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Comparative Study on Dynamic Behaviour of Various Grid Patterns on Concrete Floors

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Abstract: ***An assembly of intersecting beams placed at regular interval and interconnected to a slab of nominal thickness is known as Grid floor or Waffle floor. These slabs are used to cover a large column free area and therefore are good choice for public assembly halls. The structure is monolithic in nature and has more stiffness. It gives pleasing appearance. In the present study, an attempt is made to compare the bending moment, shear force and displacement obtained from the dynamic analysis using STAAD Pro software for various grid patterns. The size of grid patterns are 9mx9m and five basic grid patterns are selected which are varied by increasing the intermediate beams. It is important to note that the grids are analyzed for G+3 building. IS 1893:2002 is referred to apply dynamic loading on the grids and Response spectrum method is followed to apply the dynamic loading on the grids. The main aim of the study is to compare the above mentioned results obtained from the dynamic analysis of various grid patterns and study the behaviour of various grids under dynamic loading.***

Keywords: Bending moment, Shear force, Displacement, Grid patterns, IS 1893:2002, STAAD software.

1. Introduction

A structure can be defined as a body which can resist the applied loads without appreciable deformations. Civil engineering structures are created to serve some specific functions like human habitation, transportation, bridges, storage etc. in a safe and economical way. A structure is an assemblage of individual elements like pinned elements (truss elements), beam element, column, shear wall slab cable or arch. Structural engineering is concerned with the planning, designing and the construction of structures. Structure analysis involves the determination of the forces and displacements of the structures or components of a structure. Analysis is performed to predict the response of a structure to applied external loads. Grid floor system is a type of slab system consisting of beams spaced at regular intervals in perpendicular directions and monolithic with slab are used for large rooms such as auditoriums, vestibules, theatre hall , show room shops etc., Different patterns of grid are possible namely, rectangular, square, diagonal , continuous etc. Grids are found to be very efficient in load transferring. It is generally adopted when large column free space is required and reduces the span to depth ratio of rectangular grids. It leads to reduction in dead load due to voids and is suitable for longer spans with heavy loads. It also offers reduction in cost and exhibits good resistance to vibration.

2. Dynamic Analysis of Building

Using STAAD Pro software grid patterns are selected as discussed in introduction. The size of the grid patterns is 9mx9m. The member properties along with the loads assigned to each of the grid patterns. In India IS 1893(Part 1):2002, is used to calculate earthquake loads on the structures. In this Indian standard, three methods of analysis are given. Here response spectrum analysis (RSA) is used. In RSA from structural model of building, natural frequencies and natural modes are obtained. Using natural frequencies and mode shapes, static earthquake loads and response in each mode are obtained. These model responses are combined using Capacity Spectrum Method (CSM). The model combination rules have a very peculiar property that is in these combinations sign of model response is lost. The model combination rules, wherein maximum model responses are considered are used only in RSA.

2.1 Response Spectrum Analysis

Response spectrum is one of the useful tools of earthquake engineering for analyzing the performance of structures especially in earthquakes, since many systems behave as single degree of freedom systems. Thus, if you can find out the natural frequency of the structure, then the peak response of the building can be estimated by reading the value from the ground response spectrum for the appropriate frequency. In most building codes in seismic regions, this value forms the basis for calculating the forces that a structure must be designed to resist (seismic analysis). A response spectrum is a plot of the maximum response amplitude (displacement, velocity or acceleration) versus time period of many linear single degree of freedom oscillators to a give component of ground motion. The resulting plot can be used to select the response of any linear SDOF oscillator, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes. Response Spectrum Analysis (RSA) is an elastic method of analysis and lies in between equivalent force method of analysis and nonlinear analysis methods in terms of complexity. RSA is based on the structural dynamics theory and can be derived from the basic principles (e.g. Equation of motion). RSA, unlike equivalent force method, considers the influence of several modes on the seismic behaviour of the building. Damping of the structures is inherently taken into account by using a design (or response) spectrum with a predefined damping level. The maximum response of each mode is an exact solution. The sole approximation used in RSA is the combination of modal responses.

