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Comparative Study of Light Weight Construction for Low Rise Buildings using ETABS Software

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Abstract: ***Low rise buildings with LIGHT WEIGHT structural system, lightweight steel frames (LGSF) and 3D sandwich (3DSP) and steel-thermopore-steel panels (STS) under dynamic loading for 2 storey are taken for the analysis. Earthquake zone zone V (Kachchh) and soil conditions are considered to compare the results in terms of time period, storey displacement, storey drift and storey shear.***

For dynamic earthquake and dynamic wind analysis response spectrum method (IS 1893-2002) are used respectively in ETABS V16 software. For design IS 800-2007 is considered. The results of the structural analysis of the three alternative construction systems show that 3DSPhas better structural behavior in terms of resistance against lateral loads. The information for the building industry shows that the cost of construction for 3DSP construction is 32.9% lower than for STS and 26.2% lower than LGSF.

Keywords: lightweight steel frames (LGSF), 3D sandwich (3DSP), steel-thermopore-steel panels (STS), Storey displacement, Storey drift, Storey shear, ETABS.

I. INTRODUCTION

The depletion of natural resources due to the large demand for construction materials for the increasing population and demand in the construction sector has caused irrevocable ecological imbalance. Building typologies, has always been one of the most important needs of human beings.

In this respect, a high level of sensibility is required for developing appropriate principles of sustainable housing for the use of current and future generations. Several solutions have been proposed by different companies and institutions to enhance the efficiency of residential construction. In the past few decades, some methods of construction have been developed using standardized lightweight frames and materials.

Due to various economic, structural and environmental benefits, these kinds of construction techniques have rapidly changed the construction practices all around the world. The construction of these systems is clean, fast and easy. More-over, they are lightweight and need less construction materials.

These specific characteristics result in lower environmental load sand enhanced seismic resistance. Light gauge steel frame (LGSF) construction In the respect, a high level of sensibility is required for developing appropriate principles of sustainable housing for the use of current and future generations .Several solutions have been proposed by different companies and institutions to enhance the efficiency of residential construction . In the past few decades, some methods of construction have been developed using standardized lightweight frames and materials.

Due to various economic, structural and environmental benefits, these kinds of construction techniques have rapidly changed the construction practices all around the world. The construction of these systems is clean, fast and easy. More-over, they are lightweight and need less construction materials. These specific characteristics result in lower environmental load sand enhanced seismic resistance. Nowadays, platform framing is the most common method in constructing Light gauge steel frame (LGSF) construction

II. RESEARCH SIGNIFICANCE

In a buildings it is necessary to analyze dynamic loads. As the building increases, lateral loads like earthquake and wind loads acting on building it is necessary to analyze the lateral loads.

In this paper three systems are compared in terms of displacement, drift, and shear. To analyze the lateral loading 8 type of different structure are considered. The objective of this study is to find out which system is better to resist dynamic earthquake.

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III. MATERIALS

The properties of the materials used in the load-bearing structure in each construction system are given in Table 2. In Fig. 2, the details of the wall construction used in this study are illustrated. The wall, floor materials are chosen according to the most prevalent methods; these materials are used in the construction of the three kinds of structural systems investigated in this research. The main structural members in the wall construction of the steel Member thickness (mm) 1, 1.5, 2 Density (kg/m3) 7800 Modulus of elasticity (Gpa) 202.86 Poisson's ratio 0.3 Shear modulus (GPa) 77.8 Yield stress (MPa) 240 Material name: concrete Density (kg/m3) 2400 Modulus of elasticity (GPa) 24.8 Poisson's ratio 0.2 Compressive strength (MPa) 25 Material name Thermo-pore: thick thermo-pore was used as a core material in this study commonly called packing material size available is 1 m^2.

Steel: Gauge 20 steel sheet of 2.08mm thickness was used as a facing material in one of the combinations in this study. Gauges available are 18, 20 and 22.a wall having a standard spacing of 610 mm. The horizontal members, called plates, function as a holder for the studs. In order to strengthen the stud walls against lateral loads (earthquake and wind loads), sheathing is installed over the framed wall. Oriented strand boards are used as the sheathing material for the walls of the STS building investigated in this study. Glass wool of 90 mm thickness is used in the wall construction as insulation. Two layers of gypsum board are applied over both sides to ensure safety against fire. Then cement-bonded particleboard is used as the cover for the exterior walls in this building .Similar to the wall of the STS structure, studs are placed at610 mm spacing and oriented strand boards are used as sheathing materials, with 100 mm of glass wool insulation and two layers of gypsum board and vinyl cover finishing comprising the other components of the exterior walls. The 3D wall panels are structural panels that consist of a welded wire space frame integrated with a polystyrene insulation core. After the panel assembly, structural plaster is sprayed on each side of the panel. Two layers of cement mortar, one layer of gypsum plaster and granite stone are the other components of the walls in the example of the building designed for 3DSP.

