1
6.	0.1	0.2

Note: e_x and e_y are eccentricity in x and y-axis respectively.

6. RESULTS AND DISCUSSION

The nonlinear dynamic analysis of different story diagrid structures that are eleven story, twenty-one story and thirty-one story systems through mean element displacement (for Rμ=2, 4 and 6) for various angle of braces (35°, 45° and 55°) is presented with plotting as representative of the trend for both cases with the time variation lies between small to large lateral period that is 0.25sec to 2.0sec for symmetric system. Fig. [5-7] shows the mean displacement for various model structure in different story at small, intermediate and large brace angles obtained by nonlinear dynamic analysis for square diagrid plan section and as well as another part show in Fig. [8-10] for tube type analysis model structure with a circular plan shape. Fig. [5] indicates the amplification in response for square symmetric configuration may be 1.8, 1.5 and 1.1 times, whereas, for circular section response indicates 1.5, 1.3, and 0.9 times respectively for Rμ=2 show in Fig. [8]. Influence of ground motion characteristics on the nonlinear dynamic seismic response of symmetric diagrid structural system is systematically examined to achieve a fair insight into the behavior of such systems. Fig. [6] indicates the amplification in response for square symmetric configuration may be 2.6, 2.3 and 2.1 times, whereas, for circular section response indicates 2.3, 1.9, and 1.6 times respectively for Rμ=4 show in Fig. [9]. Fig. [7] indicates the amplification in response for square symmetric configuration may be 4.2, 3.9 and 3.5 times, whereas, for circular section response indicates 3.8, 3.6, and 3.4 times respectively for Rμ=6 show in Fig. [10]. Fig. [5] and Fig. [8] reveal that the increase in displacement response 0.35, 0.31, and 0.2 times for bi-directional excitation for Rμ=2. Fig. [6] and Fig. [9] reveal that the increase in displacement response 0.42, 0.4, and 0.5 times for bi-directional excitation for Rμ=4, where torsional to lateral period ratio (τ) is negligible for zero eccentric condition. Finally, Fig. [7] and Fig. [10] reveal that the increase in displacement response 0.41, 0.32, and 0.1 times for bi-directional excitation for Rμ=6.

On the other scenario, story drift one of the significant criteria for the assessment in drift demand of different story buildings under ground motions excitation are presented in Fig. [11] for square diagrid system and Fig. [12] represented for circular diagrid structural system. Fig. [11] indicates the response of drift demand for square symmetric configuration may be 0.0032, 0.0026 and 0.0024 times, whereas for circular section response indicates 0.0029, 0.0023, and 0.002 times respectively show in Fig. [12]. In this case, structures are revealed that the increase in drift demand 0.0005, 0.0003 and 0.0004 times for both case studies. It can be observed that as the slope of the braces increases, the mean value of the maximum drift also decreases that is also satisfactory for displacement demand. In the structures with brace slope of a 35° and 45°, the displacement and maximum drifts demand in the higher few stories are significantly larger due to the participation of the higher mode effects for both case studies. Drift demand is being maximum at top story if the diagrid inclination angle is being minimum. Furthermore, drift demand in intermediate story is being maximum for minimum diagrid angle, whereas in low story it varies show in Fig. [11-12]. On the other scenario, mean of normalized response are computed and presented for corner elements are more vulnerable

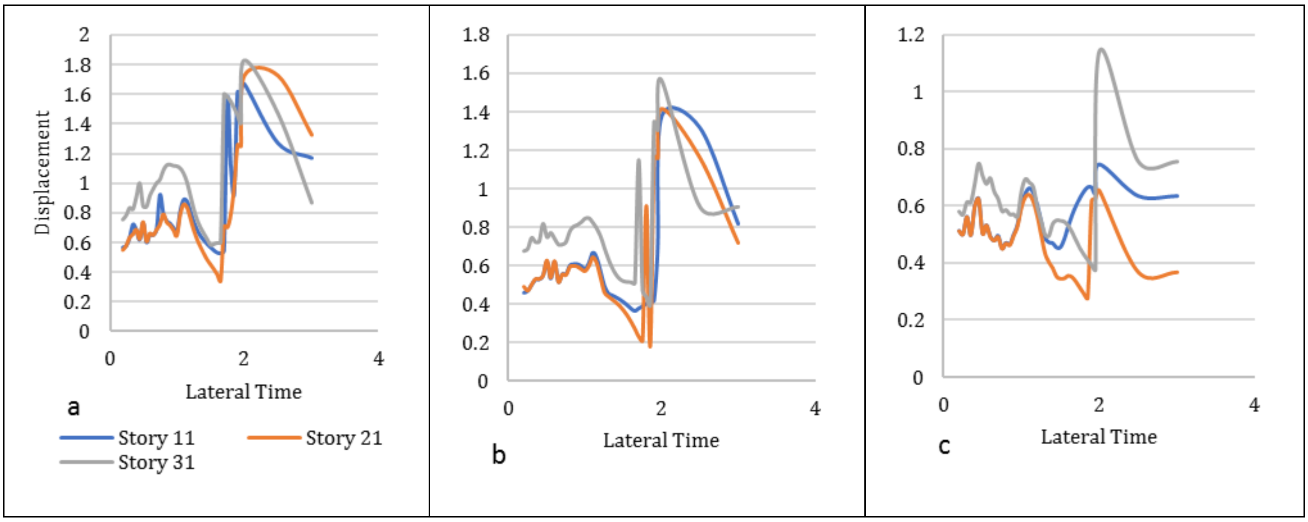


Fig. 5. Mean displacement response of square diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles (R_μ = 2).

