COMPARATIVE ANALYSIS OF DIA GRID BUILDING WITH AND WITHOUT OUTRIGGER USING ETABS SOFTWARE

CHAPALA VAMSHI KRISHNA[1], M.S PHANIKUMAR[2]

[1]M. Tech Student, Department of Civil Engineering, NRI Institute of Technology, Pothavarappadu, Nunna Rd, Agiripalli, Vijayawada, Andhra Pradesh 521212

[2]Associate Professor, Department of Civil Engineering, NRI Institute of Technology, Pothavarappadu, Nunna Rd, Agiripalli, Vijayawada, Andhra Pradesh 521212

ABSTRACT

High-rise building development is fast rising over the world in the modern era. Because of the scarcity of accessible free land and the growth of metropolitan areas, architects and engineers have begun to build cities vertically. The dia grid structural system has recently become popular for tall structures due to the structural efficiency and aesthetic possibilities given by the system's triangulation. Due to the presence of inclined columns, dia grid construction resists lateral loads more effectively than typical frame structures with outside vertical columns. The axial motion of the inclined columns installed at the external periphery of the structures resists lateral loads in the dia grid system. Seismic isolation and energy dissipation systems are a cost-effective way to improve the seismic performance of structures built to industry standards. Traditional seismic design calls for additional strength and ductility to withstand seismic forces, while these techniques reduce seismic forces by altering structural stiffness and damping. Outriggers are very stiff horizontal arm like structures that are designed to improve the buildings resistance to overturning and strength by connecting the core to distant columns. The concept of Outrigger is not new to us as Outriggers have been used in sailing vessels in the mast of the sail to improve the stability. Despite being such an old technology it has been recently been introduced in the structural framework of the buildings.

In the present study 21 storied dia grid building is analyzed using outrigger system by using ETABS software . The results like story drift, story shear, story bending, time period, model stiffness are compared for rubber base and friction pendulum models.

Key words: dia grid, ETABS, outrigger story drift, story shear, story bending, time period, model stiffness.

1. INTRODUCTION

Outrigger in Building

Outriggers are interior lateral structural systems provided to improve the overturning stiffness and strength of high-rise buildings. It is a lateral load resisting system that is located within the building. The whole system consists of a core structure connected to the perimeter columns of the building by means of structural members called outriggers. The outriggers can be in the form of horizontal beams, truss, or walls.

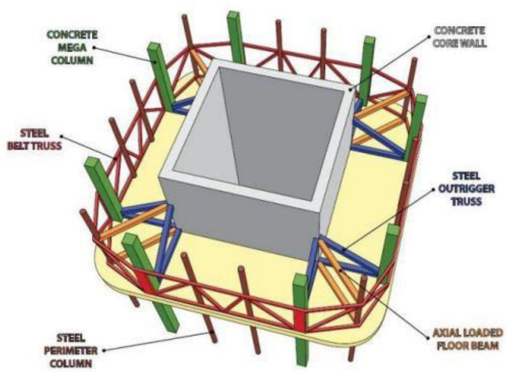


Fig 1: Outrigger Structural System

Outriggers are categorized as interior structural systems that can work efficiently for up to 150 floors. It is one of the successful and stable configurations used in high-rise construction. Outrigger structural system is popular in construction since the 1980s due to its unique combination of architectural flexibility and structural efficiency.

Fig 2: Outrigger Truss Connected to Perimeter Columns

Outrigger Structural Systems

An outrigger structure functions in a high-rise building by tying together two systems (see Figure-2), namely,

1. Core system
2. Perimeter system

As shown in Figure-1, the core structure is the most critical unit of a high-rise building. It is a combination of units like lifts, staircases, ducts, etc. Whereas the perimeter system is a combination of mega columns. The core system and mega columns located in the perimeter are connected using outriggers. Figure-2 shows a truss type outrigger connected to the perimeter column. Other than outriggers, the structure is accompanied by belt trusses around the perimeter to provide extra lateral resistance.

Both the core and perimeter systems together with the outrigger control the behavior of the whole building. This is performed by the positive interaction between the core and the perimeter system through outriggers.