A. Building Configuration

For the comparison of Light weight structure systems a square plan of 10 x 10 m having typical storey height and bottom storey height of 3m is considered. The total structure height is 6 m.

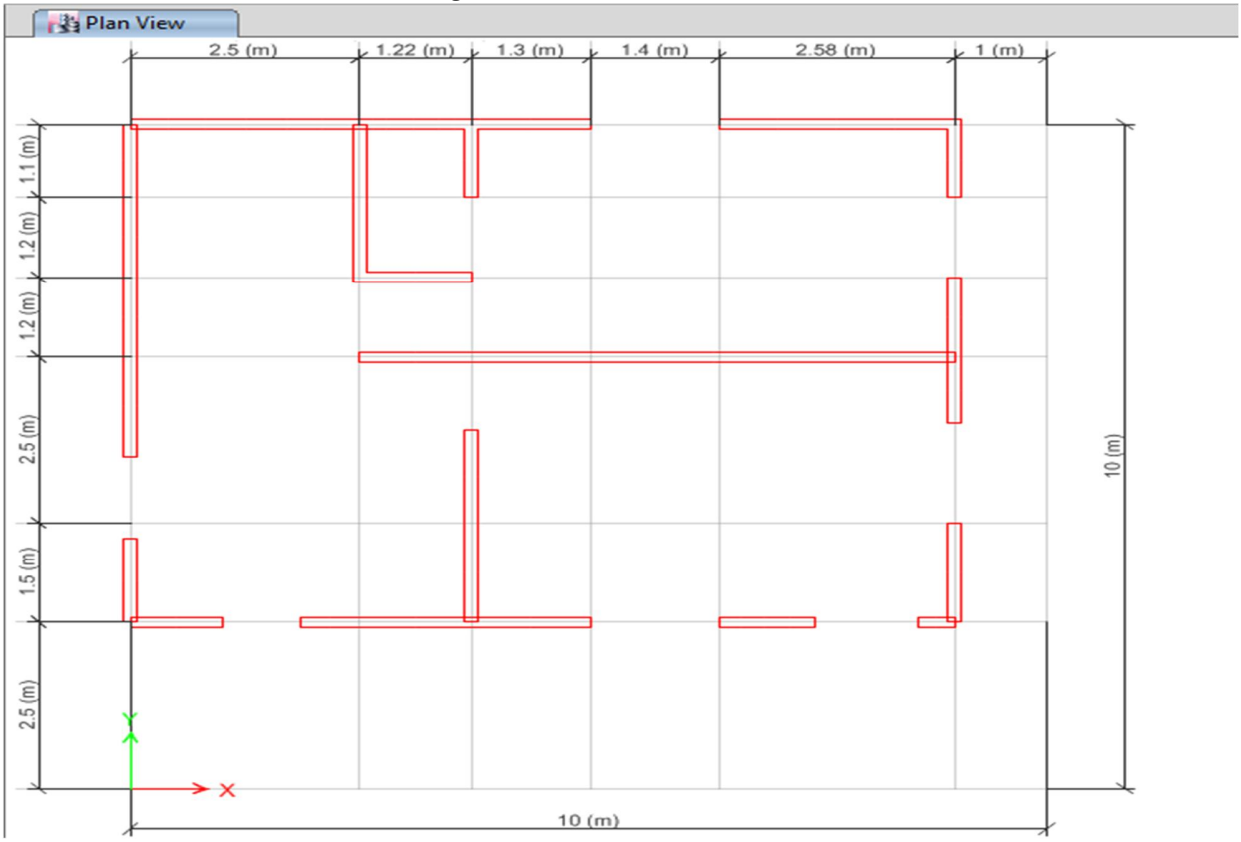


Fig-1:-Dimensions of ground floor plan in Example Building- Units in m

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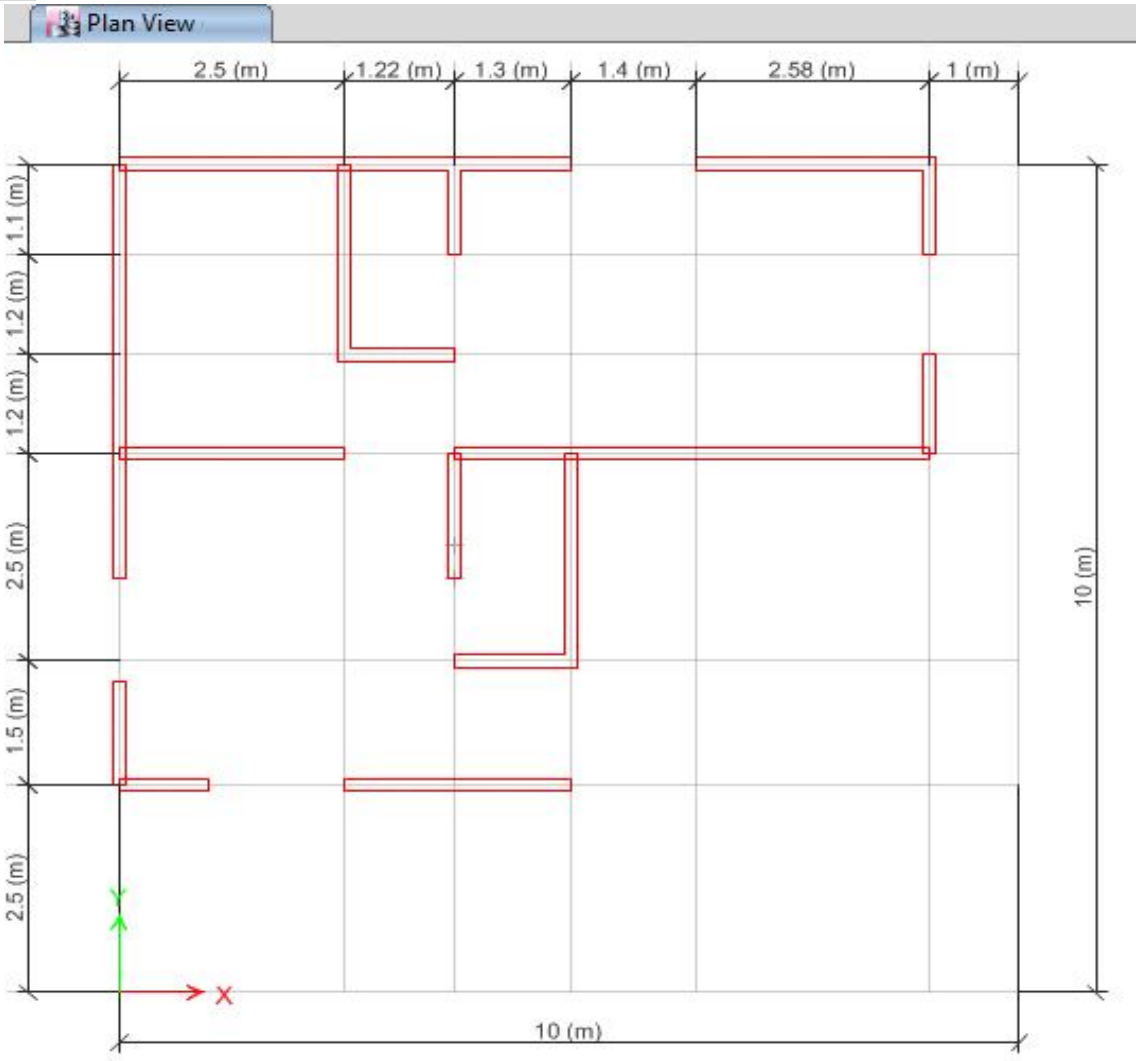


Fig2:-Dimensions of first floor plan in Example Building- Units in m

IV. MODELLING IN ETABS

In this study, structural analysis of the sample building is carried out using ETABS Software. ETABS is a programmer for linear, nonlinear, static and dynamic analysis, and the design of building systems. The input, output and numerical solution techniques of ETABS are specifically designed to take advantage of the unique physical and numerical characteristics associated with building type structures. As a result, this an analyzing design tool expedites data preparation, output interpretation and execution throughput. The example building in ETABS followed by definition of loads, material properties, section properties and load combinations. ETABS offers the widest assortment of analysis and design tools available for the structural engineer working on building structures. Owing to the complexity of the modelling stick structures in ETABS, the primary 3D modelling of STS and steel structures was done using AutoCAD software, which was then imported into ETABS in order to perform structural analysis. The structure of the stick frames is different from the conventional types of framing that have pinned connections, which are used with bracing elements to strengthen the frames against lateral loads. However, Table -1: Earthquake loading data as the structure in this investigation has pinned connections without bracing elements, the sheathing panels are considered as the resistance against lateral loads and this assumption was used in the ETABS model. The boards are defined in ETABS and applied to the building as shell elements in the modelling. AutoCAD drawing of the stick-framed building that was imported to ETABS. In the modelling process of the LGSF structure, all of the studs and tracks were designed using “Section Designer”, while the oriented strand board sheathing was defined for walls as shell elements. The LGSF framed building has simple connections and the OSB boards are used