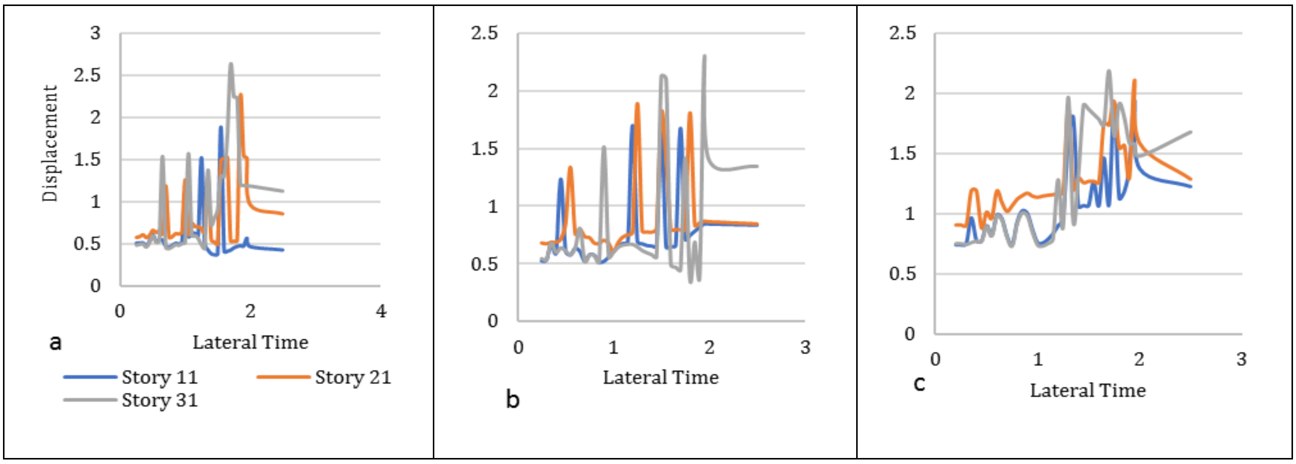


Fig. 6. Mean displacement response of square diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles ($R_\mu = 4$).

due to lateral and torsional coupling effect in asymmetric structure. These corner four elements Element 1 is flexible along both principal directions and designated as "flexible, flexible". Element 2 and Element 4 are combined as flexible and stiff for different principal axis, designated as "flexible, stiff" and "stiff, flexible" respectively. Element 3 is stiff along both principal direction and finally designated as "stiff, stiff". The response of all corner elements are developed for physical understanding due to bi-directional system of asymmetry. The considarable lateral periods for small, medium and large time history clearly

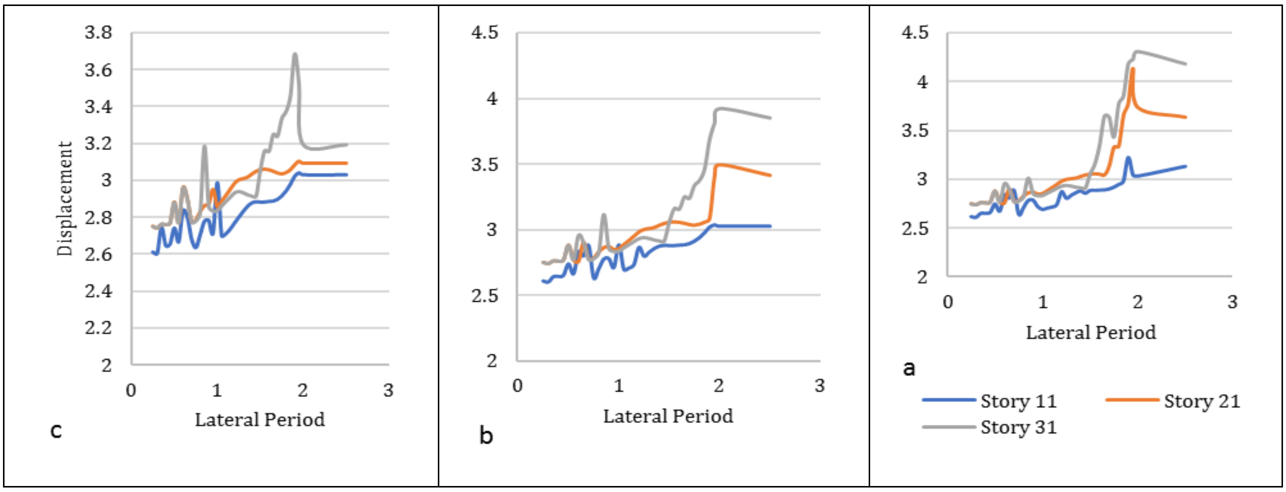


Fig. 7. Mean displacement response of square diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles ($R_\mu = 6$).