The main objectives of the project **to** study the seismic behavior of building by using IS 1893:2002**, to** analyse the 20 stories dia grid building in zone V seismic condition**, t**o compare the results of story drift, shear force, bending moment, building torsion of buildings, **to** o study the multi story buildings in ETABS in Response spectrum analysis and to compare the results of models namely bare frame model, dia grid model and outrigger model.

2. LITERATURE STUDIES

Al-Subaihawi Safwan et al. (2020) have investigated the performance of damping devices incorporated between outrigger trusses and perimeter of the column to reduce dynamic vibrations in 40-storeyhigh-rise structuresbyusing real-time hybrid simulation (RTHS) approach. The physical substructurewhich used for experimental modeling inRTHS contains two full-scale nonlinear viscous dampers, and remaining part of the building is modeled numerically as the analytical substructures. The results ofthe study show that a reduction in the maximum wind-induced roof accelerationis possible up to 37% when building gets subjected to 177km/hr basic wind speed.The investigators conclude that the stiffness of the component which is collinear with damping force path and number of dampers used play a vital role in controlling the wind-induced vibrations.

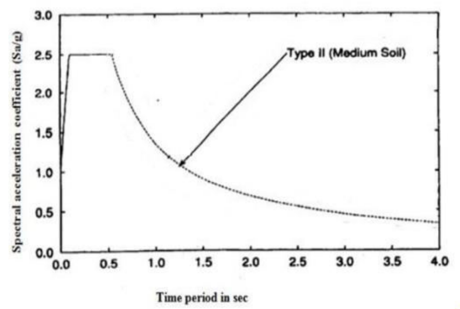
Khade R. B. and Kulkarni P. M. (2019) have examined the detailed analysis on how various earthquake responses (i.e. lateral displacement, storey drift etc.) are affected by the outrigger stiffness, outrigger optimumlocations.The study is carried out considering outriggers of concrete and steel for a 40-storeyed Rectangular and L-shaped buildings using ETABS. The results show that the rectangular building offer more resistance to lateral deflection and story drift than the L-shaped building. Researchers conclude that the concrete outriggers perform better thanthe steel outriggers fromview point of economy and displacement of the buildings.

Kumar A. S. and Varkey M. V. (2019) have carried out non-linear static seismic analysis of a 30-storey vertical regular and irregular building frames, provided with and without outrigger-braced systems, for determining the optimum locations of outriggers. The analysis ofthe building frames has been carried outfor determinationof reductionin the storey displacement and base shear values using ETABS software by time history method. The results show that the conventional outrigger with X-bracing gives maximum reduction (upto10%)inlateral displacementthanthe virtual outrigger system with V-bracing. The researchers conclude that location of outrigger (top, 3/4th height, middle and at 1/4th height) plays animportant role inhigh-rise structure to increase the strength and stiffness against the lateral load induced by earthquake.

3. METHODOLOGY USED

RESPONSE SPECTRUM METHOD

The representation of maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. This analysis is carried out according to the code IS 1893-2002 (part1). Here type of soil, seismic zone factor should be entered from IS 1893-2002 (part1). The standard response spectra for type of soil considered is applied to building for the analysis in ETABS 2013 software. Following diagram shows the standard response spectrum for medium soil type and that can be given in the form of time period versus spectral acceleration coefficient (Sa/g).



Response spectrum for medium soil type for 5% damping

This approach permits the multiple modes of response of a building to be taken in to account (in the frequency domain). This is required in many building codes for all except very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the "harmonic" computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

- absolute - peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) - a method that is an improvement on SRSS for closely spaced modes

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum.

In cases where structures are either too irregular, too tall or of significance to a community in disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static analysis or dynamic analysis.

4. Modeling of building

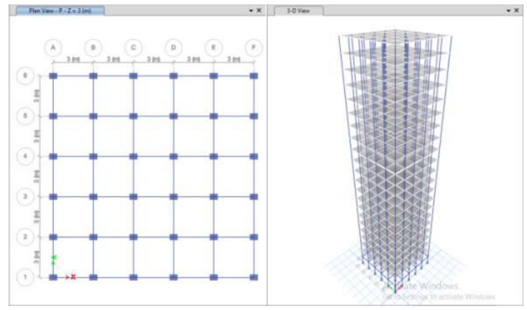
Problem statement

In the present study, analysis of G+20 stories building in Zone V seismic zones is carried out in ETABS.