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to increase the stiffness of the building against lateral loads. Furthermore, the subflooring decks were defined in software in order to make the model as similar as possible to the real structure. Fig. 2 shows the modelling of the LGSF building in ETABS software.
Fe 345 material having weight density 78 kN/m3 is selected. Typical floor slab thickness is 120mm having M30 grade of concrete is considered. Table 1 shows the values used in the seismic coefficient calculation of the STS and steel light frame buildings. In addition, some of the sections defined for the wall studs and used in the design of the STS and LGSF structures. In the modelling of 3DSP, the walls were defined in the form of 70 mm thick shear walls as shell elements. The decks were similarly defined as per their precise shape and dimension. The reinforcements in the walls were defined in order to the standard rebar sizes and spaces between them, which is being used in 3DSP walls. All the connections in this modelling were defined as rigid connections since 3DSP walls function similar to the shear walls in buildings. ETABS offers three different design methods for shear walls, namely: simplified C and T sections, uniform reinforcing pier section, and general reinforcing pier section. As 3DSPs are uniformly reinforced, the “uniform reinforcing pier section” method is quite appropriate for the modelling of this system. In this method the reinforcement of the shear walls was defined manually by the user, and ETABS was used to check the sufficiency of the walls, and provide the D/C ratio, which represents the ratio of the design load to the capacity of the walls. Fig3. shows the modelling of the building with 3DSP, which was performed in ETABS. Table 1 shows the values used in the seismic coefficient calculation of the 3D sandwich panel building.

LOCATION	Kachchh
Zone	5
Zone Factor, Z	0.36
Importance Factor ,I	1.2
Response reduction Factor, R	5

Steel structure, studs are placed at 610 mm spacing and oriented strand boards are used as sheathing materials with 100 mm of glass wool insulation and two layers of gypsum board and vinyl cover finishing comprising the other components of the exterior wall.

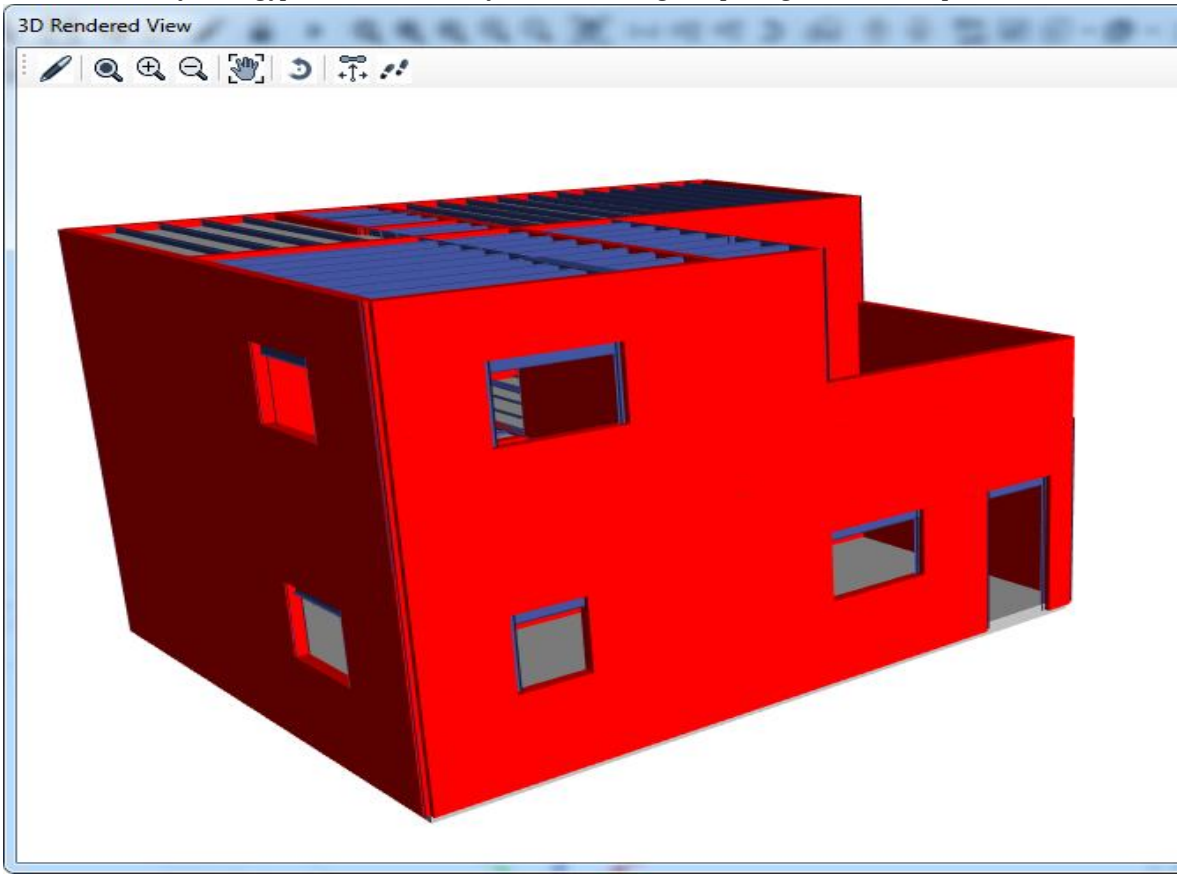


Fig3:-3D modeling of light gauge steel structure in ETABS.