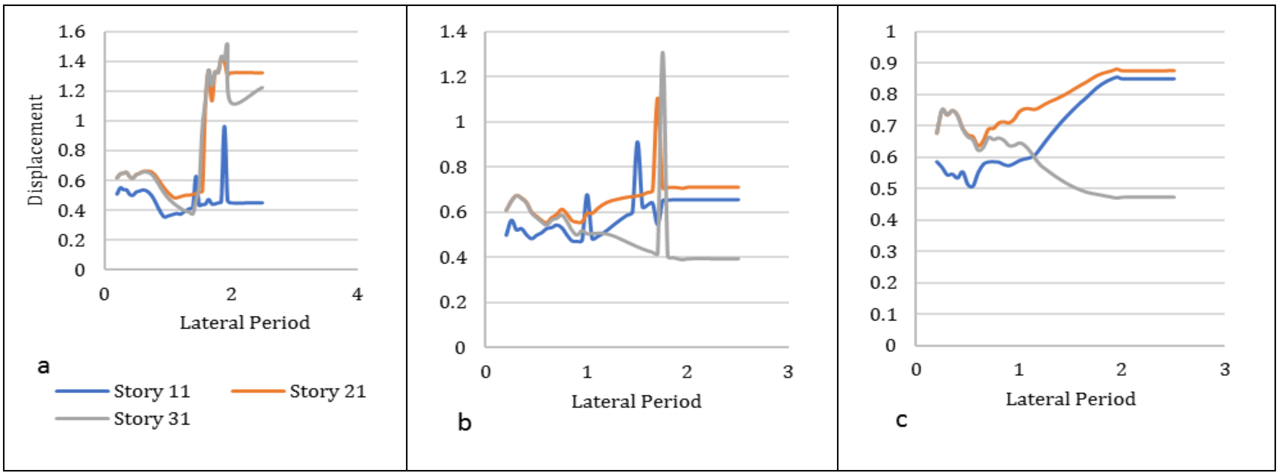


Fig. 8. Mean displacement response of circular diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles ($R_\mu = 2$).

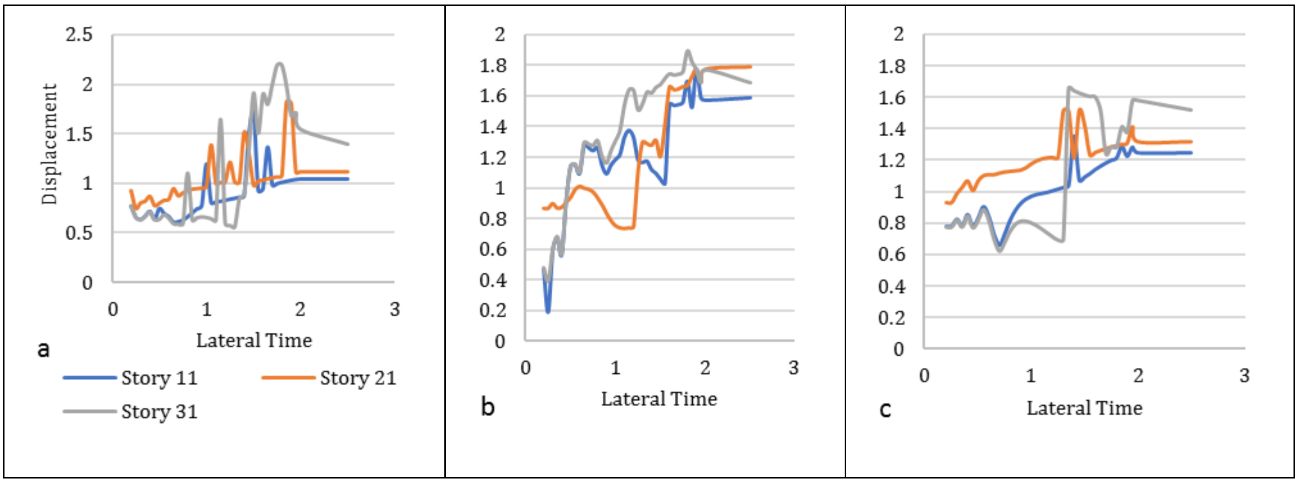


Fig. 9. Mean displacement response of circular diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles (R_μ = 4).

plotted in Fig. [13-16] also dependent on ductility reduction factor (Rμ)=4 for obtaining the critical inelastic response in zone IV at 55° standard brace angle. Fig, [13-16] has four sets of graphs shows the mean of response for a different combination of bi-directional eccentric system. In these hybrid steel-concrete structural model indicates the dynamic response upto 2 to 3.1 times for 0.25sec, 2.3 to 3.2 times for 0.5sec, 2.9 to 3.5 times for 1sec, 3.1 to 3.65 times for 2sec respect to torsional effect and

