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Analysis and Design of a Multistorey Apartment Building by using STAAD Pro

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Abstract - *STAAD or (STAAD Pro) is a software package first developed by Research Engineers International based in Yorba Linda, California. Towards the end of 2005, Research Engineer International was purchased by Bentley Systems. Data is collected and analyzed. Now, the 3-D model is created by STAAD Pro. Calculates all loads that are acting on this structure. Analyzes the same for all load combinations. And the building is designed. The received results are analyzed. Calculates the slab, beams, staircase, column designs manually.*

Key Words: Staad Pro, Auto Cad, IS 456-2000 RCC design code, design , analysis, Apartment building, Civil Engineering

1.INTRODUCTION

Human life is affected due to nature's forces like floods, hurricanes, tornadoes, earthquakes etc. The structural design for a building must ensure that the building is able to stand safely, to function without excessive deflections or movements which may cause fatigue of structural elements, cracking or failure of fixtures, fittings or partitions, or discomfort for occupants. It must account for movement sand forces due to temperature, creep, cracking and imposed loads. It must also ensure that the design is practically buildable within acceptable manufacturing tolerances of the materials. It must allow the architecture to work, and the building services to fit within the building such that it is functionable (air conditioning, ventilation, lighting etc.).

This project work aims to analyse a 5-storeyed apartment building for different load combinations using STAAD Pro software. The design of the structure is mainly developed according to the specifications of IS.

1.1 Structural components

The components of the structure are basically classified into two;
(a) Super structure
(b) Sub structure

Superstructure is the part of building that lies above the ground line. These are subjected to lateral loads like the wind load, earthquake load and other dead and live loads.

Substructure is the foundation of the building. The type of foundation adopted for the hostel building under consideration is pile foundation.

1.2 Apartment building occupancy

Apartment means a part of a building intended for any type of independent use including one or more rooms or enclosed spaces located on one or more floors or parts thereof in a building, intended to be used for residential purposes and with a direct exit to a public street, road or highway or to a common area, leading to such street, road or highway. This is a word meaning residential flat. No land develop mentor redevelopment shall be made or no building shall be constructed on any plot on any part of which there is deposited refuse, excreta or other offensive matter which in the opinion of the Secretary is considered objectionable, until such refuse, excreta or other offensive matter has been removed there from and the plot has been prepared or left in a manner suitable for land development or building purpose for the satisfaction of the Secretary.

The rear yard should be at least 1.5m in depth. Car parking building/parking plazas/parking towers shall provide minimum open space of all sides at 5m from the building. Not exceeding 15% of total floor area of the car parking building may be permitted to be utilized for shop, restaurant, hotel, and office purpose.

2. Building Details

The building which we considered for the project is a 5-storeyed apartment building located at Trivandrum
Building Dimensions
The building span 50 feet in width and 100 feet in length. The height of each floor is 12 feet. The total height of the structure is 60 feet. The area of the building will be 5000 sq ft Building Materials

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The primary structural material is reinforced concrete. For the best performance, we will use high-strength concrete with steel reinforcement bars.
Layout of Building
It includes mixed apartments of various sizes and layouts having living spaces, bedrooms, kitchen, and bathroom in them.

3. Analysis

A structure is an assemblage of individual structural elements like truss elements, beams, columns, slabs, cable or arch proportioned to resist the loads and forces.

3.1 STRUCTURAL ANALYSIS
It's the calculation of the response of the structures to actions.

3.2 ACTIONS
An action is a physical phenomenon that produces stress and deformation in the structures. Actions include:
•Loads (self-weight)
•Variation in temperature
•Settlement of support

4. LOADS ACTING

Loads can often be assumed to be either primary or secondary. Secondary loads are those loads due to temperature changes, construction eccentricities, shrinkage of structural materials, settlement to foundations, or other such loads. Although every load and loading

Primary loads are divided into DEAD LOADS and LIVE LOADS. When one considers which combinations of those two kinds of loading may occur, the probabilities for some to happen simultaneously are treated as adding up to zero.
CALCULATION: The loads taken for analysis are dead load, live load, wind load and seismic load. Since the structure will be erected in zone-3, seismic design should also be done. The loading standards ensure structural safety and eliminate wastage that may be caused due to unnecessary heavy loading without proper assessment.