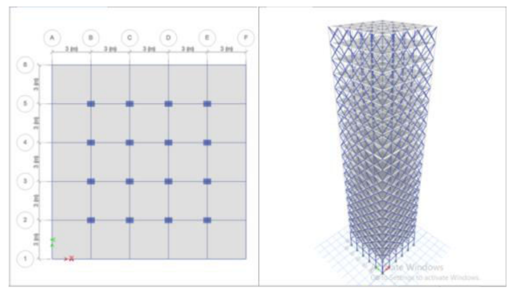
Basic parameters considered for the analysis are

1. Grade of concrete : M30
2. Grade of Reinforcing steel : HYSD Fe500
3. Dimensions of beam : 450mmX450mm,
4. Dimensions of columns :600mmX450mm
5. Dia grid RCC beam section :350mmX350mm
6. Angle of dia grid : 5 degrees
7. Dimensions of column : 500mmX500mm
8. Thickness of slab : 150mm
9. Height of bottom story : 3m
10. Height of Remaining story : 3m
11. Live load : 2.5 KN/m^2
12. Floor load : 1.5 KN/m^2
13. Density of concrete : 25 KN/m^3
14. Seismic Zone : Zone 5
15. Site type : II
16. Importance factor : 1.5
17. Response reduction factor : 5
18. Damping Ratio : 5%
19. Structure class : B
20. Basic wind speed : 39m/s
21. Risk coefficient (K1) : 1.08
22. Terrain size coefficient (K2) : 1.14
23. Topography factor (K3) : 1.36
24. Wind design code : IS 875: 1987 (Part 3)
25. RCC design code : IS 456:2000
26. Steel design code : IS 800: 2007
27. Earth quake design code : IS 1893 : 2002 (Part 1)

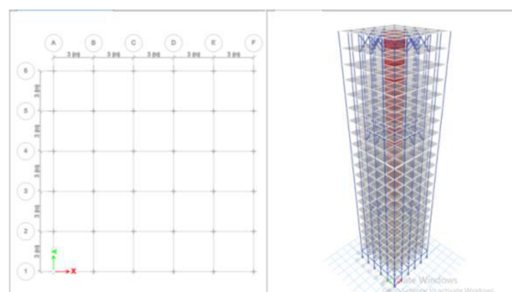
Building models in ETABS



Bare frame model

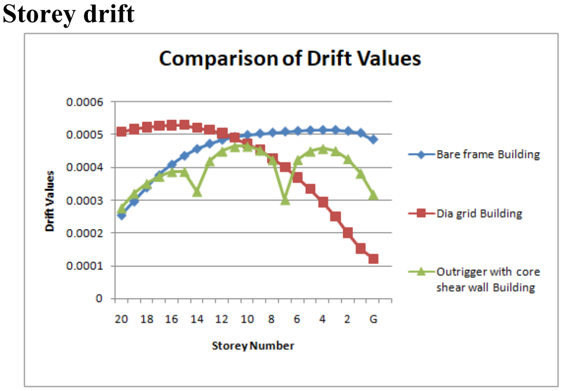


Dia grid model

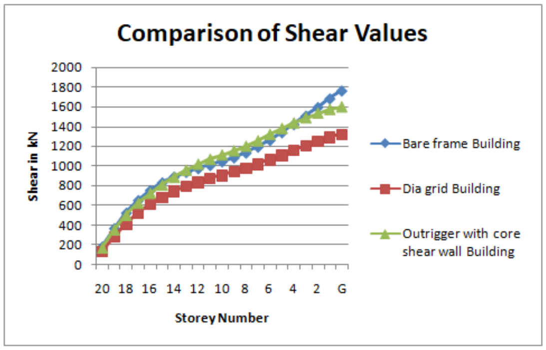


Outrigger model

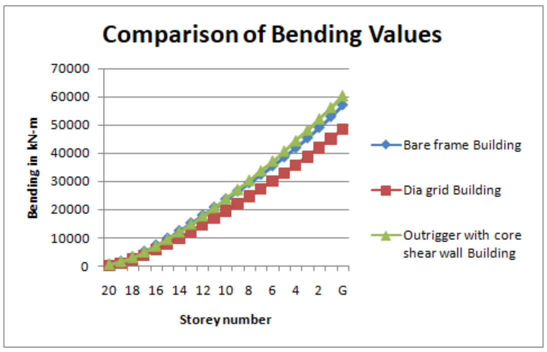
5. RESULTS AND ANALYSIS
RSA X Results
Storey drift