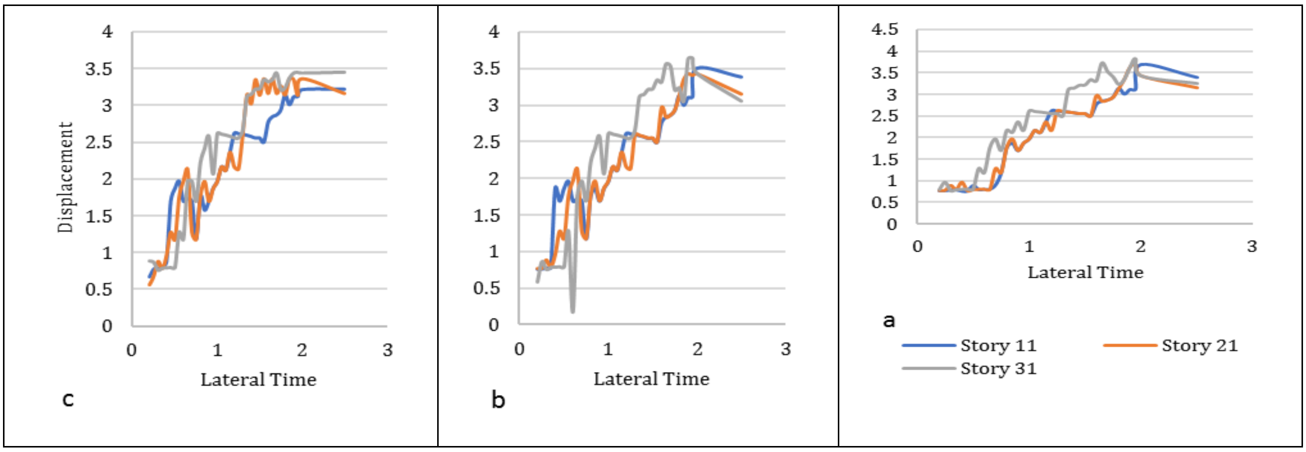


Fig. 10. Mean displacement response of circular diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles (R_μ = 6).

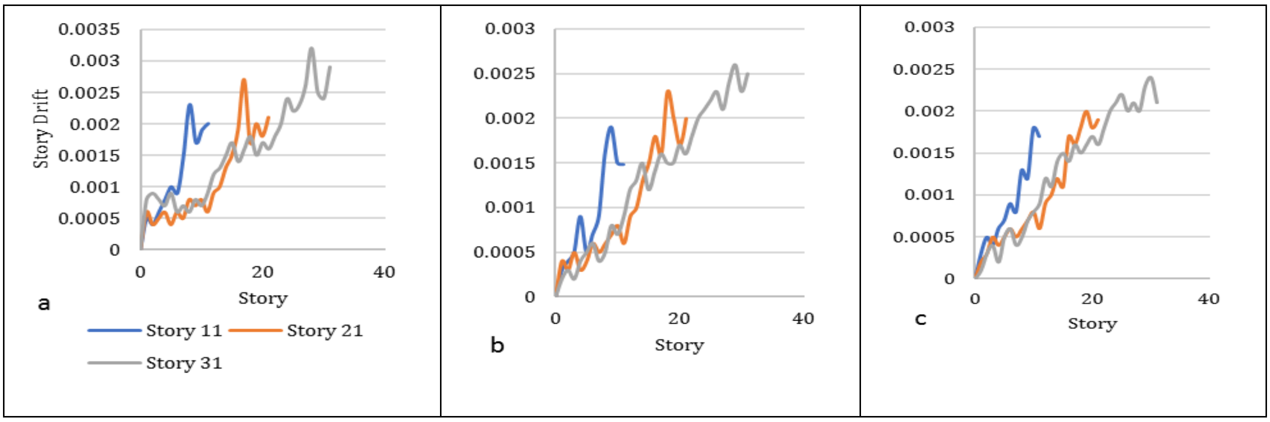


Fig. 11. Drift demand of square diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles.

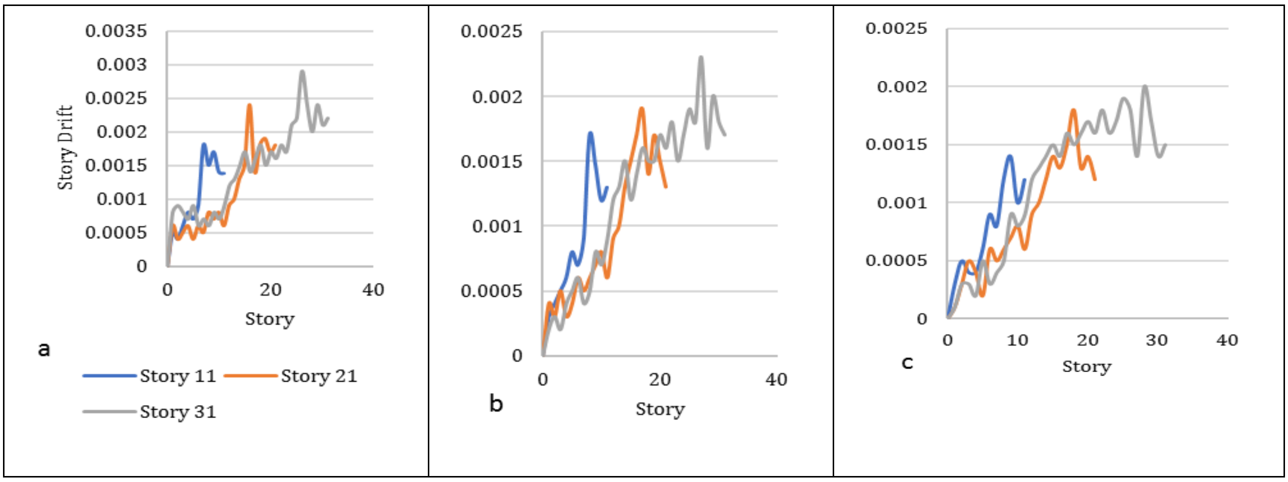


Fig. 12. Drift demand of circular diagrid system for (a) 35°, (b) 45°, (c) 55° brace angles.