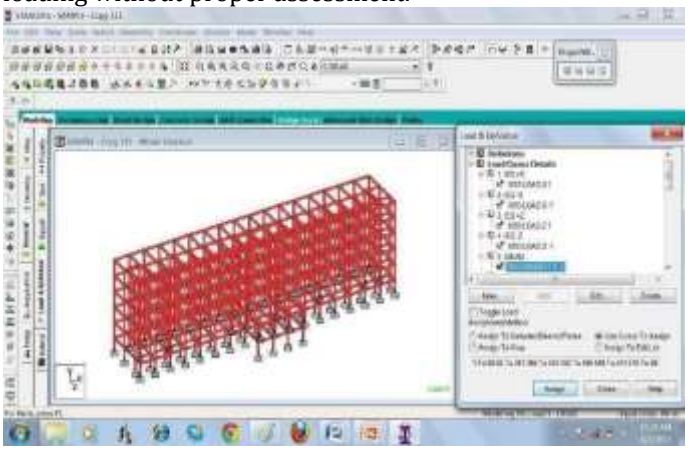

Fig 1 Dead Load

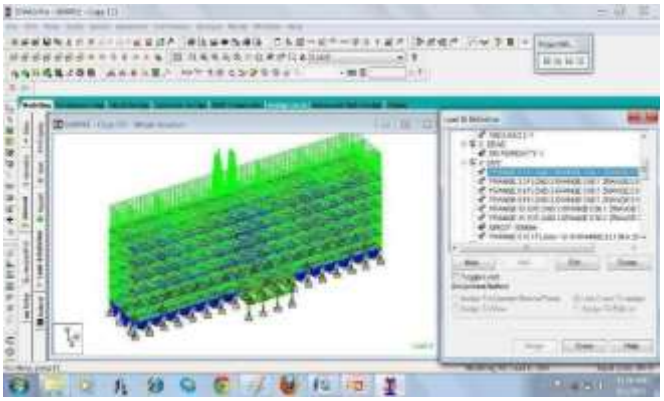

Fig 2. Live load

5.METHODOLGY

The various steps undertaken in the project are:

•Data Collection
•Data analysis
•Model generation
•Load calculation
•Building analysis
•Building design
•Result analysis
•Design and manual calculation of slab, beam, staircase and column
•Pile foundation and pile cap design

6. LOAD CALCULATION

Dead loads and live loads are given as per code provisions IS 875 (Part I):1987 is used for dead loads and IS 875(Part-II):1987, for live loads.

Wind loads and Seismic loads have to be calculated according to IS 875 (Part-III):1987 and IS875(Part-IV):1987 respectively. The calculation procedure is shown as follows.

6.1 CALCULATION OF WIND LOADS

The basic wind speed (Vb) for various wind zones of India are extracted from IS 875 (Part- III):1987 from which, the basic wind speed for each storey height 'z' is computed using the following equation.

$Vz = Vb \times k1 \times k2 \times k3$

$Pz = 0.6V2(N/m2)$

6.2 SEISMIC LOAD CALCULATION

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country is classified according to the magnitude of earth quake forces, into 4seismic zones, II to V. The structure considered for our project falls under zone III area. The effect of seismic forces is the intensity and duration of vibration and depends on the: Magnitude of earthquake, depth of focus from the ground surface, distance of structure under consideration from the epicenter, soil strata in which it is constructed characteristics of the path through which seismic waves travel. The response of a structure to ground vibrations is a function of the nature of foundation soil, materials form, size and mode of construction of structures, and the duration and characteristics of ground motion.

The design approach followed in this standard ensures that structures at least have a minimum strength to withstand minor earthquakes (<DBE-Design Basis Earthquake), which are frequently occurring, without damage; resist moderate earthquakes (DBE) without significant structural damage though some non-structural damage may occur and aims that structures withstand a major earthquake (MCE) without collapse, Actual forces that appear on structures during earthquakes are much greater than the design forces specified in this standard.

6.3 Gravitiy load calculations

6.4 Sesmic load calculations

6.5 Load combinations

7. DESIGN OF STRUCTURE

7.1 DESIGN OBJECTIVES

(a) To configure a workable and economic structural system. This involves the selection of the appropriate structural types and laying out the location and arrangements of the structural elements such as columns and beams

(b) To select structural dimension, depth and width of individual member and concrete cover

(c) To determine the required reinforcement, both longitudinal and transverse

(d) Detailing of reinforcement such as development length, hooks and bends

(e)serviceability requirements like deflection and crack width

7.2 DESIGN CRITERIA

In meeting the design objectives, there are four major design criteria of "SAFE" that need to be met.

(a) Safety, Strength and stability: Structural systems and members must be designed with adequate margins of safety against failure.

(b) Aesthetics: It involves much thought as shape, geometrical proportion, symmetry, texture and articulation.

(c) Functional requirements: Any structure has always got to be designed with function to fulfill that which is needed according to the project. Major functionality is construction. It is only the practical structural design to enable a reasonable amount of construction and construction cost.

(d) Economy: Structures must be designed and built in the target budget of the project. Design that replicates member sizes and simplify reinforcement placement toresultin easier and faster construction will naturally result in being more economical than a design that achieves minimum material quantities.

7.3DESIGN PROCESS

(a) Configure the structural system

(b) Determine the design data. This includes the design loads, design criteria and specifications. Also specify the material properties.

(c) Assume first estimate of the material properties and sizes. For instance, on basis, sizes are determined for controlling deflection in.

(d) Compute member cross sectional properties. Now do structural analysis to obtain internal forces such as moments, axial force, shear force and torsion. Using these parameters, magnitude so deflections of structural members are obtained.