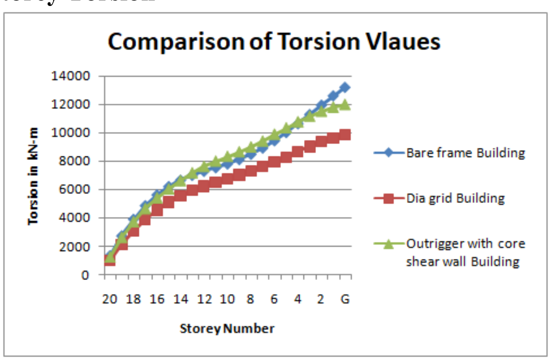
Storey shear



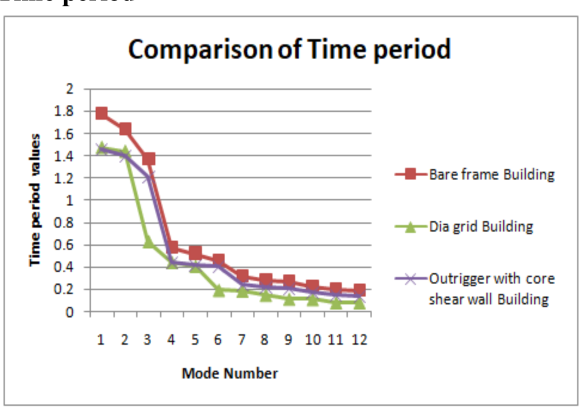
Storey Bending



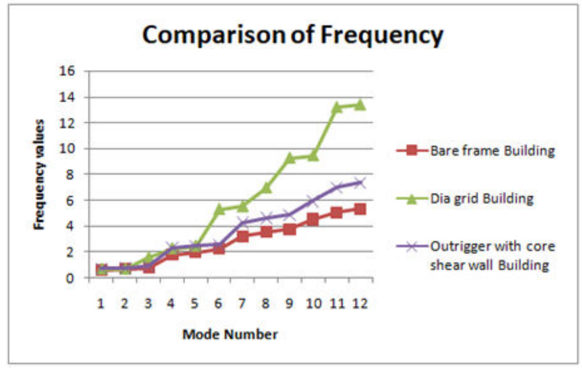
Storey Torsion



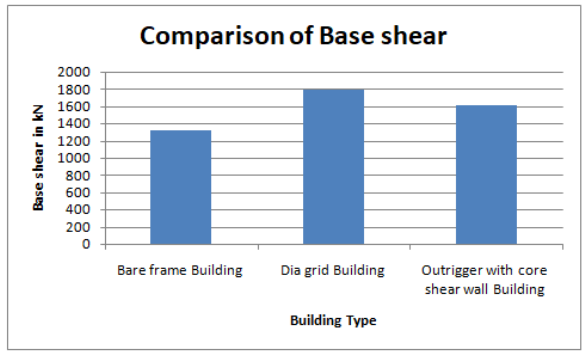
Time period



Frequency

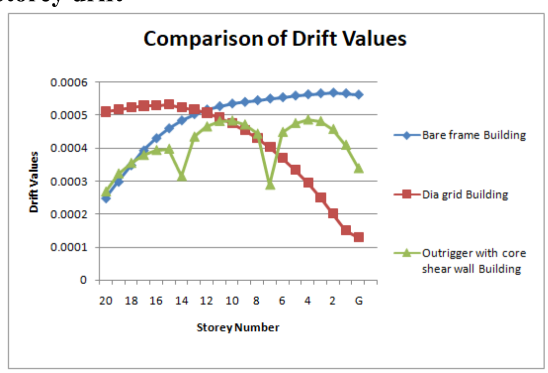


Base shear

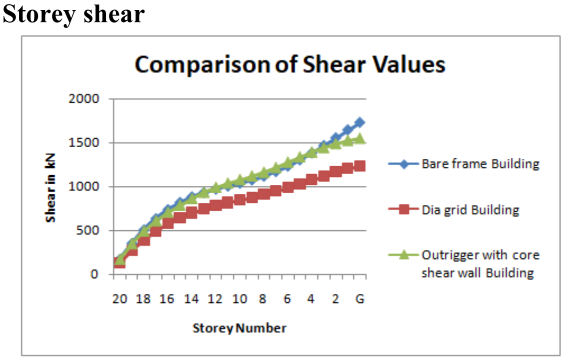


RSA Y Results

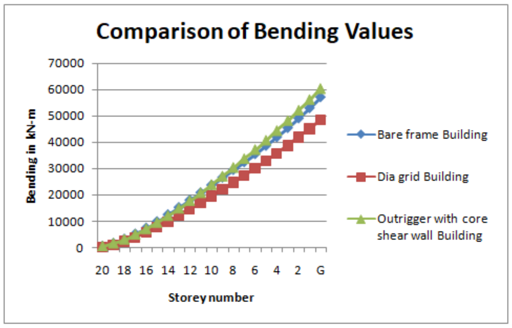
Storey drift



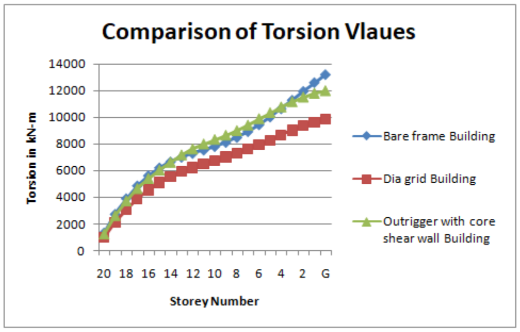
Storey shear



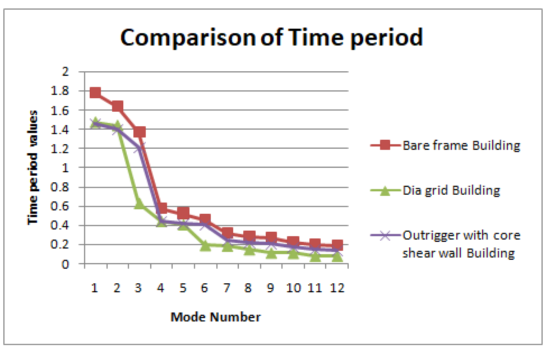
Storey Bending



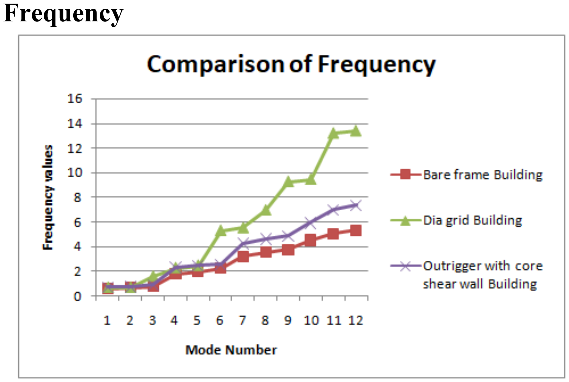
Storey Torsion



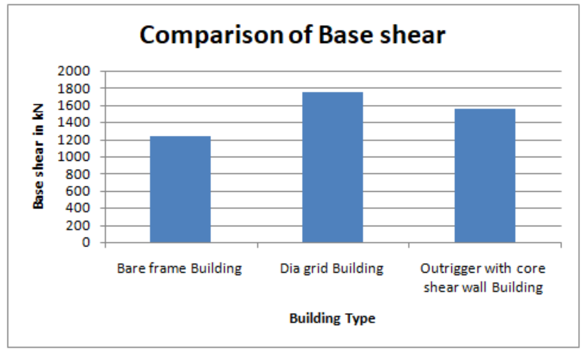
Time period



Frequency



Base shear



6. CONCLUSISONS

1. From the study it is observed that most of the lateral load is resisted by outrigger or dia grid columns on the periphery, while gravity load is resisted by both the internal columns and peripheral diagonal columns.
2. So, internal columns need to be designed for vertical load only. Due to increase in lever arm of peripheral diagonal columns, outrigger, diagrid structural system is more effective in lateral load resistance.
3. Lateral and gravity load are resisted by axial force in diagonal members on periphery of structure, which make system more effective. Diagrid structural system provides more flexibility in planning interior space and façade of the building.
4. The values of story drift in X direction and Y direction has higher values for bare frame building model than dia grid models and outrigger model.
5. The values of shear, bending in X direction and Y direction has higher values for bare frame than dia grid building and outrigger model in Zone 5 condition.