variation of stiffness-mass eccentric condition. Considering lateral period 0.25sec, the 1st Element maximum deformation lies 3.1 times and minimum 2 times for 3rd Element. In that case, Element 2 and 4 carries the almost same response that lies

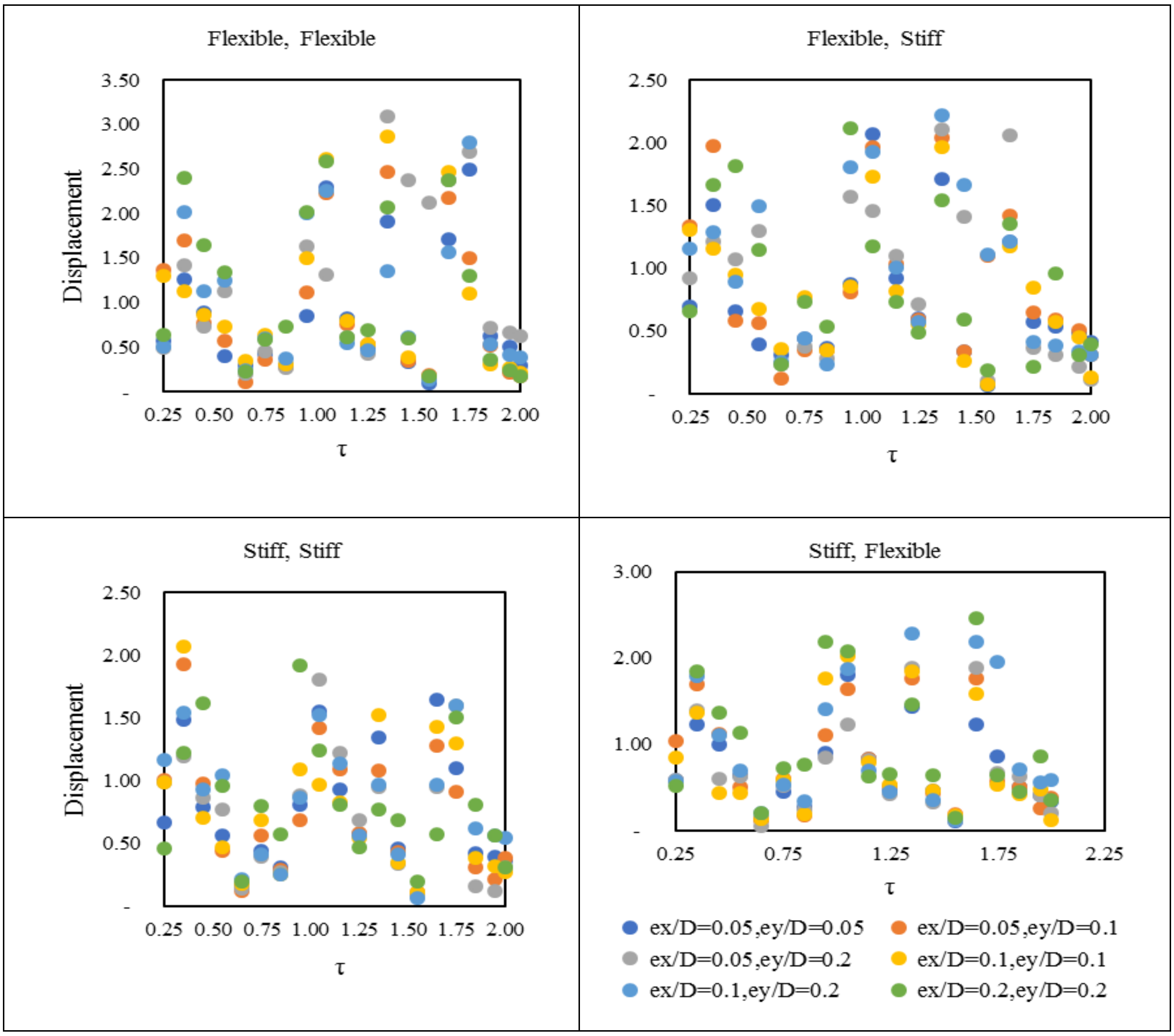


Fig. 13. Mean displacement response of asymmetric diagrid system for T=0.25 sec at 55° brace angle (R_μ = 4).