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2.2 Capacity spectrum method

The process of plotting the capacity spectrum with varying damped response spectra later became known as the Capacity Spectrum Method (CSM). It is a performance-based seismic analysis technique. The Capacity Spectrum Method (CSM), a performance-based seismic analysis technique, can be used for a variety of purposes such as rapid evaluation of a large inventory of buildings, design verification for new construction of individual buildings, evaluation of an existing structure to identify damage states, and correlation of damage states of buildings to various amplitudes of ground motion. The procedure compares the capacity of the structure (in the form of a pushover curve) with the demands on the structure (in the form of response spectra). The graphical intersection of the two curves approximates the response of the structure.

Table 1: Building Parameters considered for analysis

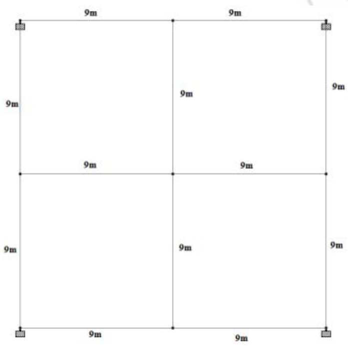
Type of building	Commercial building
Span at X & Y direction	18m X 18m
Size of main beam	0.5m X 0.6m
Size of grid beam	0.5m X 0.75m
Size of column	0.5m X0.5m
Slab thickness	0.125m
Floor to floor height	3.6m

Table 2: Parameters considered for seismic analysis

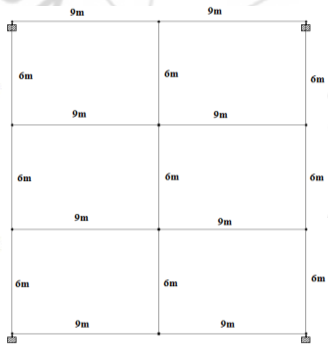
Zone	III
Importance factor	1.5
Response reduction factor	3
Soil	Medium
Damping	5%

3. Grid Patterns

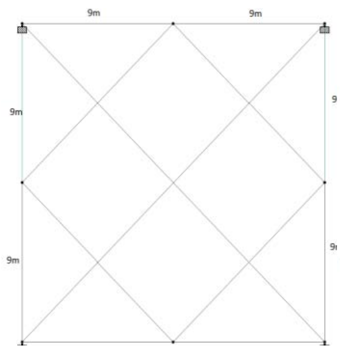
The grid patterns selected for analysis are shown by figure 1



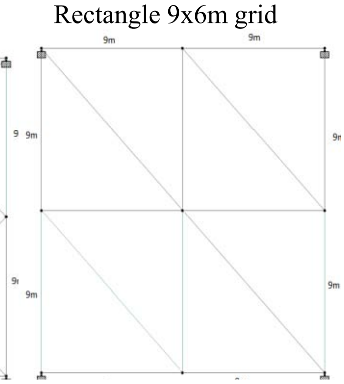
Square 9x9m grid



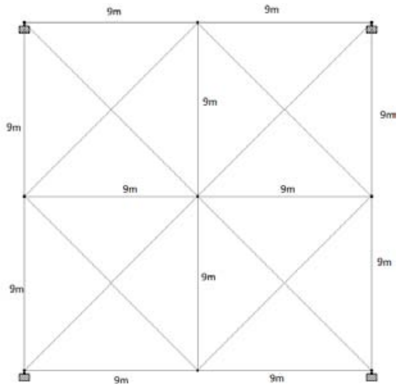
Rectangle 9x6m grid



Diagonal 9x9m grid



Diagonal three way 9x9m grids



Diagonal four way 9x9m grid

Figure 1: Plan of various grid patterns

3.1 Loads to be provided

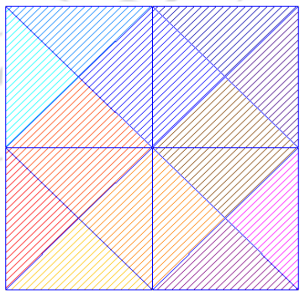
Table 3: Loads provided for analysis

DEAD LOAD	
Slab weight	4.625kN/m²
Wall weight	14.49kN/m²
LIVE LOAD	
At floor	4kN/m²
At roof level	4kN/m²

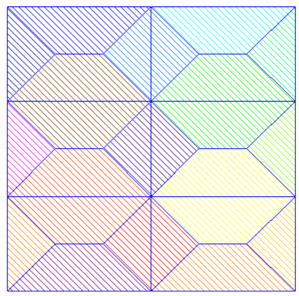
4. Seismic Analysis of Grid Patterns

Using STAAD Pro software grid patterns are selected as discussed in introduction. The size of the grid patterns is 9mx9m. The member properties along with the loads assigned to each of the grid patterns. Loads are a primary consideration in any building design because they define the nature and magnitudes of hazards are external forces that a building must resist to provide a reasonable performance (i.e., safety and serviceability) throughout the structure's useful life.