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Thermopore is the brand name of Industrial Enterprises (Pvt.) Limited used to market Expanded Polystyrene (EPS).Thermopore weight density is 35 kN/m3.The 3D wall panels are structural panels that consist of a welded wire space frame integrated with a polystyrene insulation core. After the panel assembly, structural plaster is sprayed on each side of the panel. Two layers of cement mortar, one layer of gypsum plaster and granite stone are the other components of the walls in the example of the building designed for 3DSP.

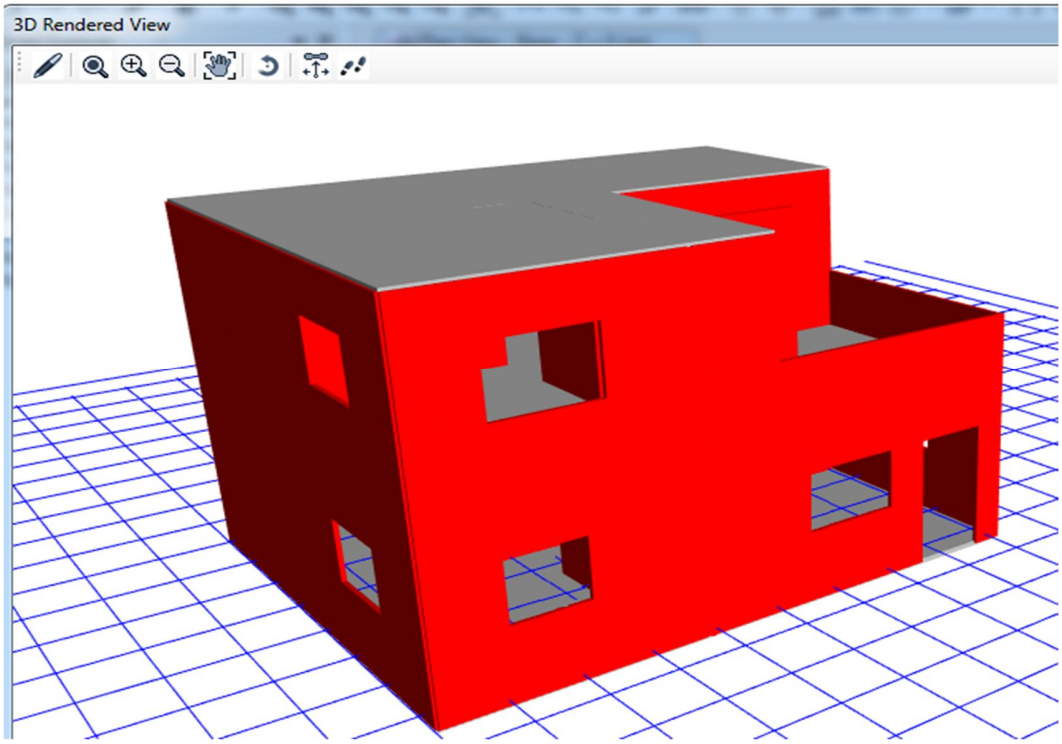


Fig4:-3D modeling of 3DSP structure in ETABS.

V. RESULTS AND DISCUSSION

Structural analysis after performing the structural analysis of the building in ETABS, the building outputs should be controlled in order to evaluate the behavior of the structure under gravity and horizontal loads. Table 6 shows some of the most important outputs, such as building weight, storey shears and storey drifts for the three structural systems. It is important to note that in order to obtain the weight of the building and structural members, the material and total weight were extracted from ETABS Software for each structural system. The settings for calculating the weight of the building in ETABS was adjusted to consider the amount of dead load in the calculation of the mass of the building. In this respect, the information drawn from ETABS was reliable enough to include in the evaluations. It can be seen from the results that the total weight of building is the highest for the first system, namely, the STS, while the LGSF is lighter than the other two systems due to less material usage.

Table:-2 Total weight, storey shears, and storey drift values of each alternative structural system.

	Building weight (kN)	Storey shear (kN)		Storey drifts (mm)			
				X direction		Y direction	
		Storey 1	Storey 2	Storey 1	Storey 2	Storey 1	Storey 2
STS	986	181.6	93.7	0.6	1	0.35	0.5
Light gauge steel frame (LGSF)	608.9	128.5	63.1	0.7	1.3	0.4	0.9
3D Sandwich panels (3DSP)	780	242.2	153.9	0.45	0.7	0.3	0.45

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The building made using the 3DSP system is lighter compared to the STS building thanks to the effective combined usage of concrete and insulating materials to enhance the structural performance and reduce material usage.