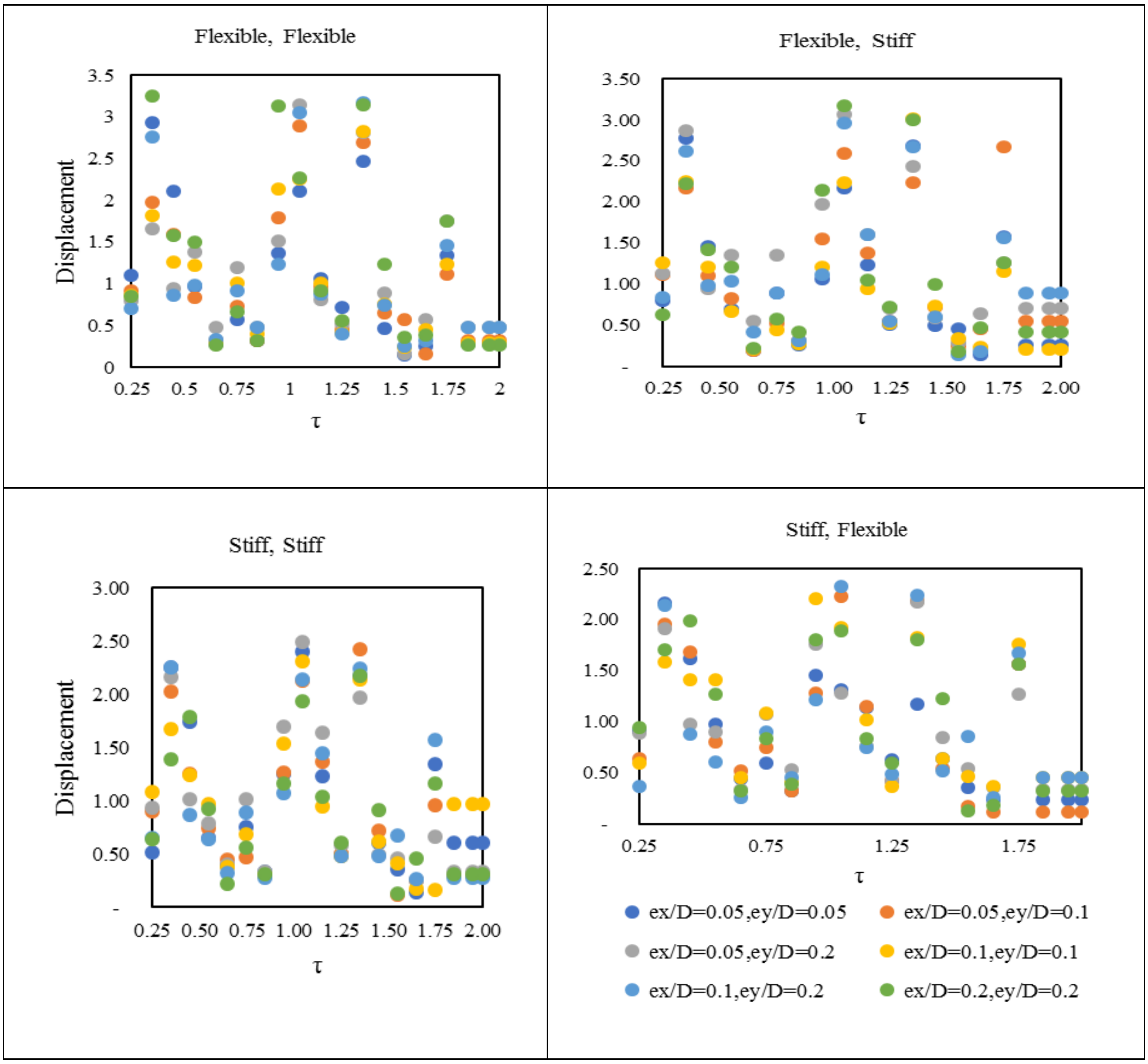
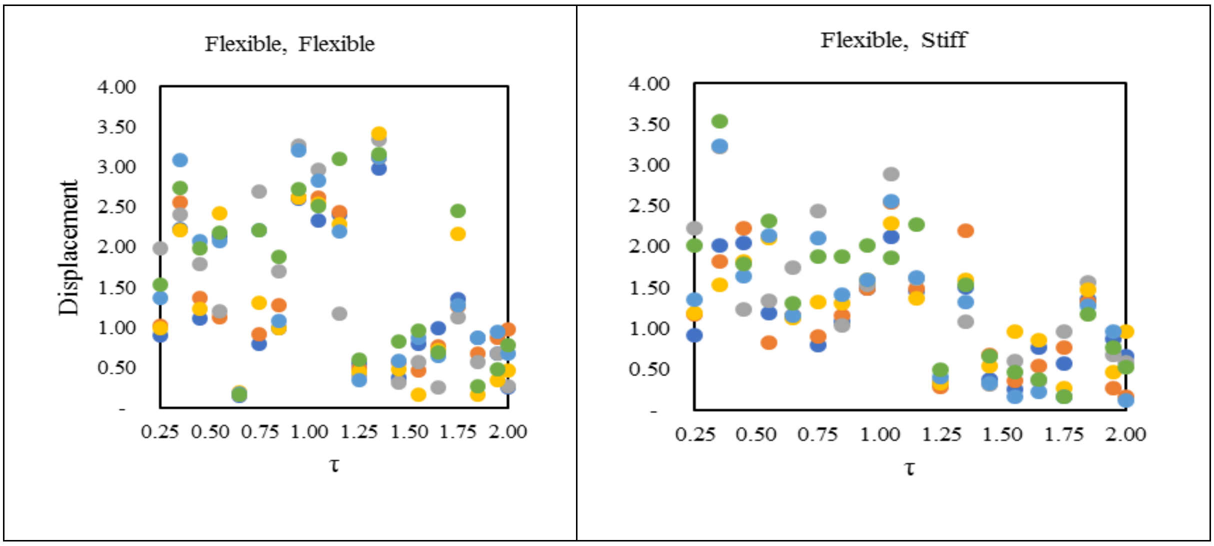


Fig. 14. Mean displacement response of asymmetric diagrid system for T=0.5sec at 55° brace angle (Rμ=4).