6. The torsion has higher intensities for bare frame models than the dia grid building structures and outrigger model.
7. The time period has higher values in case of bare frame model than remaining building structures.
8. Model stiffness has higher values for bare frame structure than dia grid model or outrigger model.

REFERENCES

[1]. Kyoung Sun Moon, et. al.1 “Structural Design and Construction of Complex-Shaped Tall Buildings” International Journal of Engineering and Technology, Vol. 7, No. 1, February 2015.

[2]. Khushbu Jani, et. al.2 , “Analysis and Design of Diagrid Structural System for High Rise Steel Buildings” Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference on Engineering, 2013.

[3]. Raghunath D. Deshpande, et. al. 3 ,“Analysis And Comparison Of Diagrid And Conventional Structural System” IRJET, June 2015.

[4]. Femy Maria Thomas, et. al. 4 , “Performance Evaluation of Tall Buildings with Steel Diagrid System”2015.

[5]. Rohit Kumar Singh, et. al.5 , “Analysis and Design of Concrete Diagrid Building and Its Comparison with Conventional Frame Building” IJSET, 2014 Vol 2.

[6]. Kyoung Sun Moon, et. al.6 “Comparative evaluation of structural systems for titled tall buildings”, International journal of high rise buildings, June 2014, Vol 3.

[7]. Sree Harsha J, et. al. 7 ,“Analysis Of Tall Buildings For Desired Angle Of Diagrids”, IJRET.

[8]. Nishith B. Panchal, et. al. 8 , “ Diagrid Structural System: Strategies To Reduce Lateral Forces On HighRise Buildings” IJRET.