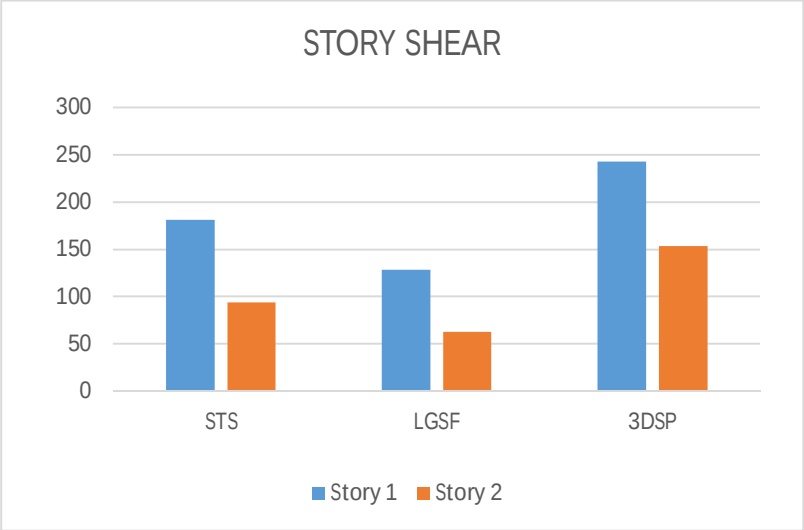


Chart 1 illustrates the values of the storey shears. It can be seen from the results that the storey shears for the 3DSP systems are greater than the other two systems, while the lowest storey shear values were obtained for the LGSF system. The reason why this building has more storey shear is related to the type of structure. Simple framed systems attract less storey shear compared to structures with rigid connections. Since the 3DSP system has rigid connections, the fundamental period of the building is relatively short.

Therefore, in response to spectrum analysis, Chart:-1 Story Shear these systems attract more storey shear than the other two structural systems with simple connections between elements (i.e. resulting in longer fundamental periods).

In addition, chart 2 illustrates the drift values of the systems in the X direction, which is caused by the earthquake loading in this direction.