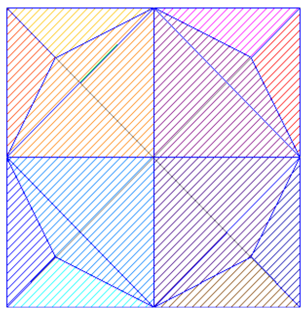
4.1 Load Dispersion Diagrams



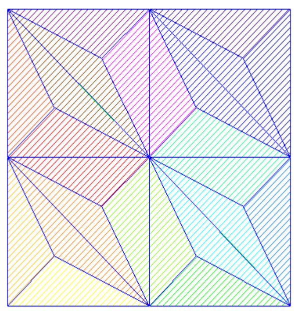
Square 9x9m grid



Rectangle 9x6m grid



Diagonal 9x9m grid



Three way 9x9m grids

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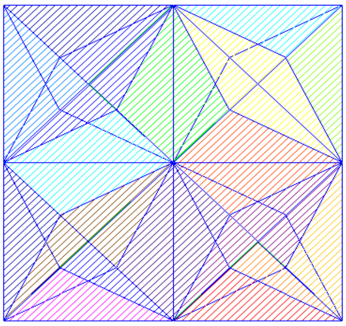

Four way 9x9m grid

Figure 2: Load dispersion diagrams for grid patterns

5. Analysis Results

Table 4: Summary of results for five grids-Beams

Maximum values for beams					
Span	S 9x9	R 9x9	D 9x9	T 9x9	F 9x9
Beam nos.	85	122	89	115	67
Shear force (kN)	349.313	399.465	349.313	316.834	174.011
Bending moment (kNm)	1263.562	1389.210	1313.418	1369.761	1594.767
Base shear (kN)	606.96	606.96	524.33	307.53	353.89
Maximum displacement (mm)	83.965	62.615	50.532	44.956	17.199

Table 5: Summary of results for five grids-Columns

Maximum values for columns					
Span	S 9x9	R 9x9	D 9x9	T 9x9	F 9x9
Beam nos.	99	137	107	123	141
Shear force (kN)	467.118	498.347	406.335	582.936	781.592
Bending moment(kNm)	919.540	980.828	778.898	1106.473	1489.853
Base shear (kN)	606.96	606.96	524.33	307.53	353.89
Maximum displacement (mm)	98.456	74.067	55.955	50.124	36.937

6. Conclusions

In the present study, an attempt is made to study the dynamic behavior of building by using five grid patterns. First part of study included the dynamic analysis of building. The results in form of S.F.D, B.M.D and deflection were obtained. A comparative table of these results for all the grids has also been presented. In the next section conclusions obtained from the study is presented.

The major conclusions drawn from the present study are as follows:

1) Loads assigned to each of the grid patterns shows different load dispersion diagrams for various grid patterns.
2) Rectangle, diagonal three way 9x9m and diagonal four way 9x9m grids are not sustaining due to heavy moments and shear force.
3) Whereas square and diagonal 9x9m grids are ready to sustain above moments and forces.
4) Displacement values are higher in Square, rectangle and diagonal 9x9 grids.
5) In three way and four way 9x9m grids displacement values get decreases.

Thus dynamic behavior of grid patterns on concrete floors shows diagonal9x9m grids are best grids for 18mx18m.

7. Future Scopes

1) In response spectrum analysis the combination of modes can be done by different methods such as sum of square root of squares (SRSS), combined quadratic combination (CQC) and absolute sum (ABS) methods.
2) For reducing the displacement dampers can be provided.
3) For the analysis equivalent static analysis and time history analysis can also be used.

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