(e)Determine longitudinal reinforcement demands based on moment and axial force demands. Determine transverse reinforcement demands from shear and torsional moment demands.

(f) If members fail to meet "SAFE" criteria, modify the design and modify steps 1 And 3.

(g) Complete detailed assessment of member design to include load cases, combinations, strength and service ability requirements as stipulated by code and specifications.

(h)Reinforcement detailing. Make design drawings and construction specifications.

7.4DETAILING

The hostel building to be designed is situated in seismic zone III. The building is analyzed as OMRF (Ordinary Moment Resisting Frame) and RRF (Response Reduction Factor) is considered to be 3 Therefore the detailing is done accordingly.

8. PLANNING AND DESIGN OF FOUNDATION

8.1 INTRODUCTION

Proper design of a substructure of a multi- storeyed structure is important for its stability and durability. The major function of substructure is to transmit load from the superstructure uniformly and safely to the strata of soil below it. The type of foundation to be adopted and designed depends on the nature of the load and the supporting soil. According to the IS codes, the various loads acting on the

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structure are obtained and calculated at load calculation. The soil characteristics for designing the foundation such as

internal angle of friction, standard penetration number, position of water table, depth of refusal stratum, which can be obtained from the report from the soil investigation carried at the proposed site.

The foundation is designed to carry a heavy structure as a five- storeyed building with a column beam structure. Considering the safety of the proposed building, deep foundation is provided. Deep foundation can be pile foundation, well foundation or caissons. Pile foundation was found to be the best solution for the load and soil conditions at the site.

8.2 PILE DESIGN THEORY

According to the design recommendations, the foundation for the proposed structure is end-bearing piles. Static method is applied for the design of end bearing pile. The ultimate bearing capacity (Qu) of the pile at the pile tip can be calculated from the bearing capacity equation,

$Qu= Ap(Pd\times Nq+0.5\times\gamma\times B \times N\gamma)$

Where,

Ap =area of the pile tip

Pd = effective overburden pressure at the pile tip B = lateral dimension of the pile γ=unit weight of soilNq, Nγ = bearing capacity factors for deep foundations

8.3 PILE CAPACITY DETERMINATION

As stated in the abstract, pile capacity is calculated by using the static pile capacity equation. For every column, circular end bearing piles of 0.7 m and 0.9 m diameter is fixed. The piles are resting on a hard stratum that is 1.5 m below the ground level.

Pile capacity, $Qu = Ap(Pd \times Nq + 0.5 \times \gamma \times B \times N\gamma)$ Diameter=0.9m

Assuming pile capacity is one, Qu = 1280 KN Assuming a factor of safety of 3,

Safe bearing capacity = 1280/3 = 420 KN

8.4 PILE GROUP DETERMINATION

Number of pile required under each column, i.e. the pile group is determined by dividing the maximum axial force occurring at the column by single pile capacity. For 100% group efficiency, pile spacing in the group is fixed as 2.5 times the pile diameter. STAAD Pro analysis gives the ultimate load for each load case. Pile groups are fixed based on the working loads as shown in the example below. For critically loded column,

Ultimate axial load=2280.63 KN

Working loa d= 2280.63/1.5 = 1520.42 KN Number of pile s= 1520.40/420 = 4

Thus pile group is fixed as 2 ×2.

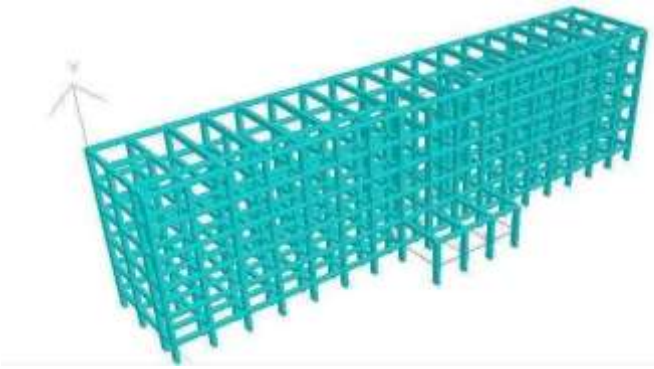

Fig 3. 3-D view

9. CONCLUSIONS

Our project aimed to have a planning, analysis and designing of multi-storeyed earthquake-resistant residential building. Given nine chapters of the pertinent features, we managed to finish our project quite successful and efficiently.
Planning of this building has been done based on the space requirements suggested by the prevailing rules stipulated in Kerala Building Rules, 1999. The design is completely based on relevant Indian Standard Codes. The analysis has been done with the help of STAAD Pro and the drawings have been made with the help of AutoCAD. We have completed this project to the best four knowledge and ability.

ACKNOWLEDGEMENT

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Above all, I wish to appreciate my family who has made it possible for me to successfully complete this project with their support, patience, and encouraging words.

It is a proof of the collective efforts of all parties, and I am truly thankful for their contributions.

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