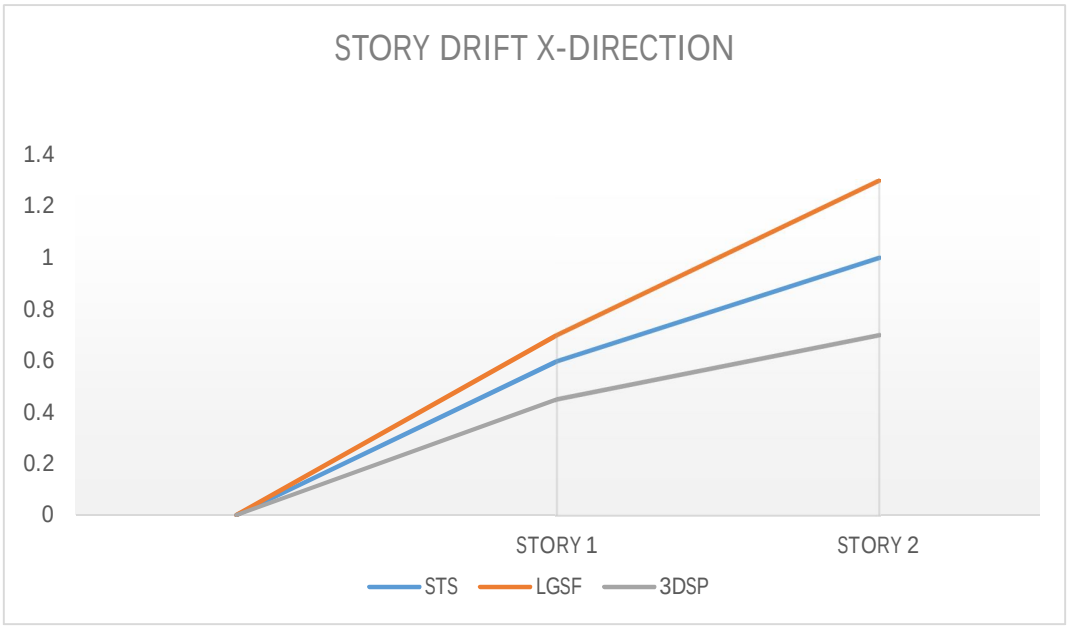


Chart2:- Story Drift in X-direction

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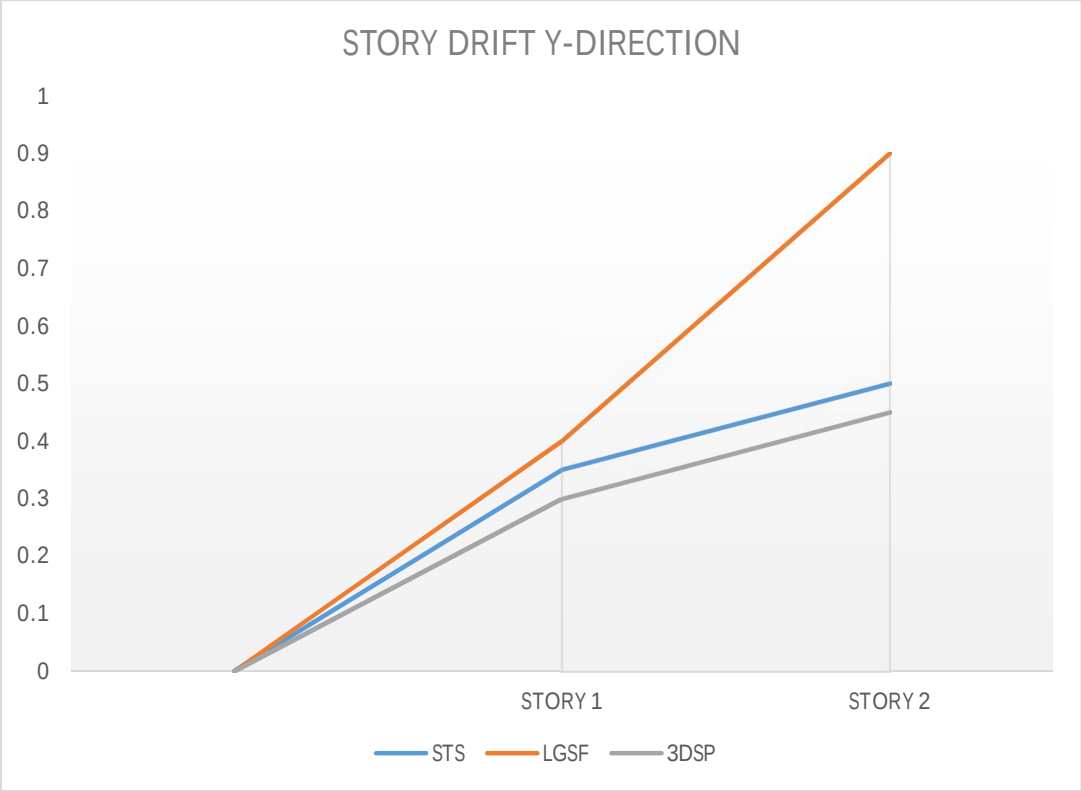


Chart3:-Story Drift in Y-direction

Similarly, Chart 3 illustrates the drift values of the systems in the Y direction, which is caused by the earthquake loading in the Y direction. It is evident from the numerical results that, for all three structures, the drift value is greater in the X direction compared to the Y direction. This is evident because the sum of the wall lengths is greater in the Y direction, which results in greater building stiffness in the Y direction.

The highest drift values belong to the LGSF sys-tem in both directions. The structure made of 3DSP shows better behavior in terms of storey drifts in both directions.

The higher values for storey drifts in the STS and LGSF are related to their framing type. Frames with simple connections experience larger lateral deflections and storey drifts when compared to rigidly connected frames. The 3DSP shows lower storey drifts as expected. Table shows the first three modes for each structure and building period in each mode. In addition, the mode shapes are mentioned in Table.

The modal information of the structure shows that the building period values for the 3DSP system are shorter than for the other two systems. The mass and rigidity centers of the three sample buildings for the ground floor are shown in Fig. 3. It is obvious from Fig. 3 that there is a considerable distance between the mass and rigidity centers in the STS and LGSF buildings. In this respect, it is obvious that the 3DSP system shows much better behavior when subjected to seismic loads.

Economy Economic issues and saving money are among the most important challenges in all aspects of human life. In this respect, it is also important to discuss the construction cost of each structural system. It is noteworthy that the construction and energy costs are based on local aspects.

This means that the cost for each alternative structural system differs and depends on the country in which it is constructed. The construction cost of each structural system in KUTCH for the year 2018 is mentioned in Table. All of these values are given for a two storey sample house, the information for which was taken from construction companies in Turkey.

It can be concluded from Table 10 that the cost of construction for 3DSP construction is 30.9% lower than STS and 27.7% lower than LGSF. In this respect, the 3DSP system is more economical considering Turkey's local resources and conditions. The STS construction is the second most economical alternative and the construction of LGSF is the most expensive compared to the other two construction

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VI. CONCLUSION

A. This study has been carried out in order to evaluate the general performance of three types of lightweight residential system. Based on the study, the following conclusions can be drawn.

B. The calculations related to the weight of the structures show that, as expected, LGSF is the lightest among these three structures

C. The STS structure is heavier than the other two structural systems; this is basically due to the thin concrete layers used in the 3DSP construction and relatively heavier solid sections used in the STS construction. Notwithstanding the fact that steel structure is lighter and Kachchh shears are low in this system, the results from the structural analyses show that the storey drifts are considerably higher in this structure.