[9]. Ravish Khan, et. al.9 ,“Analysis Of Diagrid Structure In Comparison With Exterior Braced Frame Structure” IJRET.

[10]. D. Lee, S. Shin, “Advanced high strength steel tube diagrid using TRIZ and non-linear pushover analysis”, Journal of Constructional Steel Research, 96 (2014) 151–158.

[11]. E. K. Julistiono, “Structural pattern’s granularity variation to optimize a vertical structure”, Procedia Engineering, 180 (2017) 725–734.

[12]. G. M. Montuori, E. Mele, G. Brandonisio, A. D. Luca, “Geometrical patterns for diagrid buildings: Exploring alternative design strategies from the structural point of view”, Engineering Structures, 71 (2014) 112–127.

[13]. H. U. Lee, Y. C. Kim, “Preliminary design of tall building structures with a hexagrid system”, Procedia Engineering, 171 (2017) 1085– 1091

[14]. K. Jani, P. V. Patel, “Analysis and Design of Diagrid Structural System for High Rise Steel Buildings”, Procedia Engineering, 51 (2013) 92–100.

[15]. K. Kamath, S. Hirannaiah, J. C. K. B. Noronha, “An analytical study on performance of a diagrid structure using non-linear static pushover analysis”, Perspectives in Science, (2016) 8, 90–92.

[16]. K. S. Moon, “Diagrid Structures for Complex-Shaped Tall Buildings”, Procedia Engineering, 14 (2011) 1343–1350.

[17]. R. D. Deshpande, S. M. Patil, S. Ratan, “Analysis and comparison of diagrid and conventional structural system”, International Research Journal of Engineering and Technology (IRJET), June 2015, Vol. 2, Issue 3, PP 2295–2300.

[18]. T. H. Kim, H. U. Lee, Y. C. Kim, “Development of a building structural system using an IsoTruss® grid”, Procedia Engineering, 171 (2017) 1077–1084.