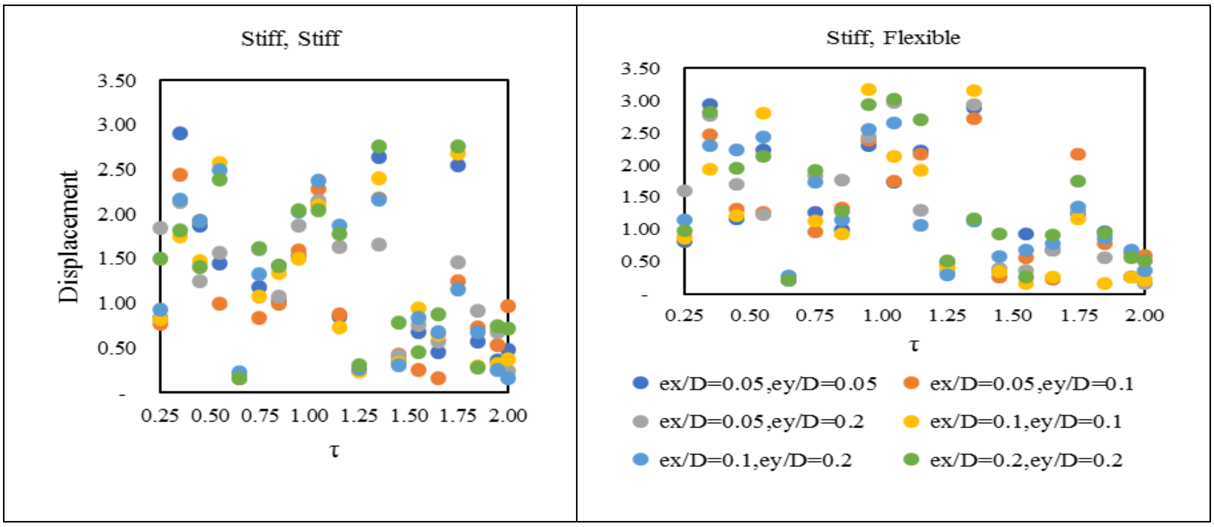


Fig. 15. Mean displacement response of asymmetric diagrid system for T=1.0sec at 55° brace angle (Rμ=4).