D. The higher values for the storey drifts in the STS and LGSF are related to their frame type in which, as expected, the Simple Connection 3DSP show lower storey drifts because of the rigid element connections. An overall evaluation of the structural analysis of the buildings shows that the 3DSP walls show better performance in terms of seismic resistance.

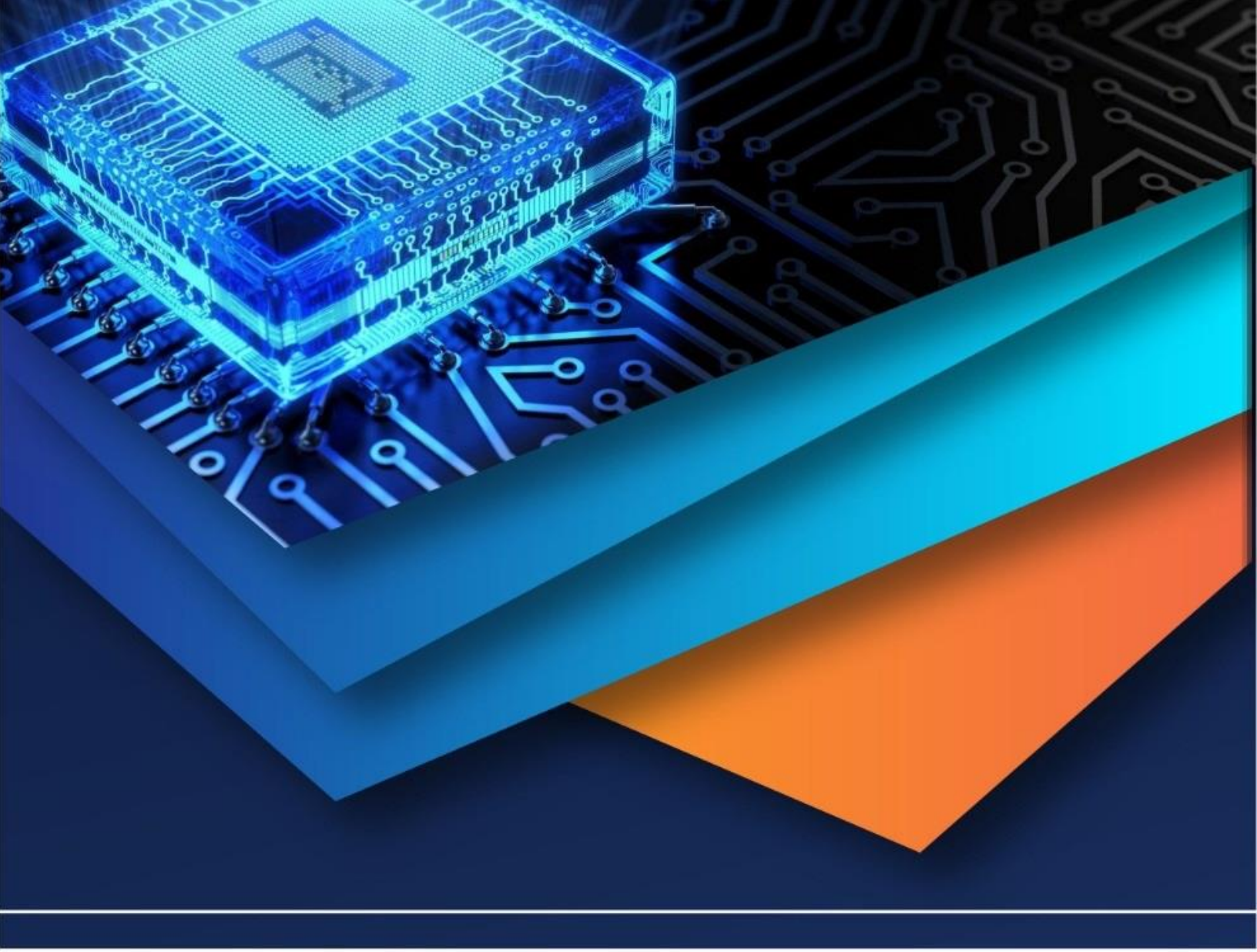
E. This research has been carried out considering data specifically for Kachchh.
Kachchh is a city with high seismic risks and, therefore, the seismic resistance of the buildings is of great importance.
While evaluating the cost of the building construction it can be concluded that the most economical construction is associated with 3DSP, while the costs of construction for lightweight steel structures are higher compared to the two alternative systems.

F. The estimations of construction costs for the three alternative buildings show that the 3DSP construction is more economi calconsidering Kachchh local resources and conditions. As an overall evaluation for this particular area, the usage of 3DSP is recommended.

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