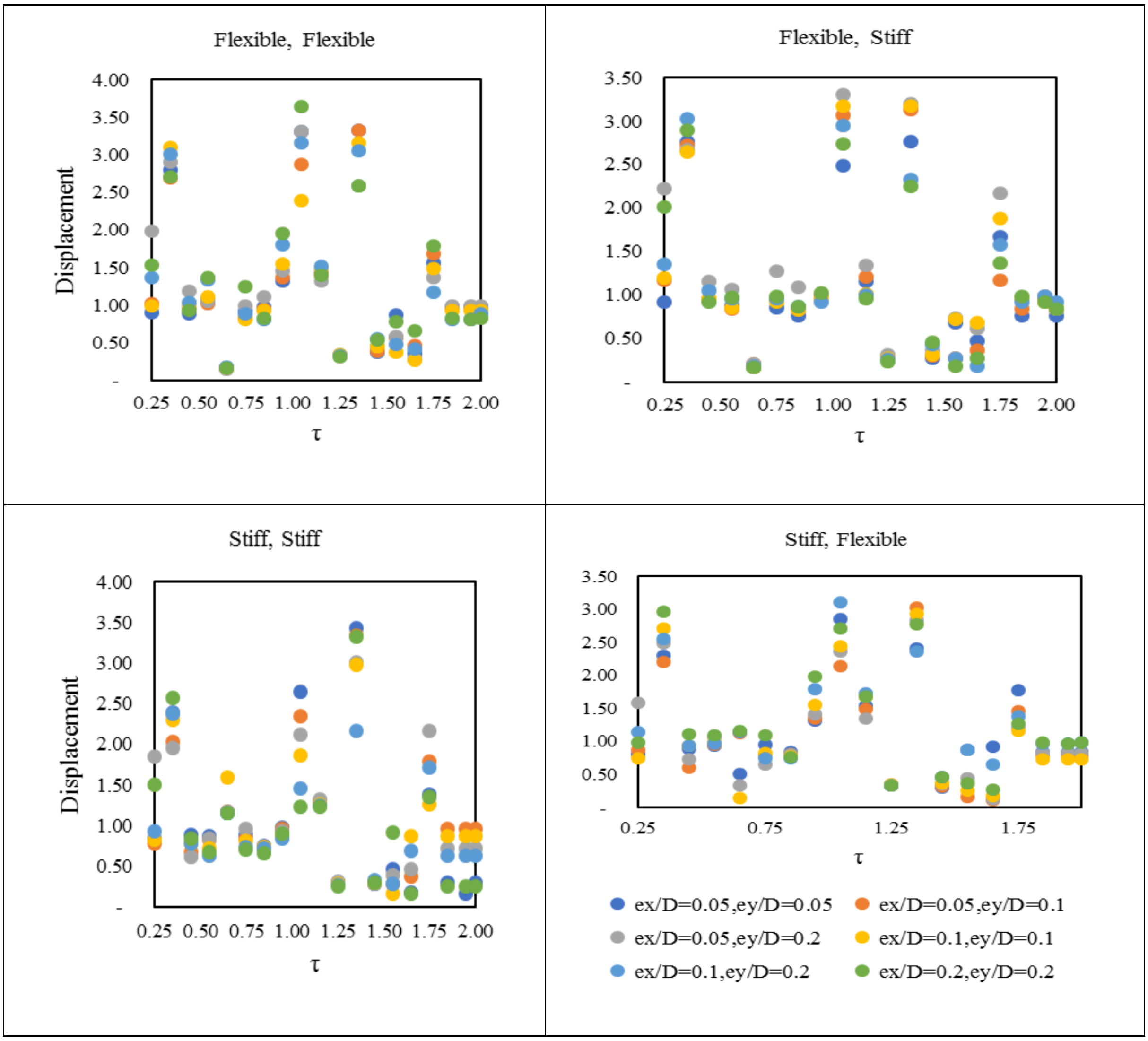


Fig. 16. Mean displacement response of asymmetric diagrid system for T=2.0sec at 55° brace angle (Rμ=4).

between 2.2-2.4 shown in Fig. [13]. Furthermore, considering lateral period 0.5sec, the Element 1 lies maximum deformation at 3.2 times and minimum 2.3 times for Element 4. Element 2 and 3 carries the average inelastic demand lies between 2.5-3.1 shown in Fig. [14]. For lateral time 1sec, the element 2 lies maximum deformation at 3.5 times and minimum 2.9 times for Element 3. Element 1 and 4 obtain the demand lies between 3.2-3.4 times shown in Fig. [15]. Fig. [16] shows the maximum Element 1 deformation for 3.65 times whereas minimum carried out for Element 4 at 3.1 times. Element 2 and 3 shows the displacement between 3.3-3.4 times that near about same. In this context, it is needed to observe from 15 earthquake data that is plotted for two different extreme combinations of eccentricities along X and Y directions. However, in this point, the observation for inelastic seismic response of asymmetric diagrid system in small to large combination of different eccentric conditions that assemble an effective scenario in seismic zone IV for suitability.

7. CONCLUSIONS

The present investigation analyzes the inelastic seismic performance of different story diagrid symmetric and asymmetric model plan structures with various angle of braces are evaluated under critical seismic zone IV in India owing to bi-directional NF ground excitation. The results are also indicated to compare the performance with square plan diagrid structures to circular model plan diagrid structures for the suitability in critical seismic zone IV in India. Also, the asymmetric systems have been attempted the performance analysis for better understanding of serviceability. The following broad conclusions emerge.

1. The strong vulnerability of grid structural load resisting elements due to the bi-directional ground motion clearly shows that the elements are less amount of losses on lateral periods than R/C structural system. The response of structures for both case studies indicate that the higher overstrength with smaller ductility, depends on critical angle of braces. Further, the seismic demand of elements appears to vary irregularly, as a result the story wise variation of both systems varies similarly. In this study, dynamic observation appears to be more important from the viewpoint of mechanics.

2. Consideration of symmetric configuration effect owing to simultaneous bidirectional shaking may produce the inelastic demand. The result analysis implies for both cases amplifies the response considerably. The structural deformation of the square diagrid system is higher than circular system with respect to the lateral periods. On the other hand, story drift demand clearly demonstrates that the higher demanding values, significantly scatter randomly on higher story level than lower story. In that case, drift demand is maximum for square system that influences the inelastic response of higher modal effect. The bird's eye observation represents the performance of circular system is better than square system due to ground excitation.

3. The diagrid structure with the brace angle between 50° to 60° seems that it is resisting to be more efficient with lateral loads as well as gravitational easily in zone IV. Also, it is demonstrated that this standard brace angle is suitable for any asymmetric system. Brace angle between 40°-50° is acceptable for square and circular systems that controls the large number of deformation and drift demand. In this diagrid structural system M25 grade of concrete is suitable for light weight of elements and also steel grid section is preferable with pin-joint connection for flexibility than concrete grid joint connection.

4. Consideration of bi-directional interaction for asymmetric diagrid system may produce higher inelastic demand. With increasing the uncoupled lateral period of structure, decreasing the inelastic range for such flexible systems and lies constant. The response of asymmetric system at 55° brace angle lucidly concludes that the response due to bi-directional ground motion obtains a major effectiveness of load resisting elements under the variation of eccentric conditions in zone IV. The elemental deformation for large brace angle lies between 50°-60° consider as suitable for zone IV, relaxing modal effect in random vibration.

Thus, the present paper may be helpful in the process of response analysis of the built or to-be-built structures in the event of any anticipated earthquake prone and believe to be new. Safety level of the structures are undergoing seismic excitation without collapse may be assessed to plan for the post-earthquake strategy. Such a symmetric and asymmetric diagrid plan structures serve various functional and architectural requirements due to plan and interconnection activities leads to the additional vulnerability of system. Furthermore, the sensitivity of the bi-directionally attacking forces execute the seismic deterioration of such systems. This present paper may prove useful to provide broad guidelines to address all essential issues and to highlight the needs for investigating the same in further details. These results can, therefore, help to evaluate the retrofitting assessment due to additional strength demand. These findings point out the limitation of current codes developed primarily on research in this particular aspect that employed a multi-story model. Hence, this interesting study may be extended to assess the soil-structure interaction effect for asymmetric diagrid structural system obtaining further insight.

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